Proceedings of
International Conference on Future Technologies in Mechanical Engineering (ICFTME)

Under the Auspices of

International Conferences on
Trends in Information, Management, Engineering and Sciences
(ICTIMES)

MALLA REDDY COLLEGE OF ENGINEERING (MRCE)
(Permanently Affiliated to JNTUH & Approved by AICTE,
New Delhi, An ISO 9001: 2008 Certified Institution)
Maisammaguda, Hyderabad-500014.
www.mrce.in

Editor in Chief
Dr.P. John Paul
Principal

Editor
Dr. D.K. Nageswara Rao
HoD- Mech. Engg.

Proceedings of

International Conference on Future Technologies in Mechanical Engineering (ICFTME)

ISBN: 978-93-85101-61-8

Under the Auspices of

International Conferences on Trends in Information, Management, Engineering and Sciences (ICTIMES)

KNOWLEDGE IS DIVINE

MALLA REDDY COLLEGE OF ENGINEERING

MALLA REDDY COLLEGE OF ENGINEERING (MRCE)

(Permanently Affiliated to JNTUH & Approved by AICTE, New Delhi, An ISO 9001: 2008 Certified Institution)

Maisammaguda, Hyderabad-500014.

www.mrce.in

Editor in Chief

Dr.P. John Paul
Principal

Editor

Dr. D.K. Nageswara Rao
HoD- Mech.Engg.

International Conference on
Future Technologies in Mechanical Engineering

23rd, 24th Jan 2015

Malla Reddy College of Engineering,Hyderabad-500100

Malla Reddy College of Engineering (MRCE)

Best Wishes
from
Sri. Ch. Malla Reddy garu,
Founder Chairman, MRGI

Congratulations to the Department of Mechanical Engineering for conducting the International Conference on Future Technologies in Mechanical Engineering

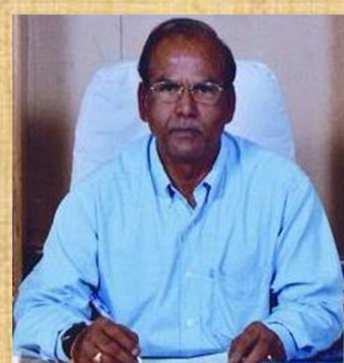
Malla Reddy College of Engineering (MRCE)

Best Wishes from

Sri.Ch. Mahender Reddy
Secretary, MRGI

Dr.Ch. Bhadra Reddy
Treasurer, MRGI

Prof. R. Madan Mohan,
Director-Academics, MRGI



Col. G. Ram Reddy
Director/Administrations, MRGI

Malla Reddy College of Engineering (MRCE)

Mr.N.Sudhir Reddy,
Director

**Hearty Wishes to the
Department of Mechanical Engineering
for conducting the International Conference
on
Future Technologies in
Mechanical Engineering**

Malla Reddy College of Engineering (MRCE)

Dr. P. John Paul,
Principal, MRCE
Editor in-Chief

**Best Wishes to the
Department of Mechanical Engineering
for conducting the International Conference
on
Future Technologies in
Mechanical Engineering**

Malla Reddy College of Engineering (MRCE)

Dr.Seow Ta Wee,

University Tun Hussein Onn Malaysia,

Best Wishes to the Department of Mechanical Engineering for conducting the International Conference on Future Technologies in Mechanical Engineering

Malla Reddy College of Engineering (MRCE)

Dr.K.VIJAYA KUMAR,
CEO FIRST ESCO INDIA LTD
VIZAG

Best Wishes to the
Department of Mechanical Engineering
for conducting the International Conference
on
Future Technologies in
Mechanical Engineering

Malla Reddy College of Engineering (MRCE)

Dr. D.K. Nageswara Rao
HEAD, MECH ENGG.
Editor

Best Wishes to the Department of Mechanical Engineering for conducting the International Conference on Future Technologies in Mechanical Engineering

CONTENTS

Stroh Formalism for Stress Distribution around Holes in Composite Laminates

D.K. Nageswara Rao[1*] M. Ramesh Babu[2] G. Ramesh[3] M. Yadi Reddy[4]

[1]Professor, Dept of Mech. Engg. Malla Reddy College of Engg. Hyderabad, INDIA
[2]Assoc. Professor, Mech. Engg *Christu Jyothi Inst. of Technology & Science, Janagaon-506 167, A.P, INDIA*
[3]Asst. Professor, Malla Reddy College of Engg. Hyderabad, *INDIA* [4]*Asst. Professor,MGIT, Hyderabad,, INDIA*

[*]*Corresponding author: email: dr.dknrao@ gmail.com Tel: 91-9393399960*

***Abstract*--The general solution for stresses around holes in laminates using Stroh formalism is presented in this paper. This is a one-stop solution for all cases of in-plane loading on infinite plates. The results of solutions by different formulations in the literature are reproduced exactly by the present solution. This is achieved by using Savin's mapping function in a generalized form and also introducing the arbitrary biaxial loading condition into the basic equations of Stroh formalism. This solution is highly useful for parametric study of the effect of shape of hole, material, fiber orientation, stacking sequence and type of loading on stress distribution around the cutout. Results are presented for new cases such as, cross-ply, angle-ply laminates and different laminas of Graphite/epoxy, Boron/epoxy and glass/epoxy with circular, elliptical, triangular and rectangular holes under uni-axial, biaxial and shear loading. The material identities are handled elegantly by MATLAB.**

Keywords--Stroh formalism; anisotropic plates; cutouts in laminates; in-plane loading.

I. INTRODUCTION

Composite panels are widely used in aircraft wings, transportation equipment and construction applications. Cutouts are made in laminates for practical purposes, such as access to system equipment, maintenance of hydraulic piping, electrical wiring etc. Holes in aircraft wings, ship decks and other transportation equipment result in degradation of the strength of the laminate. In order to predict the structural behavior the laminates with certain degree of accuracy, it is necessary to study the effect of anisotropy, laminate geometry, fiber orientation, shape of hole, type of loading on the stress distribution around the cutouts.

Many analytical solutions are available in the literature with varying degree of complexity. Most of the researchers have considered only specific shapes of holes in the laminate under certain case of in-plane loading. Earliest solution by Lekhnitskii [1] for stresses around holes in anisotropic plates has used an expression for the shape of hole that gives only an approximate polygonal hole as a degeneration of the circular hole. The shapes have curved edges and rounded corners. The stress functions are taken in series requiring lengthy mathematical procedure. The unknown constants are determined by applying the boundary conditions. The first solution on multi-layered plates is given for unidirectional and bidirectional laminates of Graphite/epoxy, Boron/epoxy and glass/epoxy with circular hole under uni-axial and biaxial loading conditions given Gao[2]. The influence of bluntness curvature and material properties on the state of stress around triangular hole in uni-directional layers of different materials under tensile loading was studied in another solution of Daoust and Hoa [3]. In this solution, the triangular hole is taken based on an expression that gives a degenerated circular hole. Another solution by Hwu [4,5] was given for stresses around holes in anisotropic plates under arbitrary uni-directional loading at infinity. The expression used in this solution could produce several shapes of holes whose shapes were only approximate. To investigate the effect of the shape of cutout on the maximum stress and its location in a flat plate under uni-axial tension was given for triangular, square and hexagonal cutouts in composite plates Rezaeepazhand and Jafari [6,7,8] was given in the similar lines of the earliest solution [8]. The solution given by Ukadgaonker and Rao [9], Nageswara Rao et al.[10] is based on Savin's formulation Savin[11] using the stress functions. The hole shape is given by an expression with number of terms. Results in all the solutions indicated that the maximum stress was dependent on the material as well on the shape of the cutout.

The present general solution is derived by incorporating a generalized form of mapping function and an arbitrary biaxial loading condition into the basic equations of Stroh formalism. The generalized mapping function for polygonal holes is obtained from the Schwarz-Christoffel formula Savin[11]. This solution gives the stresses around holes with given constants of the mapping function, constants for type of loading, type of material, fiber orientation and stacking sequence. The solution by Stroh formalism is very elegant as it converts the complex eigenvalues and eigenvectors into real form in a simple manner making it applicable for both anisotropic and isotropic plates.

I. STROH FORMALISM

The basic equations of two-dimensional anisotropic elasticity are:

$$\varepsilon_{ij} = \frac{1}{2}(u_{i.j} + u_{j,i}) \quad \ldots(1)$$

$$\sigma_{ij} = C_{ijkl}\varepsilon_{kl} \quad \ldots(2)$$

$$\sigma_{ij,j} = 0 \text{ ,where, } i, j, k, l = 1,2,3 \quad \ldots(3)$$

Considering the classical laminate theory, the mid-plane displacements of the laminate are represented by u_i,(i=$1,2,3$) along the three axes. For the assumption of positive energy, the elastic constants C_{ijkl} are fully symmetric with respect to interchange of indices as given in (4).

$$C_{ijkl} = C_{jikl} = C_{ijlk} = C_{klij} \text{ where, } i, j, k, l = 1, 2, 3 \quad \dots(4)$$

The equations (1) and (2) are taken in terms of displacements and are introduced into (3). Then the equilibrium equations (3) become

$$C_{ijkl} u_{k,lj} = 0 \quad \dots(5)$$

The solution for the set of partial differential equations (5) is obtained by considering a general form of displacement **u** as a linear combination of x_1 and x_2. The general form of displacements and stress function vector satisfying the basic equations (1)-(3) are

$$\mathbf{u} = 2\mathbf{Re}\left[\mathbf{Af(z)}\right] \quad \varphi = 2\mathbf{Re}\left[\mathbf{Bf(z)}\right] \quad \dots(6)$$

where, $\mathbf{f(z)}=[f_1(z_1)\ f_2(z_2)\ f_3(z_3)]^T$ is function vector composed of three holomorphic functions with complex variables, $z_j=x_1+\mu_j x_2$, $j=1,2,3$. The complex eigenvector matrices are given by

$$\mathbf{A} = \left[\mathbf{a_1} \quad \mathbf{a_2} \quad \mathbf{a_3}\right], \mathbf{B} = \left[\mathbf{b_1} \quad \mathbf{b_2} \quad \mathbf{b_3}\right] \quad \dots(7)$$

The Stroh formalism is more attractive than the conventional series solution of stress functions of Lekhnitskii[1]. It is because of the eigen relation that relates the eigen modes of stress functions and displacements in terms of material properties. The general form of eigen relation in a rotated co-ordinate system as given by Ting [12] is

$$\mathbf{N}(\theta)\xi = \mu(\theta)\xi \quad \dots(8)$$

where,

$$\mathbf{N}(\theta) = \begin{bmatrix} \mathbf{N_1}(\theta) & \mathbf{N_2}(\theta) \\ \mathbf{N_3}(\theta) & \mathbf{N_1^T}(\theta) \end{bmatrix},$$

$$\mathbf{N}_1(\theta) = -\mathbf{T}^{-1}(\theta)\mathbf{R}^{\mathbf{T}}(\theta)\,,\ \mathbf{N_2}(\theta) = \mathbf{T}^{-1}(\theta) = \mathbf{N_2}(\theta)\,;$$

$$\mathbf{N_3}(\theta) = \mathbf{R}(\theta)\mathbf{T}^{-1}(\theta)\mathbf{R}^{\mathbf{T}}(\theta) - \mathbf{Q}(\theta) = \mathbf{N_3}^{\mathbf{T}}(\theta) \quad \dots(9)$$

where, $\mathbf{Q}(\theta)$, $\mathbf{R}(\theta)$ and $\mathbf{T}(\theta)$ are transformed 3x3 material real matrices (10)
given in terms of **Q, R** and **T.**

$$\mathbf{Q}(\theta) = \mathbf{Q}\cos^2\theta + (\mathbf{R} + \mathbf{R}^{\mathbf{T}})\sin\theta\cos\theta + \mathbf{T}\sin^2\theta$$

$$\mathbf{R}(\theta) = \mathbf{R}\cos^2\theta + (\mathbf{T} - \mathbf{Q})\sin\theta\cos\theta - \mathbf{R}^{\mathbf{T}}\sin^2\theta$$

$$\mathbf{T}(\theta) = \mathbf{T}\cos^2\theta - (\mathbf{R} + \mathbf{R}^{\mathbf{T}})\sin\theta\cos\theta + \mathbf{Q}\sin^2\theta \quad \dots(10)$$

The **Q**, **R** and **T** matrices in (10) are given by

$$\mathbf{Q} = \begin{bmatrix} C_{11} & C_{16} & C_{15} \\ C_{16} & C_{66} & C_{56} \\ C_{15} & C_{56} & C_{55} \end{bmatrix} \quad \mathbf{R} = \begin{bmatrix} C_{16} & C_{12} & C_{14} \\ C_{66} & C_{26} & C_{46} \\ C_{56} & C_{25} & C_{45} \end{bmatrix}$$

$$\mathbf{T} = \begin{bmatrix} C_{66} & C_{26} & C_{46} \\ C_{26} & C_{22} & C_{24} \\ C_{46} & C_{24} & C_{44} \end{bmatrix} \quad \dots(11)$$

The elastic stiffness constants $C_{i,j}$ (i,j=1,2,6) in (11) for unidirectional laminas different materials are obtained using (A1). The material properties for some unidirectional laminas are given in Table 1. The elastic constants for laminas with different fiber orientations are calculated using (A2)-(A3) in Appendix-A.

The values of μ_j are obtained from the standard eigen relation (8) by taking $\theta = 0$. These values depend on the type of elastic anisotropy and elastic constants. For positive strain energy, the roots of the eigenrelation (8) shall have three pairs of complex conjugates. The column eigenvectors $\mathbf{a_1}$, $\mathbf{a_2}$, $\mathbf{a_3}$ and $\mathbf{b_1}$, $\mathbf{b_2}$, $\mathbf{b_3}$ in (7) are obtained by using

$$\begin{bmatrix} -\mathbf{Q} & \mathbf{0} \\ -\mathbf{R^T} & \mathbf{I} \end{bmatrix}\begin{bmatrix} \mathbf{a} \\ \mathbf{b} \end{bmatrix} = \mu\begin{bmatrix} \mathbf{R} & \mathbf{I} \\ \mathbf{T} & \mathbf{0} \end{bmatrix}\begin{bmatrix} \mathbf{a} \\ \mathbf{b} \end{bmatrix} \quad \dots(12)$$

where, **I** is the identity matrix of size 3×3 represented in terms of material property matrices **R** and **T** by

$$\mathbf{I} = \begin{bmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{bmatrix} = \begin{bmatrix} \mathbf{0} & \mathbf{T}^{-1} \\ \mathbf{I} & -\mathbf{RT}^{-1} \end{bmatrix}\begin{bmatrix} \mathbf{R} & \mathbf{I} \\ \mathbf{T} & \mathbf{0} \end{bmatrix} \quad \dots(13)$$

The transformed eigenvalues $\mu_j(\theta)$ for various θ positions around the hole boundary are given by

$$\mu_j(\theta) = \frac{-\sin\theta + \mu_j\cos\theta}{\cos\theta + \mu_j\sin\theta} \quad \dots(14)$$

$$\operatorname{Im}\mu_j(\theta) > 0,\ \ \mu_{j+3}(\theta) = \overline{\mu_j(\theta)}\,,$$

$$\mathbf{a}_{j+3} = \bar{\mathbf{a}}_j \qquad \mathbf{b}_{j+3} = \bar{\mathbf{b}}_j \quad \dots(15)$$

For distinct eigen values $\mu_j(\theta)$, the corresponding column eigenvectors a_j, b_j are independent of each other. By post-multiplying (8) by $[A^{-1}\ \ B^{-1}]$ on both sides, we get the following identities (16).

$$2\mathbf{A}\left\langle\mu_j(\theta)\right\rangle\mathbf{A}^{-1} = \left[\mathbf{N_1}(\theta)\mathbf{S^T} + \mathbf{N}_2(\theta)\mathbf{S^T}\mathbf{H}^{-1}\right] + i\mathbf{N_1}(\theta)$$

$$2\mathbf{A}\left\langle\mu_j(\theta)\right\rangle\mathbf{B}^{-1} = \left[\mathbf{N_2}(\theta) - \mathbf{N_1}(\theta)\mathbf{SL}^{-1}\right] - i\mathbf{N_1}(\theta)\mathbf{L}^{-1}$$

$$2\mathbf{B}\left\langle\mu_j(\theta)\right\rangle\mathbf{B}^{-1} = \left[\mathbf{N_1^T}(\theta) - \mathbf{N_3}(\theta)\mathbf{SL}^{-1}\right] - i\mathbf{N_3}(\theta)\mathbf{L}^{-1}$$

$$2\mathbf{B}\left\langle\mu_j(\theta)\right\rangle\mathbf{A}^{-1} = \left[\mathbf{N_3}(\theta) + \mathbf{N}_1(\theta)\mathbf{S^T}\mathbf{H}^{-1}\right] + i\mathbf{N_1^T}(\theta)\mathbf{H}^{-1} \quad \dots(16)$$

The identities in (16) are expressed in terms of real matrices $\mathbf{N_1}$, $\mathbf{N_2}$and $\mathbf{N_3}$, **S, H** and **L.** The derivatives of stress function vectors w.r.t **n** and **s** are expressed in terms of these identities. Real form stress values are obtained directly as these identities in the equations are replaced by the expression with real matrices.

II. GENERALIZED MAPPING FUNCTION

In the theory of complex variables, the conformal mapping facilitates representing the area external to the given hole in z-plane by the area outside the unit circle in ζ -plane using a transformation function called the mapping function. To consider any shape of hole, a generalized form of Savin's mapping function (17) is introduced into the Stroh formalism. For isotropic materials such a mapping function is given by

$$z = \omega(\zeta) = R\left(\zeta + \sum_{k=1}^{N}\frac{m_k}{\zeta^k}\right) \quad \dots(17)$$

where, m_k are the constants of the mapping function as given in Table 2. R is a constant for the size of the hole which is taken equal to unity since the stress concentration in the present analysis depends on the shape of the hole rather than on its size. By taking $\zeta = \rho e^{i\psi}$, where ρ, ψ are the coordinates in ζ-plane and $\rho = 1$ on unit circle, we have, $\zeta = (\cos\psi + i\sin\psi)$. The mapping function (17) is written as

$$z = \omega(\zeta) = R\left[\left(\cos\psi + \sum_{k=1}^{N} m_k \cos k\psi\right) + i\left(\sin\psi - \sum_{k=1}^{N} m_k \sin k\psi\right)\right] \quad \ldots(18)$$

For anisotropic materials, the deformation undergoes affine transformation. Hence, the complex parameters of anisotropy μ_j are introduced into (17) as in $z = x_1 + \mu_j x_2$ where x_1, x_2 are the real and imaginary parts of (18) respectively, thereby resulting in (18).

$$z_j = \omega_j(\zeta) = \frac{R}{2}\left[a_j\left(\frac{1}{\zeta} + \sum_{k=1}^{N} m_k \zeta^k\right) + b_j\left(\zeta + \sum_{k=1}^{N} \frac{m_k}{\zeta^k}\right)\right] \quad \ldots(19)$$

where $a_j = (1 + i\mu_j)$, $\quad b_j = (1 - i\mu_j)$ ...(20)

III. Arbitrary Biaxial Loading Condition

In order to consider several cases of in-plane loading in this solution, the boundary conditions are derived by introducing the arbitrary biaxial loading condition Gao[2] into the boundary conditions. By means of this condition, the results for biaxial tension or shear stress at infinity can be obtained without the need for superposition of the solutions of uni-axial loading.

The remotely applied loading is considered about arbitrary coordinate axes $x_1'0x_2'$ rotated by an angle β from the principal body directions x_10x_2 as shown in Fig. 1(a) and λ is the biaxial loading factor. The boundary conditions are:

$$\sigma_{1'1'}^{\infty} = \lambda\sigma,\ \sigma_{2'2'}^{\infty} = \sigma;\ \sigma_{1'2'}^{\infty} = 0 \text{ at } |z| \to \infty \quad \ldots(21)$$

where, $\sigma_{1'1'}, \sigma_{2'2'}$ are the stresses applied about x_1', x_2' axes at infinity. The stresses along x_1, x_2 co-ordinates are obtained by transforming the corresponding loading along x_1', x_2' co-ordinates

$$\sigma_{1'1'}^{\infty} + \sigma_{2'2'}^{\infty} = \sigma_{11}^{\infty} + \sigma_{22}^{\infty}$$

$$\sigma_{1'1'}^{\infty} + \sigma_{2'2'}^{\infty} + 2i\sigma_{1'2'}^{\infty} = (\sigma_{11}^{\infty} + \sigma_{22}^{\infty} + 2i\sigma_{12}^{\infty})e^{2i\beta} \quad \ldots(22)$$

The boundary conditions along x_1, x_2 axes are given by

$$\sigma_{11}^{\infty} = \frac{\sigma}{2}\left[(\lambda+1) + (\lambda-1)\cos 2\beta\right];$$

$$\sigma_{22}^{\infty} = \frac{\sigma}{2}\left[(\lambda+1) - (\lambda-1)\cos 2\beta\right];$$

$$\sigma_{12}^{\infty} = \frac{\sigma}{2}\left[(\lambda-1)\sin 2\beta\right] \quad \ldots(23)$$

The stresses at infinity in (23) are expressed in terms of stress vectors, $\mathbf{t}_1^{\infty}$, $\mathbf{t}_2^{\infty}$ where,

$$\mathbf{t}_1^{\infty} = \begin{bmatrix}\sigma_{11} & \sigma_{12} & 0\end{bmatrix}^T,\ \mathbf{t}_2^{\infty} = \begin{bmatrix}\sigma_{12} & \sigma_{22} & 0\end{bmatrix}^T \quad \ldots(24)$$

The stress vectors (24) are useful to determine the stress functions for plate without hole. To consider required case of in-plane loading, appropriate values of λ and β are taken into (23).

tension along x_1-axis: $\lambda = 0,\ \beta = \pi/2$
tension along x_2-axis: $\lambda = 0,\ \beta = 0$
inclined uni-axial loading: $\lambda = 0,\ \beta \neq 0$
biaxial loading-arbitrary: $\lambda = 1,\ \beta \neq 0$
equi-biaxial loading: $\lambda = 1,\ \beta = 0$
shear loading: $\lambda = -1,\ \beta = \pi/4$, or $3\pi/4$

IV. Problem Definition and Method of Solution

A centrally placed cutout of arbitrary shape is considered in an infinite symmetric laminate. The boundary of the cut-out is free from loading and the laminate is subjected to arbitrary uniaxial, biaxial, and shear loading. It is required to determine the stress around the cutout and identify the factors influencing the maximum stress and its location.

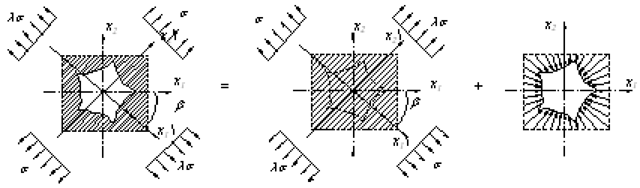
Circular, elliptical, triangular, square hole in normal and rotated positions and a rectangular holes are considered in infinite Graphite/epoxy Boron/epoxy and Glass/epoxy, cross-ply and angle-ply laminates under uniaxial tension in *x*-, *y*- directions, equi-biaxial tension and shear stress at infinity.

The method of solution for the problem is illustrated in Fig.1. The laminate with hole under remotely applied loading is shown in Fig 1(a). The solution of the problem is obtained by superposition the stress functions from the first and second stages.

A. First Stage Solution

In the first stage of the solution, the laminate without hole under remotely applied stress about arbitrary coordinate axes is considered as shown in Fig. 1(b). This produces a uniform state of stress throughout the plate. The stresses around the fictitious hole due to uniform stress state are given by

$$\boldsymbol{\varphi}^{I} = (x_2\mathbf{t}_1^{\infty} - x_1\mathbf{t}_2^{\infty}) \quad \ldots(25)$$



(a) (b) (c)

Figure 1. Scheme of solution (a) plate with hole, loading at infinity (b) uniform plate with loading at infinity (c) plate with no external loading and with negative loading on the edge of the hole

B. Second Stage Solution

In the second stage, a negative loading opposite to that of (25) is considered on the hole boundary as shown in Fig. 1(c). The boundary conditions for the plate with traction free hole and loading at infinity are

$\varphi \to \varphi^{\infty}$ at infinity; $\mathbf{t}_n = \varphi_{,s} = 0$ along the hole boundary …(26)

To satisfy the boundary conditions (26) at infinity, the function, $f(\zeta)$ is considered as a polynomial with negative powers. The negative powers of ζ makes the stress function φ^{II} equal to zero at infinity since $\zeta \to \infty$, when $z \to \infty$. The stress functions satisfying this boundary condition are given by

$$\varphi^{II} = -\left[2\,\mathrm{Re}\left[\mathbf{B} \left\langle f(z_j) \right\rangle \mathbf{c} \right] + 2 \sum_{k=1}^{N} \mathrm{Re}\left[\mathbf{B} \left\langle f(z_j) \right\rangle \mathbf{c}_k \right] \right] \quad \ldots(27)$$

C. Final Solution

The stress function for the given plate with a traction free hole and loading at infinity is obtained by superposing (25) and (27).

$$\varphi = \varphi^{I} + \varphi^{II} \quad \ldots(28)$$

Then, the stress function given by (28) is further simplified as

$$\varphi = \left((x_2 \mathbf{t}_1^{\infty} - x_1 \mathbf{t}_2^{\infty}) - 2\,\mathrm{Re}\,\mathbf{B} \left[\left\langle f(z_j) \right\rangle \mathbf{c} + \sum_{k=1}^{N} \left\langle f(z_j) \right\rangle \mathbf{c}_k \right] \right) \quad \ldots(29)$$

The constants $\mathbf{c}$, $\mathbf{c}_k$ in (29) are given by: $\mathbf{c} = -\dfrac{R\mathbf{B}^{-1}(\mathbf{t}_2^{\infty} - i\mathbf{t}_1^{\infty})}{2}$,

$$\mathbf{c}_k = -\frac{Rm_k \mathbf{B}^{-1}(\mathbf{t}_2^{\infty} + i\mathbf{t}_1^{\infty})}{2} \quad \ldots(30)$$

Now the complex function $f(z)$ in (29) is transformed to $f(\zeta)$ using (19) and it is determined by using the Schwarz formula.

$$f(\zeta) = \int_{\gamma} \mathrm{Re}\left[f(z) \right] \frac{t + \zeta}{t - \zeta} \frac{dt}{t} \quad \ldots(31)$$

The following results are used while evaluating the integrals in (31).

$$\int_{\gamma} \frac{1}{t^k} \left(\frac{t+\zeta}{t-\zeta} \right) \frac{dt}{t} = \frac{4\pi i}{\zeta^k}, \quad \int_{\gamma} t^k \left(\frac{t+\zeta}{t-\zeta} \right) \frac{dt}{t} = 0 \quad \ldots(32)$$

V. STRESSES AROUND THE HOLE BOUNDARY

The stress around the hole in anisotropic plates is given by evaluating the derivative of stress function $\boldsymbol{\varphi}$ with respect to normal and tangential directions respectively. The tangential stress around the hole is given by

$$\sigma_{ss} = -\mathbf{s}^{\mathbf{T}} \varphi_{,n} \quad \ldots(33)$$

where, $\boldsymbol{s}$ and $\boldsymbol{n}$ denote the unit tangent and normal to the hole boundary respectively as shown in Fig.2. They are given by

$$\mathbf{n}^{\mathbf{T}} = \left[-\sin\theta \quad \cos\theta \quad 0 \right], \ \mathbf{s}^{\mathbf{T}} = \left[\cos\theta \quad \sin\theta \quad 0 \right] \ \ldots(34)$$

where, angle θ is directed counter clockwise from the positive x_1-axis to the direction of **s** is as shown in Fig.2**.**

Considering an element of the hole contour AB, measuring ds subtending an elemental angle $d\psi$ at the hole centre and ψ is the angle measured in counter clockwise direction from the x_1 -axis for different points on the hole boundary, while moving from A to B in Fig.2 we have,

$$\cos\theta = \frac{-dx_1}{ds}, \ \sin\theta = \frac{-dx_2}{ds} \quad \ldots \quad (35)$$

where, $ds = \rho d\psi$ is the arc length of the hole boundary. By designating the real and imaginary parts of (18) as x_1 and x_2 respectively and taking the derivatives of x_1 and x_2 w.r.t. ψ , we have,

$$\frac{dx_1}{d\psi} = -R\left(\sin\psi + \sum_{k=1}^{N} km_k \sin k\psi \right); \qquad \frac{dx_2}{d\psi} = R\left(\cos\psi - \sum_{k=1}^{N} km_k \cos k\psi \right) \quad \ldots(36)$$

By introducing (35) into (36), we obtain the relation between angle θ and contour parameter ψ

$$\rho\cos\theta = R(\sin\psi + \sum_{k=1}^{N} km_k \sin k\psi); \qquad \rho\sin\theta = -R(\cos\psi - \sum_{k=1}^{N} km_k \cos k\psi) \quad \ldots(37)$$

where,

$$\rho = \sqrt{(\cos\psi - \sum_{k=1}^{N} km_k \cos k\psi)^2 + (\sin\psi + \sum_{k=1}^{N} km_k \sin k\psi)^2} \ \ldots(38)$$

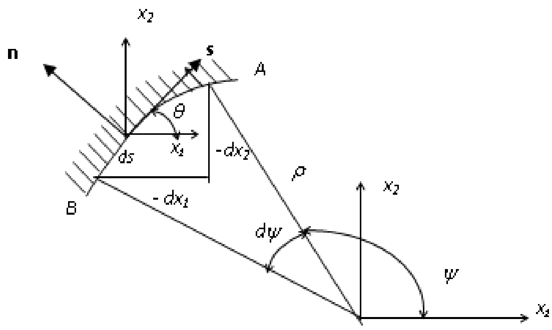


Figure 2. Directions of unit normal and tangent to the hole boundary

after taking R=1 for the size of the hole as explained in section 3. The derivative of stress function (29) with respect to normal direction **n** is obtained in the following.

$$\varphi_{,n} = \left\{ \begin{aligned} &\left(\frac{dx_2}{dn} \mathbf{t}_1^{\infty} - \frac{dx_1}{dn} \mathbf{t}_2^{\infty} \right) \\ &-2\,\mathrm{Re}\,\mathbf{B}\left[\left\langle f(\zeta)_{,n} \right\rangle \mathbf{c} + \sum_{k=1}^{N} \left\langle f(\zeta)_{,n} \right\rangle \mathbf{c}_k \right] \end{aligned} \right\} \quad \ldots(39)$$

The chain rule is applied to evaluate the derivative in (39)

$$\frac{\partial f(\zeta)}{\partial n} = \frac{\partial f(\zeta)}{\partial \zeta} \frac{\partial \zeta}{\partial \psi} \frac{\partial \psi}{\partial z} \left[\frac{\partial z}{\partial x_1} \frac{\partial x_1}{\partial n} + \frac{\partial z}{\partial x_2} \frac{\partial x_2}{\partial n} \right] \quad \ldots(40)$$

By introducing the result from (40) into (39) and also taking (41)

$$f(\zeta) = \zeta^{-k} \ \text{ where } k=1, N \ \text{ and } \frac{\partial x_1}{\partial n} = -\sin\theta,$$

$$\frac{\partial x_2}{\partial n} = \cos\theta\,,\ \frac{\partial z}{\partial x_1} = 1\,,\ \frac{\partial z}{\partial x_2} = \mu_j$$

$$\frac{\partial z_j}{\partial \psi} = \rho(\cos\theta + \mu_j \sin\theta) \qquad \ldots(41)$$

we obtain, $\dfrac{\partial f(\zeta)}{\partial n} = -i\dfrac{k\zeta^{-k}}{\rho}\mu_j(\theta)$ …(42)

After introducing the constants $\mathbf{c}_1$, $\mathbf{c}_k$ in (30) and (42) into (39), the derivative of the stress function with respect to normal direction **n,** is given by

$$\boldsymbol{\varphi}_{,n} = -\mathbf{t}_2^{\infty}\sin\theta - \mathbf{t}_1^{\infty}\cos\theta - \frac{1}{\rho}2\,\mathrm{Re}\left[\left(\mathbf{B}\left\langle\mu_j(\theta)\right\rangle\mathbf{B}^{-1}\right)\mathbf{c}\frac{1}{\zeta}\right]$$
$$-\frac{1}{\rho}2\,\mathrm{Re}\sum_{k=1}^{N}\left[\left(\mathbf{B}\left\langle\mu_j(\theta)\right\rangle\mathbf{B}^{-1}\right)\mathbf{c}_k\frac{1}{\zeta^k}\right] \qquad \ldots(43)$$

To convert the complex form of (43) into real form, the third of identities (16) is introduced in (43). The constants c, c_k from (30) are introduced into (43).

$$\mathbf{B}\langle\mu_j(\theta)\rangle\mathbf{B}^{-1} = \mathbf{G}_1(\theta) + i\mathbf{G}_3(\theta)$$
$$\mathbf{G}_1(\theta) = \left(\mathbf{N}_1^T(\theta) - \mathbf{N}_3(\theta)\mathbf{S}\mathbf{L}^{-1}\right),$$
$$\mathbf{G}_3(\theta) = \mathbf{N}_3(\theta)\mathbf{L}^{-1}$$
$$\mathbf{S} = i(2\mathbf{A}\mathbf{B}^{\mathbf{T}} - \mathbf{I})\,,\ \mathbf{H} = 2i\mathbf{A}\mathbf{A}^{\mathbf{T}}\,,\ \mathbf{L} = -2i\mathbf{B}\mathbf{B}^{\mathbf{T}} \qquad \ldots(44)$$

where, $\mathbf{G}_1(\theta)$ and $\mathbf{G}_3(\theta)$ are two real matrices defined by generalized fundamental matrices $\mathbf{N}_i(\theta)$ and Barnett-Lothe[13] tensors **S**, **H** and **L**. The derivative of the stress function with respect to normal direction **n** is given by

$$\boldsymbol{\varphi}_{,n} = -\mathbf{t}_2^{\infty}\sin\theta - \mathbf{t}_1^{\infty}\cos\theta + \frac{1}{\rho}\mathrm{Re}\left[\left\{\mathbf{G}_3(\theta) + i\mathbf{G}_1(\theta)\right\}(\mathbf{t}_2^{\infty} - i\mathbf{t}_1^{\infty})\frac{1}{\zeta}\right]$$
$$+\frac{1}{\rho}\mathrm{Re}\left[\left\{\mathbf{G}_3(\theta) + i\mathbf{G}_1(\theta)\right\}(\mathbf{t}_2^{\infty} + i\mathbf{t}_1^{\infty})\sum_{k=1}^{N}k\frac{m_k}{\zeta^k}\right] \qquad \ldots(45)$$

By using (33), (34) and (45), the normal stress or the hoop stresses, σ_{ss} and shear stresses, σ_{sn} on the hole boundary are given by

$$\sigma_{ss} = -\mathbf{s}^{\mathbf{T}}\boldsymbol{\varphi}_{,n} \qquad \sigma_{sn} = \mathbf{n}^{\mathbf{T}}\boldsymbol{\varphi}_{,n} = \sigma_{ns} \qquad \ldots(46)$$

Steps of the solution

a. Calculation of elastic constants $C_{i,j}$ (i,j=1,2,6) using equations (A1)-(A4) in Appendix-A**.**
b. Calculation of material eigenvector matrices **A**, **B** using (7).
c. Calculation of eigen values and eigenvectors using (8), listed in Table 3.
d. Obtain matrices $\mathbf{N}_1(\theta)$, $\mathbf{N}_2(\theta)$ and $\mathbf{N}_3(\theta)$ using (9).
e. Calculation of $\mathbf{Q}(\theta)$, $\mathbf{R}(\theta)$, $\mathbf{T}(\theta)$ matrices using (10) and material properties in Table 1.
f. Calculation of stress vectors $\mathbf{t}_1^{\infty}$ and $\mathbf{t}_2^{\infty}$ using (24) and λ and β from Section 4.
g. Evaluation of matrices **S**, **H** and **L** using (44).
h. Calculation of stresses around the hole using (46) and mapping function constants from Table 2.

VI. RESULTS AND DISCUSSION

The solution is proved by reproducing the results of various solutions in the literature [3,14,15]. New results are obtained for stresses around circular, elliptical, triangular and rectangular holes in laminates and laminas of Graphite/epoxy, Boron/epoxy, CF/T300, glass/epoxy, plywood and also isotropic material under uni-axial, biaxial and shear loading. The engineering constants for the materials chosen are given in Table 1 [16]. Mapping constants for different shapes opf holes are given in Table 2. The material eigen values for different fiber orientations and stacking sequence are given in Table 3.

TABLE 1. ENGINEERING CONSTANTS FOR DIFFERENT COMPOSITE MATERIALS

Material	E_1 (GPa)	E_2 (GPa)	G_{12} (GPa)	ν_{12}	ν_{21}
Graphite/ epoxy	181.00	10.30	7.77	0.28	0.02
Boron/ epoxy	282.77	23.79	10.35	0.27	0.023
CF/T300	63.80	63.80	3.20	0.036	0.036
Plywood	11.29	5.89	0.69	0.07	0.134
Glass/ epoxy	47.40	16.20	7.00	0.26	0.089

TABLE 2. MAPPING FUNCTION CONSTANTS

Shape of hole	Mapping function constants
circle	All constants are zero
ellipse	$m_1=(a-b)/(a+b)$, a, b are major, minor axes
triangle	m_2=1/3, m_5=1/45, m_8=1/162, m_{11}=7/2673, m_{14}=1/729, m_{17}=91/111537
rectangle (side ratio:5)	m_1 = 0.643, m_3 = -0.098, m_5 = -0.038, m_7 = -0.011, m_9 = 0.00056, m_{11}=0.004

A. Effect of Material

The stress distribution around triangular hole in Boron/epoxy, Graphite/epoxy, glass/epoxy, plywood unidirectional laminas and isotropic materials under x-axis loading is studied and the effect of material on maximum σ_{ss}/σ is considered. The variation of normal stress around the triangular hole for different materials is shown in Fig. 3. The highest and almost equal values of σ_{ss}/σ are obtained for Boron/epoxy and Graphite/epoxy which are equal to 21.66 and 21.48 respectively. For ply-wood, it is equal to 16.55 and for glass/epoxy it is equal to 12.12. For isotropic material, the maximum σ_{ss}/σ is equal to 8.17. In all the cases, the maximum value occurred at the corners only.

B. Effect of Fiber Orientation

The stress distribution around triangular hole in Graphite/epoxy laminas with different fiber orientations such as 0°, 30°, 45°, 60° and 90° under x-axis loading is studied and the results are shown in Fig. 4. The maximum value of σ_{ss}/σ is equal to 73.12 for 30^{o}orientation and it is 0.63 for 0^o orientation.

TABLE 3. MATERIAL EIGENVALUES FOR DIFFERENT ORIENTATION OF FIBER/STACKING SEQUENCE

Fiber orientation	Graphite/epoxy	Boron/epoxy
0^0	μ_1: 4.8932i μ_2: 0.8566i	5.1325i 0.6717i
15^0	μ_1: -2.2612+ 1.9287i μ_2: 0.0677+ 0.8722i	-2.3486+ 1.9026i 0.1425+ 0.6973i
30^0	μ_1: -1.4750+ 0.7263i μ_2: 0.1235+ 0.9177i	-1.4959+ 0.6997i 0.2755+ 0.7785i
45^0	μ_1: 0.1536+ 0.9814i μ_2: -0.9198+ 0.3923i	0.3782+0.9257i -0.9269+0.3754i
60^0	μ_1: 0.1440+ 1.0703i μ_2: -0.5456+ 0.2687i	0.4039+1.1416i -0.5485+0.2565i
75^0	μ_1: 0.0886+ 1.1397i μ_2: -0.2560+ 0.2184i	0.2812 -1.3766i -0.2571+0.2083i
90^0	μ_1: 1.1674i μ_2: 0.2043i	1.4888i 0.1948i
$[0/90]_s$	μ_1: 3.6404i μ_2: 0.2747i	4.1266i 0.2423i
$[45/-45]_s$	μ_1: -0.8597+ 0.5109i μ_2: 0.8597+ 0.5109i	-0.8891+0.4578i 0.8891+0.4578i

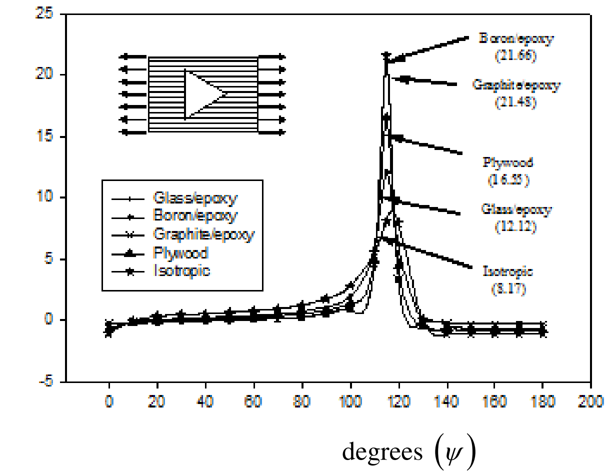


Figure 3. Effect of material on stress distribution around triangular hole in Graphite/epoxy plates

C. *Effect of Type of Loading*

Graphite/epoxy lamina with triangular hole is subjected to uni-axial loading in *x*- and *y*-directions, equi-biaxial and shear loading. The maximum values of σ_{ss}/σ for triangular hole in single layered for uni-axial, equi-biaxial and shear loading are 11.62, 16.51, 28.17 and 37.27 respectively are shown in Fig.5. Maximum value of σ_{ss}/σ has occurred for shear loading and equi-biaxial loading also has the next given higher value.

D. Effect of Laminate Geometry

The variation of normalized tangential stress around triangular hole in $[0/90]_s$ and $[45/-45]_s$ laminates of Graphite/epoxy laminates for *x*-axis loading are shown in Fig.6. Highest value of 30.39 is obtained for the $[-45/45]_s$ laminate and the $[0/90]_s$ laminate has the maximum value equal to 16.16. The combination of shape of hole and the fiber orientation has influenced the maximum value of σ_θ/σ significantly.

D. Effect of Shape of Hole

Triangular hole

The stress distribution around the triangular hole in $[0/90]_s$ laminates of Graphite/epoxy and Boron/epoxy under *x*-axis loading is shown in Fig.7 and 8 respectively. For graphite/epoxy, the maximum value of σ_{ss}/σ at 120^o is equal to 16.16 for Graphite/epoxy and for Boron/epoxy it is equal to 15.54.

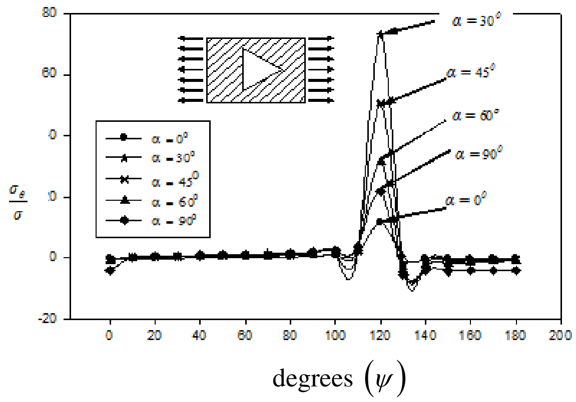


Figure 4. Effect of fiber orientation on stress distribution around triangular hole in Graphite/epoxy plates

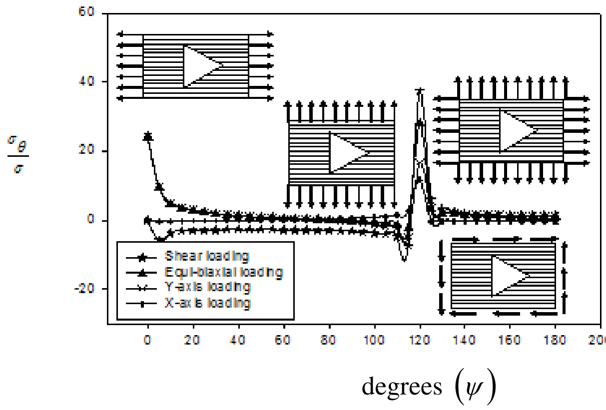


Figure 5. Effect of loading on stress distribution around triangular hole in Graphite/epoxy plates

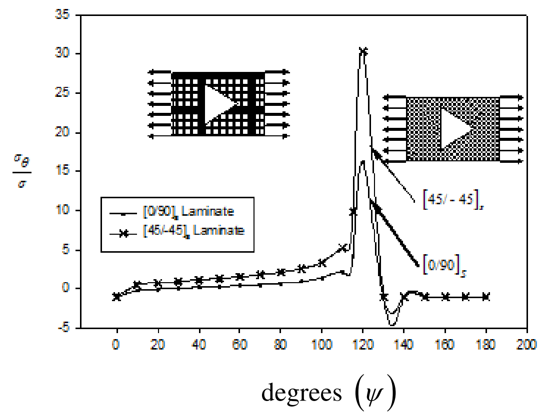


Figure 6. Effect of laminate on stress distribution around triangular hole in Graphite/epoxy plates

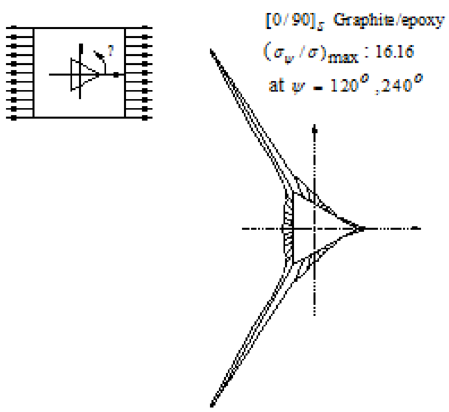


Figure 7. Stress distribution around triangular hole in $[0/90]_s$ Graphite/epoxy laminate

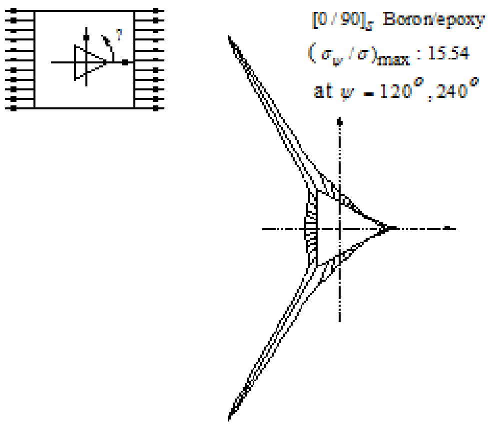


Figure 8. Stress distribution around triangular hole in $[0/90]_s$ Boron/epoxy laminate

Rectangular hole

The stress distribution around rectangular hole under *x*-axis loading on $[0/90]_s$ laminates of Graphite/epoxy and Boron/epoxy is presented in Figs. 9 and 10 respectively. cross-ply laminates behavior around the hole is almost same for both cases. The maximum value of σ_{ss}/σ for boron/epoxy is 5.51 and for graphite/epoxy, it is equal to 5.37. In both the cases, the maximum value is nearly uniform and occurred at 30°.

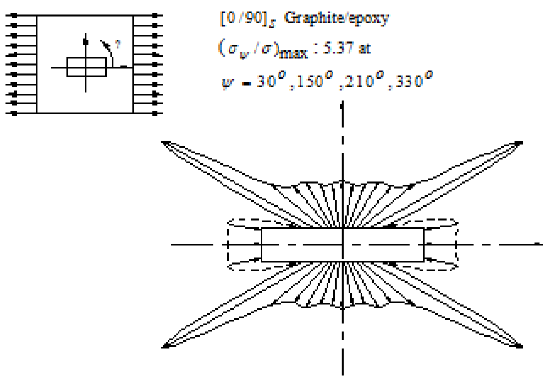


Figure 9. Stress distribution around rectangular hole in $[0/90]_s$ Graphite/epoxy laminate

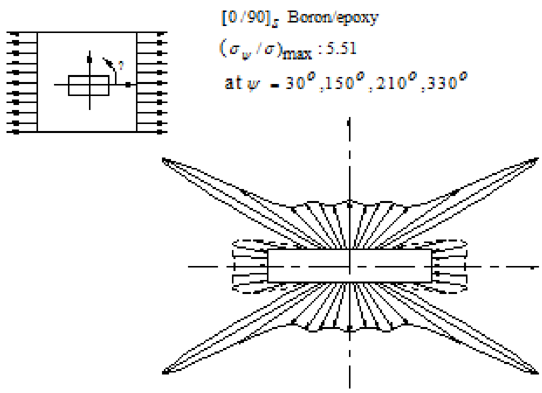


Figure 10. Stress distribution around rectangular hole in $[0/90]_s$ Boron/epoxy laminate

Elliptical hole

The value σ_{ss}/σ around the elliptical hole in $[0/90]_s$ in laminates of Graphite/epoxy and Boron/epoxy under uni-axial tension is presented in Fig.11 and Fig.12 respectively. The maximum value has occurred at 90° which is equal to 3.05 for Boron/epoxy and 2.96 for Graphite/epoxy. Lower value of σ_{ss}/σ has occurred because of the lesser radius of curvature of the hole at 90° position.

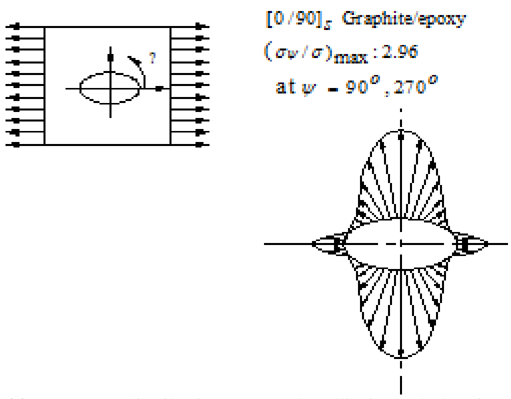


Figure 11. Stress distribution around elliptical hole in $[0/90]_s$ Graphite/epoxy laminate

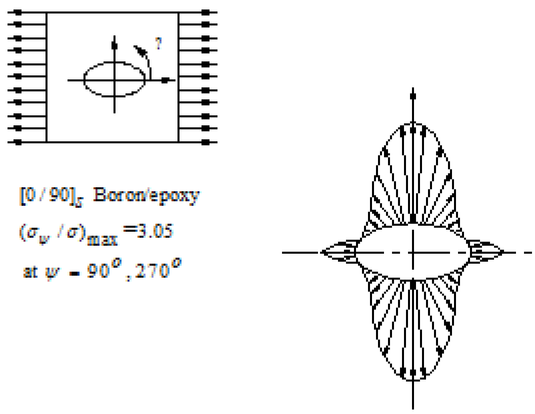


Figure 12. Stress distribution around elliptical hole in $[0/90]_s$ Boron/epoxy laminate

Circular hole

The stress distribution around circular hole in $[0/90]_s$ laminates of Graphite/epoxy and Boron/epoxy under uni-axial tension is presented in Fig. 13 and 14 respectively. The behavior of stress is more or less same for both cases. The maximum value of σ_{ss}/σ for Boron/epoxy is 5.1. It is equal to 4.9 for Graphite/epoxy and is very much close that of Boron/epoxy. The maximum value has occurred at 90^o.

The influence of variation of material on maximum σ_{ss}/σ around the hole is significant for different class of materials. For materials of the same kind, for example, Boron/epoxy and Graphite/epoxy they have nearly the same values for a particular shape of hole. However, σ_{ss}/σ is very much influenced by the shape of hole. The highest σ_{ss}/σ is obtained for the triangular hole and the value is reduced gradually from that of rectangular hole to circular hole and it is much less for the elliptical hole.

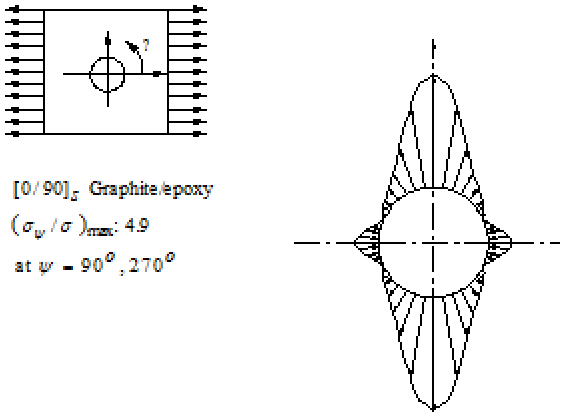


Figure 13. Stress distribution around circular hole in $[0/90]_s$ Graphite/epoxy laminate

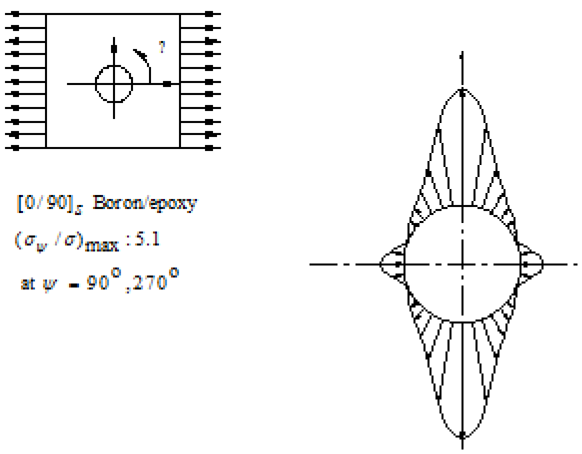


Figure 14. Stress distribution around circular hole in $[0/90]_s$ Boron/epoxy laminate

VII. Conclusion

The present general solution is unique and the enhanced capabilities of the solution have been proved by reproducing the results of several solutions in the literature. Results are obtained for several new cases, such as circular, elliptical, triangular and rectangular holes in cross-ply and angle-ply laminates and laminas of Graphite/epoxy and boron/epoxy laminates under uni-axial loading in *x*-, *y*- directions, biaxial and shear loading. The results indicate that the maximum stress around the cutout depends on factors such as, shape of hole, loading, material and laminate geometry. These results are useful to calculate the residual strength of the laminate with cutout using various failure criteria.

Appendix – A Calculation of Stiffness Coefficients

A. *Stiffness coefficients for single layered plates, C_{ij}*

For in-plane problems, the equations for calculating the elastic stiffness constants for single and multilayer anisotropic plates are given in the following. E_1, E_2, G_{12}, ν_{12} are the elastic engineering constants in principal material directions. Initially the elastic stiffness coefficients for lamina along the principal material axes are determined by following relations.

$$C_{11} = \frac{E_1}{1-\nu_{12}\nu_{21}}, \quad C_{22} = \frac{E_2}{1-\nu_{12}\nu_{21}},$$

$$C_{66} = G_{12}, \quad C_{12} = \frac{\nu_{21}E_2}{1-\nu_{12}\nu_{21}} = \frac{\nu_{12}E_1}{1-\nu_{12}\nu_{21}}$$

$$C_{14} = C_{15} = C_{24} = C_{25} = C_{44} = C_{45} = C_{46} = C_{55} = C_{56} = 0 \quad \text{(A-1)}$$

The transformed stiffness coefficients for unidirectional layers with oriented fibers are given by the following equations

$$\bar{C}_{ij} = \begin{bmatrix} \bar{C}_{11} & \bar{C}_{12} & \bar{C}_{16} \\ \bar{C}_{21} & \bar{C}_{22} & \bar{C}_{26} \\ \bar{C}_{61} & \bar{C}_{62} & \bar{C}_{66} \end{bmatrix} \quad \text{...(A-2)}$$

The transformed stiffness coefficients $\bar{C}_{ij}$ for laminas with required fiber orientation are obtained using the following equations.

$$\bar{C}_{11} = C_{11}m^4 + C_{22}n^4 + 2C_{12}m^2n^2 + 4C_{66}m^2n^2$$
$$\bar{C}_{22} = C_{11}n^4 + C_{22}m^4 + 2C_{12}m^2n^2 + 4C_{66}m^2n^2$$
$$\bar{C}_{12} = C_{11}m^2n^2 + C_{22}m^2n^2 + C_{12}\left(m^4 + n^4\right) - 4C_{66}m^2n^2$$
$$\bar{C}_{66} = C_{11}m^2n^2 + C_{22}m^2n^2 - 2C_{12}m^2n^2 + C_{66}\left(m^2 - n^2\right)^2$$
$$\bar{C}_{16} = C_{11}m^3n - C_{22}mn^3 + 2C_{12}\left(mn^3 - m^3n\right) + 2C_{66}\left(mn^3 - m^3n\right)$$
$$\bar{C}_{26} = C_{11}mn^3 - C_{22}m^3n + 2C_{12}\left(m^3n - mn^3\right) + 2C_{66}\left(m^3n - mn^3\right)$$
$$\bar{C}_{26} = C_{11}mn^3 - C_{22}m^3n + 2C_{12}\left(m^3n - mn^3\right) + 2C_{66}\left(m^3n - mn^3\right)$$
$$\text{...(A-3)}$$

B. *Stiffness constants for multilayered anisotropic plates, $\bar{Q}_{ij}$*

The stiffness constants for multilayered anisotropic plates are determined by introducing the reduced stiffness constants (A-3) into following equation.

$$\bar{Q}_{ij} = \frac{1}{h}\sum_{k=1}^{n}\left(\bar{C}_{ij}\right)^k t_k \quad \text{....(A-4)}$$

where, $\bar{C}_{ij}$, h and t_k are stiffness constant for individual layers with oriented fibers, total thickness of n layers and thickness of k^{th} layer respectively.

References

1. Lekhnitskii S.G. 1968. *Anisotropic Plates*. Gordon and Breach, New York.
2. Gao X.L. 1996. A general solution of an infinite elastic plate with an elliptical hole under biaxial loading. *International Journal of Pressure Vessels and Piping*. Vol.67, pp.95-104.
3. Daoust J. and Hoa S.V. 1991. An analytical solution for anisotropic plates containing triangular holes. *Composite Structures.* Vol.19, pp.107–30.
4. Hwu C. 1990. Anisotropic plates with various openings under uniform loading or pure bending. *Journal of Applied Mechanics.* Vol. 57, pp.700-706.
5. Hwu C. 1992. Polygonal holes in anisotropic media. *International Journal of Solids and Structures*. Vol. 29, pp.2369-2384.
6. Rezaeepazhand J. and Jafari M. 2005. Stress analysis of perforated composite plates. *Composite Structures.* Vol. 71, pp. 463-468.
7. Rezaeepazhand J. and Jafari M. 2008. Stress analysis of composite plates with non-circular cutout. *Key Engineering Materials,* pp.385-387.
8. Rezaeepazhand J. and Jafari M. 2010. Stress Concentration in Metallic Plates with Special Shape Cutouts. *InternationaJournal of Mechanical Sciences,* Vol. 52, pp.96-102.
9. Ukadgaonker VG, DKN Rao, A General Solution for Stresses around Holes in Symmetric Laminates *Composite Structures*, 49(3), 2000, pp.339-354.
10. D.K.Nageswara Rao, M. Ramesh Babu, K. RajaNarender Reddy, D. Sunil, Stress around square and rectangular cutouts in Symmetric Laminates, *Composite Structures*, 92(12), 2010, pp. 2845-2859.
11. Savin G.N. 1961. *Stress Concentration around Holes.* Pergamon Press, New York.
12. Ting T. C. T. 1996. *Anisotropic Elasticity-Theory and Applications*, Oxford, New York.
13. Barnett D.M. and Lothe J. 1973. Synthesis of the sextic and the integral formalism for dislocations, greens functions and surface waves in anisotropic elastic solids *Physica Norvegica*, Vol.7, No.1, pp.13–19.
14. Greszczuk L.B. 1972. *Stress concentrations and failure criteria for orthotropic and anisotropic plates with circular openings*. In: *Composite Materials: Testing and Design* (Second Conference), ASTM STP 497, ASTM. pp.363–81.
15. Hayashi T. 1986. *Stress analysis of the anisotropic plate with a hole under the uniaxial loading*. In: Kawata K, Umekawa S, Kobayashi A, editors. *Composites'86: Recent Advances in Japan and the US.* Proc Japan, U.S.C.C.M – III, Tokyo, pp.197–204.
16. Tsai SW and Hahn HT. 1980. *Introduction to composite materials*, Technomic Publishing, Lancaster..

Mechanical, Thermal and Water Absorption Properties of Kenaf Fibre Composites

D.K. Nageswara Rao[1*] K. Raja Narender Reddy[2] T. Ramu[3] L. Priyanka[4]

[1]Professor, Mech.Engg Malla Reddy College of Engg , Hyderabad-500100, India, dr.dknrao@gmail.com, mobile: +919393399960
[2]Professor, Mech. Engg., Kakatiya Institute of Tech. & Science, Warangal-506015,India, krajanr@rediffmail.com mobile: +91 9396431009
[3]Asst. Professor, Department of Mech. Engg., Laqshya Inst. of Tech. and Sci., Khammam-507123,India ramu.teja@gmail.com mobile: +91 99500 94333
[4]Asst.Professor, Malla Reddy College of Engg. Hyderabad-500100,India, lohilakshmi.lakshmi@gmail.com

[*]*Corresponding author: email: dr.dknrao@ gmail.com Tel: 91-9393399960*

Abstract—**Most of the studies available in the literature on kenaf fibre (KF) composites pertain to composites with short fibres. A comprehensive testing is carried out on woven KF composites and the results of various studies, viz., flexural, tensile, impact, hardness, thermal resistance and water absorption properties of treated and untreated composites are presented in this paper. The effect of alkali treatment on various properties is brought out very clearly. The glass transition temperature, T_g is obtained through DSC and thermal degradation of the composite is analyzed through TGA. Fracture behavior of the composites is studied through SEM. Results reveal that the untreated kenaf fiber composite has superior flexural modulus, high tensile strength, tensile modulus, high impact strength as well as high barcol hardness. Treated fiber composite has high flexural strength, low water absorption capacity and high thermal stability. SEM study reveals a brittle fracture for treated fiber composite while significant fiber pull out is observed for the untreated fiber composite.**

Keywords—kenaf fiber composites; natural fiber composites; mechanical properties; moisture absorption properties; differential scanning calorimetry; thermogravimetric analysis; scanning electron microscopy.

I. INTRODUCTION

Kenaf, Hibiscus cannabinus, L. belongs to the Malvaceae family, which is largely grown in Asia and Central America. Kenaf has been a potential fibre for various domestic applications, such as coarse canvas, sacks and gunny bags, floor matting, rug and chair backing, etc. It is suitable for manufacture of paper pulp. The cuttings are employed in paper manufacture. In the context of developing biodegradable materials from renewable sources, kenaf fiber has been used extensively. Various components can be molded using thermosetting or biodegradable polymers with woven kenaf fiber mats as reinforcement. These laminates can be used as casings for different equipment and machinery and also for sports and domestic products. Present work involves extraction and treatment of kenaf fibers and preparation of laminates using kenaf fiber mats as reinforcement. Such laminates are tested for various mechanical, thermal and moisture absorption properties. Results are compared for treated (*k-t*) and untreated (*k-ut*) kenaf fiber composites.

II. LITERATURE REVIEW

Initial focus during 2000s was on comparative study of the properties of natural and glass fibre composites. Due to increased attention on sustainability of the environment, the bio-composites have subsequently emerged as a new class of materials. Ford Motors [1] have started using natural fibre composites for their interiors since 1930s. However, contemporary research on composites is progressing towards green and nano composites. Green composites are produced using natural fibers and thermoplastic/thermosetting resins [2-4]. Hybrid composites [5-9] have been made out of combination of fibers such as, natural fibre/fabric and glass fibre/fabric, banana/kenaf, jute/cotton, woven betel palm and kenaf fibre with polyester matrix. These composites are found to have superior strength, thermal stability and dielectric properties than the individual composites. Surface treatments [10-16] like, alkalization, benzoylation, etc., on natural fibres have significantly improved the strength properties, glass transition temperature, storage modulus, loss modulus and damping factor. These treatments have decreased the water absorption capacity of the composite. Treatment of sisal fibres with poly methyl methacrylate and admicellar polymerization [17-19] has enhanced the tensile, flexural and impact strengths, dynamic mechanical behaviour, electrostatic charge, thermal stability, dielectric constant and ac conductivity. Storage modulus, activation energy, etc., are found to be higher for the cured polyester resin (neat resin). Maya and Anandjiwala [20], have done extensive studies on surface modification of natural fibres and bio-composites. Studies on banana, doum palm and piassava fibre composites [21-26] have revealed very good mechanical and thermal properties. Doum palm and piassava fibres are very strong and they are subjected to a combination of treatments like, alkali/enzymatic and mercerization/ acetylation treatments to improve softness and adhesion. Silk fabric reinforced epoxy phenol cashew nut shell liquid toughened composites [27] have enhanced the properties compared to those of pure epoxy/silk composites. Hemp and agave fibre composites are found to have superior mechanical, thermal and water absorption properties [28, 29]. Chemically treated okra fibre composites [30, 31] have increased the tensile strength, tensile modulus and thermal stability. Most recently, Januar,et.al. [32], have published the results of DSC and TGA analysis on pineapple leaf fiber (PALF) reinforced high impact poly styrene (HIPS) composites. Due to superior physical characteristics of length, texture and ease of extraction, the kenaf fibre (KF) has been identified as having great potential for making bio-degradable composites. Treatment of kenaf fibres with silane coupling agent has improved the dynamic mechanical properties [33]. Flexural and tensile strengths and water absorption properties [34, 35] are found to have increased with increase in fibre content and mould pressure.

In the present paper, treated (kfc-t) and untreated (kfc-ut) woven kenaf fiber polyester composites are investigated for flexural, tensile and impact strengths, barcol hardness, thermal resistance and water absorption properties. Glass transition temperature, T_g is obtained through DSC and thermal degradation of the composite is analysed through TGA. SEM studies are carried out to observe the fracture behavior of the composite.

III. Experimental Work

A. Materials for Composite

Kenaf fibers (KF) are produced from the fibrous outer layer of the plant. Soft and useful fibers are obtained by retting process. The fiber strands are 2-3m long. Uni-directional mats are prepared on an indigenous weaving set up using untreated and treated fibers. General purpose isopthalic polyester resin is procured from M/s Sakthi Fiber Glass, Chennai, India. 2% Methyl Ethyl Ketone Peroxide (MEKP) and 2% cobalt napthalate are used as additives. Wax polish and poly vinyl alcohol (PVA) are used as releasing agents.

B. Fiber modifications

For chemical treatment, the dried fibers are soaked in 2% NaOH solution for 24 hrs at room temperature. This treatment helps in dissolving lignin and hemicelluloses and exposes more of the fiber OH groups. The fibers are washed thoroughly with double distilled water to remove NaOH. These treated fibers are dried at room temperature for 24 hours.

C. Composites

KF composites are fabricated with 15% volume fraction (by weight of fibers) in an open mold process between two thick glass plates. To create a releasing surface between the composite and the glass plate, a thin coat of PVA is applied on the contacting surfaces of plate. The fiber mat is rolled by hand roller for proper wetting of the mat with the resin and to release the entrapped air. After keeping the mold under pressure for 24 hours, the laminates are post cured at room temperature for another 24 hours. Two types of composites, one with treated fiber and the other with untreated fiber are made and they are referred in the text and figures as: KF composite-treated (kfc-t) and KF composite-untreated (kfc-ut).

D. Flexural Test

Flexural properties are evaluated as per ASTM D-790 through three-point bend test on compression testing machine at a cross head speed of 1.25 mm/minute, supplied by Hydraulic and Engineering Instruments, New Delhi.

E. Flexural Strength

Flexural strength is the maximum stress in the outer specimen at the moment of break. When the homogeneous elastic material is tested with three-point system, the maximum stress occurs at the midpoint. This stress is evaluated for any point on the load deflection curve using (1).

$$\sigma_f = \frac{3PL}{2bd^2} \qquad \dots (1)$$

where σ_f = stress in the outer specimen at midpoint, MPa

P = load at a given point on the load deflection curve, N

L = support span, mm

b = width of beam tested, mm

d = depth of beam tested, mm

F. Flexural Modulus

Flexural modulus or Modulus of elasticity is a measure of the stiffness during the initial part of the bending process. Flexural modulus is the ratio of stress to corresponding strain within the elastic limit. A tangent line is drawn to the steepest initial straight line portion of the load deflection curve and the flexural modulus is calculated using (2).

$$E_B = \frac{L^3 m}{4bd^3} \qquad \dots (2)$$

where E_B = modulus of elasticity in bending, MPa

L = support span, mm

m = slope of the tangent to the initial straight line portion of the load-deflection curve, N/mm of deflection

b = width of specimen, mm

d = depth of specimen, mm

G. Tensile Test, Tensile Strength and Tensile Modulus

Tensile test is conducted on Zwick /Roell Z010-10KN-UTM at a cross head speed of 3mm/min. Standard Type IV dumb bell shaped specimens as per ASTM D-638 are used. The values of tensile strength and tensile modulus are obtained by the maximum load resisted up to the point of fracture and the associated strain.

H. Impact strength

Notched impact performance of the composite is evaluated as per ASTM D-256 using Izod impact supplied by

PSI Sales Pvt. Ltd., New Delhi. This method elaborates the determination of the resistance to breakage by flexural shock.

I. Barcol hardness

Standard test method ASTM D-2583 is used to find indentation hardness of the composite through barcol impresser model no. 934-1. This test employs a hardened steel truncated cone indenter having an angle of 20º with a flat tip at 0.157mm diameter.

J. Morphology

Morphology of the fractured surfaces and fiber pull out are observed by Scanning Electron Microscopy (SEM) using EVOMA15 Smart SEM.

K. Water absorption

Water absorption tests are conducted as per ASTM D-570 on rectangular specimens of 25.4×76.2 mm^2 size. Samples are conditioned by heating in an oven at 50^{o}C for 24 hours and then cooling. The weights of the samples are taken by Shimadzu Electronic Balance with readability of 0.001g. All the samples are immersed in double distilled water for 24 hrs at room temperature. Reconditioning is done by keeping them once again in the oven for 24 hrs at 50^{o}C. Percentage increase in weight of the specimens during immersion is obtained by the ratio of increase in average weight of the conditioned specimen after immersion in water for 24 hrs and the average weight of reconditioned specimen calculated nearest to 0.01%. The amount of soluble matter lost is given by the decrease in weight of the specimen after reconditioning.

L. Differential Scanning Calorimetry (DSC)

DSC is performed with the help of Mettler using Star SW 8.1 analyzer to measure glass transition temperature (T_g). The temperature is programmed in the range of 25°- 300°C, under nitrogen atmosphere.

M. Thermogravimetric Analysis (TGA)

Thermal decomposition is observed in terms of loss of global mass by using a TA Instrument TGAQ50 V20.10 Build 36 thermogravimetric analyzer. The temperature change is controlled from room temperature to 800 ^{o}C at a heating rate of 20^o C/min. A high purity nitrogen stream was continuously passed into the furnace at a flow rate of 60 ml/min at room temperature and atmospheric pressure. Before starting each run, nitrogen is used to purge the furnace for 30 min to establish an inert environment to prevent any unwanted oxidative decomposition.

IV. Results and Discussion

A. Flexural Strength

Load-deflection diagram for flexural strength test on KF composites is shown in Fig. 1. The values of flexural strength and flexural modulus for treated and untreated KF composites are given in Table 1. For treated fiber composite, the flexural strength is equal to 95 MPa and for untreated fiber composite, it is equal to 87 MPa. For neat resin, it is equal to 136 MPa. The flexural strength of the composite is determined based on maximum bending load at failure using (1). Due to increased adhesion between the matrix and the fibres, the treated fibre composite has higher flexural strength. The composite has failed at a lower bending load in case of untreated fibre composite. Contrastingly, for the same untreated KF composite, the flexural modulus is higher equal to 35037 MPa which is 4.87 times that of neat resin. For the treated fiber composite, it is equal to 16754 MPa. The treated fibre composite was very thin due to alkali treatment of the fibre and the slope in the initial part of the load deflection curve has been very low. It can be inferred that prolonged exposure of fibre during treatment has weakened the fibre surfaces and reduced the property. This supports the statement by Reid, et. al., [36] that increased concentrations will damage the fibre surface and reduce the mechanical properties. The modulus of elasticity for bending is calculated using (2) as per ASTM D-790. For untreated fibre composite, the fibres are inherently coarse and the composite was thick. It exhibited higher rigidity, resulting in higher flexural modulus. Specific flexural strength and specific flexural modulus of the composite and the neat resin are obtained by taking into account of the weight density of the specimens and the values are shown in Figs. 2 and 3.

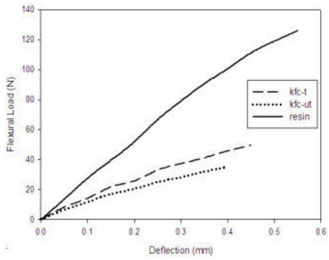


Fig.1. Load-deflection diagram of KF composites.

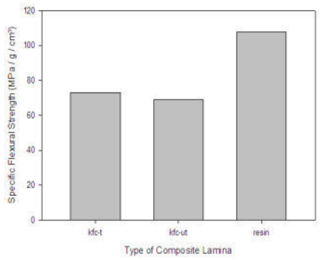


Fig 2. Specific flexural strength for flexural test on KF composites.

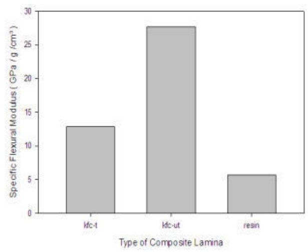


Fig.3. Specific flexural modulus for of KF composites.

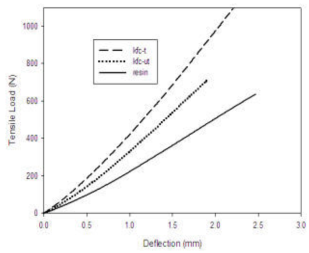


Fig. 4. Load-deflection diagram tensile test on KF composites.

B. Tensile Strength

The load-deflection diagram is shown in Fig. 4. The ultimate tensile strength of treated fiber composite is equal to

97 MPa and for untreated fiber composite, it is equal to 99 MPa. For the neat resin, it is equal to 39 MPa. These values are given in Table 1. The untreated KF composite has the highest tensile modulus equal to 1340 MPa which is 3.36 times that of neat resin and 1.22 times that of treated fiber composite. Specific tensile strength and specific tensile moduli for different composites are shown in Figs. 5 and 6 respectively.

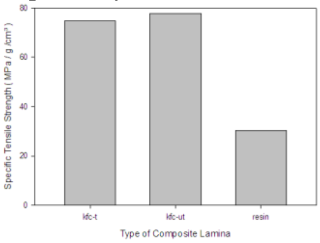


Fig.5. Specific tensile strength of KF composites.

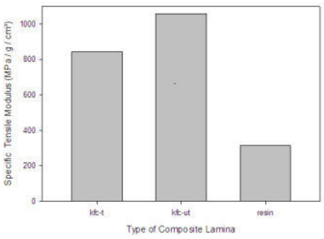


Fig.6.Specific tensile modulus of KF composites.

TABLE1. MECHANICAL PROPERTIES OF KF COMPOSITES.

Property	kfc-t	kfc-ut	neat resin
Flexure strength(MPa)	95	87	136
Flexure modulus(MPa)	16754	35037	7191
Ultimate tensile strength (MPa)	97	99	39
Tensile modulus(MPa)	1097	1340	399
Impact strength (kJ/m^2)	25.6	14.8	1.9
Barcol Hardness	58	59	56
Density (g/cm^3)	1.30	1.27	1.27

C. Morphology

The SEM micrographs of the fractured surfaces of treated and untreated KF composites are shown in Figs. 7 and 8 respectively. In Fig. 7, a sharp, brittle fracture is observed for the treated fiber composite while traces of fiber pull out are observed in Fig. 8 for the untreated fiber composite indicating a weak interface bonding. Alkali treatment has dissolved the fibres and resulted in straight microscopic pits. This surface modification has increased the interaction between fibres and resin. Improved fibre-matrix adhesion has resulted in brittle fracture of the composite.

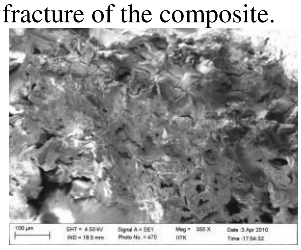


Fig.7. SEM image of fractured treated KF composite.

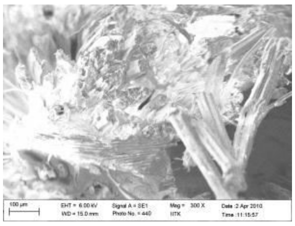


Fig.8. SEM image of fractured untreated KF composite

D. Impact Strength

For treated fiber composite, the impact strength is equal to14.8 kJ/m^2 while the untreated KF composite has the highest value of 25.6kJ/m^2. Treated fiber composites showed lower impact strength as a consequence of higher interface adhesion resulting in lack of energy absorption mechanism in the impact test. The impact strength of neat resin is 1.9 kJ/m^2. The values of impact for different composites are shown in Table 1.

E. Barcol Hardness

Barcol hardness for treated KF composite, it is equal to 58 and for untreated fibre composite, it is 59 as given in Table 1.

N. DSC Analysis

DSC analysis is done in nitrogen atmosphere of 30 ml/min with a heating rate of 10^{o}C between 25^{o}C-150^{o}C. Results of the analysis for composites and neat resin are given in Table 2. For amorphous solid like the fiber composite, a state of transition occurs due to change in heat capacity from hard brittle state to soft rubbery state. For composite with treated fibers, the glass transition temperature, T_g is 71.69^{o}C with a heat flow of -0.956 mw/min and at a heat capacity of -0.0956 mw/°C. Similarly, for composite with untreated fibers, the T_g is 72.76^{o}C with a heat flow of -0.479 mw/min and at a heat capacity of -0.0479 mw/°C. For neat resin, T_g is observed at 73.4^{o}C with a heat flow of -0.625 mw/min and at a heat capacity of -0.0625 mw/°C.

TABLE 2. THERMAL PROPERTIES OF COMPOSITES AND NEAT RESIN BY DSC

Type of fiber	Weight of the sample mg	Glass transition temperature ^{o}C	Heat capacity mJ
kfc-ut	10.199	72.76	-7.98(exo)
kfc-t	10.199	71.69	12.96(exo)

O. Thermogravimetric Analysis

Thermogravimetric analysis (TGA) curves are used to determine the thermal degradation and thermal stability of the polymeric material. Thermal decomposition of each sample took place in a programmed temperature range of 25°-800°C. The neat resin showed only one stage of weight loss process. This has a transition temperature from 340°C to 417°C, and it is clear that the peak transition temperature has occurred at 401°C. The weight loss and residual weight of neat resin for the TG analysis are found to be 91% and 3%, respectively. TG curves show that the thermal stability of the composites is found to be higher than that of the neat resin. Beginning of decomposition took place at 260^{o}C for both treated and untreated composites and for neat resin, it is at 340^{o}C. However, the decomposition has ended at 475^{o}C for treated fibre composite while it is at 463^{o}C and 417^{o}C for untreated fibre composite and for neat resin respectively, as shown in Table 3. Therefore, the thermal stability of the treated fiber composite is higher compared to that of untreated fiber composite. Lower percentage losses are obtained for the treated fibre composite. Higher thermal stability of treated composites is due to improved fiber/matrix interactions that produced additional intermolecular bonding between fiber and matrix. This is also evident from the lower weight loss at different temperatures.

Table 3. Thermogravimetric analysis of KF composites

	Transition temperature (°C)			**% weight loss at transition Temp.**	**Residual weight (%) at 460°C**
	Beginning of decomposition	Max. decomposition	End of decomposition		
kfc-t	260	390	475	21	3
kfc-ut	260	380	463	22	3
neat resin	340	401	417	60	3

P. Water absorption

Treated fiber composite has absorbed less water compared to that of untreated fibre composite. Treatment of kenaf fibers with NaOH for 24 hrs has made the fibers less hydrophilic and decreased the water absorption capacity by 61%. The moisture absorption behavior of various composites is shown in Fig. 11. As the fibers are hydrophilic in nature, they absorbed water during immersion and loss of matter has been observed upon reconditioning. The percentage loss of soluble matter during immersion after reconditioning the specimens is shown in Fig.12. The fiber surface treatment has decreased the loss of soluble matter by 91%. Absorption of water by ligno-cellulose material has rendered the formation of hydrogen bonds between water and hydroxyl groups of cellulose, hemi-cellulose and lignin in the cell wall [20] and caused the swelling of the composite. This has resulted in increase in width and reduction in length of the composite. Less water absorption by treated composite is due to replacement of hydrophilic OH groups of fiber by more hydrophobic ester groups or otherwise due to formation of a protective layer on the interfacial zone that prevented water molecules from penetrating into the cell wall. The moisture absorption behavior for long-time immersion up to 1200 hours is shown in Fig. 13. It can be noted that there is a gradual increase in water absorption and the state of saturation has occurred at around 600 hours. At saturation, the maximum moisture absorption for treated and untreated fiber composites is 12%, 8% respectively. For the treated fibre composite, there is an increase in thickness by 16% and width by 4%. During this period, the thickness and width of untreated fibre composite has increased by 16%and 6% respectively while the length is slightly decreased by 0.2%. The thickness, width and length of neat resin are slightly increased due to long time immersion as shown in Figs. 11-14.

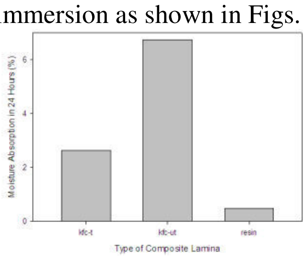


Fig.9 Moisture absorption behavior of composites.

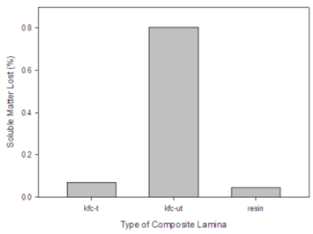


Fig.10.Soluble matter lost for KF composites.

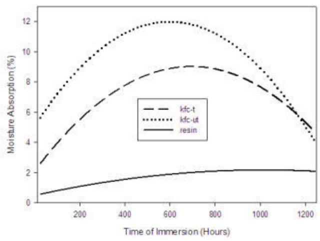


Fig.11.Moisture absorption behavior of KF composites for long-time immersion.

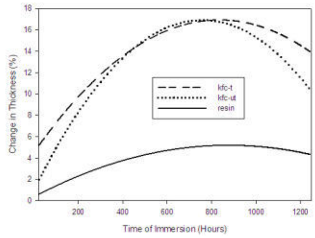


Fig.12.Change in thickness of KF composites for long-time immersion

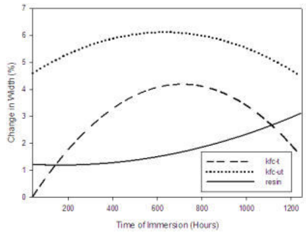


Fig.13.Change in width of KF composites for long-time immersion

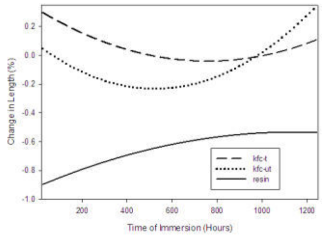


Fig.14. Change in length of KF composites for long-time immersion

V. CONCLUSION

Flexural, tensile and impact strengths, SEM, barcol hardness, DSC, TGA and water absorption studies on KF treated and untreated composites are presented. To estimate the influence of reinforcement, a comparison is made with the corresponding properties of pure resin. The treated fibre composite has higher flexural, tensile and impact strengths, high Barcol hardness, higher T_g and decomposition temperatures and reduced water absorption capacity. In all the cases, reinforcement with fibres has improved the properties of the composite compared to those of pure resin except for the flexural strength. Alkali treatment has removed the impurities on the surface of the fibres and produced a rough surface topography and has produced fiber fibrillation. Although alkali treatment has enhanced the fibre-matrix adhesion and increased the flexural strength, there is a decrease in flexural modulus due to decrease in rigidity of the composite. The decrease in rigidity is due to reduced thickness of the composite as a result of thinning of fibres. However, for untreated fibre composite, the flexure strength is 4.87 times and tensile strength is 2.56 times that of neat resin. SEM studies revealed the traces of fiber pull out for the untreated kenaf fiber composite while brittle fracture is noted for the treated fibre composite. Barcol hardness and impact strengths are higher for untreated fiber composite compared to that of neat resin. Due to stronger interaction between the natural fiber and the polyester matrix and formation of covalent bond at the fibre-matrix interface, there is an increase in thermal resistance of the composite. TGA gave higher decomposition temperature and low weight loss. It has also reduced the moisture absorption capacity due to the formation of protective layer in the fiber-matrix interface and also prevented the loss of soluble matter.

References

[1] Gerard Mougin, Maida Magnum, Nicole Eikelenberg, Natural-fibres composites for the automotive industry: challenges, solutions and applications, *International Journal of Materials and Product Technology,* Vol. 36(1-4), 2009: pp. 176 – 188.

[2] C. Santulli, Mechanical and impact properties of untreated jute fabric reinforced polyester laminates compared with different E-glass fibre reinforced laminates, *Science and Engineering of Composite Materials* 9 (4), 2000, pp.177-188.

[3] S.V. Joshi, L.T. Drzal, A.K. Mohanty, S. Arora, Are natural fiber composites environmentally superior to glass fiber reinforced composites? *Composites: Part A*, 35, 2004, pp.371-376.

[4] Exequiel Rodriguez, Roberto Petrucci, Debora Puglia, Jose M. Kenny and Analia Vazquez, Characterization of composites based on natural and glass fibers obtained by vacuum infusion, *Journal of Compposite Materials*, Vol. 39(3), 2005, pp.265-282.

[5] G. Venkata Reddy, S. Venkata Naidu, T. Shobha Rani, Impact properties of kapok based unsaturated polyester hybrid composites, *Journal of Reinforced Plastics and Composites,* Vol. 27(16-17), 2008: pp.1789-1804.

[6] L. A. Pothan, Chandy N. George, Maya Jacob John and Sabu Thomas, Dynamic mechanical and dielectric behaviour of banana-glass hybrid fiber reinforced polyester composites, Journal of Reinforced Plastics and Composites, Vol. 29(8), 2010: pp.1131-1145.

[7] R.Velmurugan, V. Manikandan, Mechanical properties of glass/palmyra fiber waste sandwich composites, *Indian Journal of Engineering & Materials Science*, Vol. 12, 2005, pp.563-570.

[8] M.Thiruchitrambalam, A. Alavudeen, A. Athijayamani, N. Venkateswaran, A. Elaya Perumal, Improving mechanical properties of banana/kenaf polyester hybrid composites using sodium laulryl sulfate treatment, *Materials Physics and Mechanics*, Vol. 8, 2009: pp.165-173.

[9] Eliton S. de Medeiros, Jose A.M. Agnell, Kuruvilla Joseph, Laura H. De carvalho and Luiz H.C. Mattoso, Mechanical properties of phenolic composites reinforced with jute/cotton hybrid fabrics, *Polymer Composites*, Vol. 26: 2005, pp. 1-11.

[10] Sharifah H. Aziz and Martin P. Ansell The effect of alkalization and fibre alignment on the mechanical and thermal properties of kenaf and hemp bast fibre composites: Part 1–polyester resin matrix, *Composites Science and Technology*, Vol. 64(9), 2004, pp.219-1230.

[11] W. L. Lai, M. Mariatti, Mohamad Jani S., The properties of woven kenaf and betel palm (*Areca catechu*) reinforced unsaturated polyester composites, *Polymer-Plastics Technology and Engineering*, Vol. 47(12), 2008: pp.1193-1199.

[12] Exequiel S. Rodriguez, Pablo M. Stefani and Analia Vazquez, Effects of fibers' alkali treatment on the resin transfer molding processing and mechanical properties of jute-vinylester composites, *Journal of Compposite Materials*, Vol. 41(14), 2007, pp.1729-1741.

[13] S.K. Acharya, P. Mishra, S.C. Mishra, Effect of environment on the mechancical properties of fly-ash-jute polymer composite, Indian journal of Engineering & Materials Science, Vol. 15, 2008: pp.483-488.

[14] Arnold N. Towo, Martin P. Ansell, Fatigue evaluation and dynamic mechanical thermal analysis of sisal fibre–thermosetting resin composites *Composites Science and Technology,* Vol. 68(3-4), 2008: pp.925-932.

[15] L.A. Pothan, Y.W. Mai, S. Thomas, R.K.Y. Li, Tensile and flexural behavior of sisal fabric/polyester textile composites prepared by resin transfer molding technique, *Journal of Reinforced Plastics and Composites,* Vol. 27 (16-17), 2008: pp.1847-1866.

[16] Sreekumar, P.A., Saiah Redouan , Saiter Jean Marc, Leblanc Nathalie, Joseph Kuruvilla, Unnikrishnan, G., Thomas Sabu, What's the Effect of chemical treatment on dynamic mechanical properties of sisal fiber-reinforced polyester composites fabricated by resin transfer molding, *Composite Interfaces*, Vol.15(2-3), 2008 : pp. 263-279.

[17] Supranee Sangthong, Thirawudh Pongprayoon and Nantaya Yanumet, Mechanical property improvement of unsaturated polyester composite reinforced with admicellar-treated sisal fibers *Composites Part A: Applied Science and Manufacturing,* Vol. 40(6-7), 2009: pp.687-694.

[18] P.A. Sreekumar, Redouan Saiah, Jean Marc Saiter, Nathalie Leblanc, Kuruvilla Joseph, G. Unnikrishnan, Sabu Thomas, Dynamic mechanical properties of sisal fiber reinforced polyester composites fabricated by resin transfer molding, *Polymer Composites*, Vol. 30(6), 2009: pp. 768–775.

[19] Annapurna Patra, Dillip Kumar Bisoyi, Dielectric and impedance spectroscopy studies on sisal fibre-reinforced polyester composite, *J Mater Sci*, 45, 2010: pp.5742–5748.

[20] Maya Jacob John, Rajesh D. Anandjiwala, Recent developments in chemical modification and characterization of natural fiber-reinforced composites, Polymer Composites, Vol. 29,(2), 2008: pp.187-207.

[21] M.A. Maleque, F.Y.Belal, Mechanical properties study of pseudo-stem banana fiber reinforced epoxy composite, *The Arabian Journal for Science and Engineering,* Vol. 32 (2B), 2007: pp.359-354.

[22] P. A Sreekumar, Pradeesh Albert, G. Unnikrishnan, Kuruvilla Joseph, Sabu Thomas, Mechanical and water sorption studies of ecofriendly banana fiber-reinforced polyester composites fabricated by RTM, *Journal of Applied Polymer Science,* Vol. 109(3), 2008: pp. 1547–1555.

[23] F. Zbidi, S. Sghaier, M.B. Nejma and M. Zidi, Influence of alkaline and enzymatic treatments on the properties of doum palm fibers and composite, *Journal of Applied Sciences*, Vol. 9(2), 2009: pp.366-371.

[24] A.L.F.S.K. d'Almeida, V. Calado, D.W. Barreto, Effect of surface treatments on the dynamic mechanical behavior of piassava fiber-polyester matrix composites, *Journal of Thermal Analysis and Calorimetry*, 10.1007/s10973-010-1027-y, On line first, published on line:18 September 2010.

[25] D.C.O. Nascimento, F.P.D. Lopes, S.N. Monteiro, Tensile behavior of lignocellulosic fiber reinforced polymer composites: Part I piassava/epoxy, *Revista Matéria,* Vol. 15(2), 2010: pp.189-194.

[26] Fabiana Ferreira Avelar, Maria Lúcia Bianchi, Maraisa Gonçalves and Estella Gaspar da Mota The use of piassava fibers (*Attalea funifera*) in the preparation of activated carbon, *Bioresource Technology*, Vol. 101(12), June 2010, pp. 4639-4645.

[27] S. Padma Priya, H.V. Ramakrishna and K.S. Rai, Utilization of waste silk fabric as reinforcement in epoxy phenol cashew nut shell liquid toughened epoxy resin: studies on mechanical properties, *Journal of Composite Materials*, Vol. 40(14), 2006, pp.1301-1311.

[28] H.N. Dhakkal, Z.Y. Zhang, M.O.W. Richardson, Effect of water absorption on the mechanical properties of hemp fibre reinforced unsaturated polyester composites, *Composites Science and Technology*, vol. 67, issues 7-8, June 2007, pp.1674-1683.

[29] Bessadok, D. Langevin, F. Gouanve, C. Chappey, S. Roudesli, S. Maris, Study of water sorption on modified Agave fibers, *Carbohydrate Polymers*, Vol. 76(1,2), 2009: pp.74-85.

[30] N. Srinivasababu, K. Murali Mohana Rao and J. Suresh Kumar, Tensile properties characterization of okra woven fiber reinforced polyester composites, International Journal of Engineering, Vol.3(4), 2009: pp.403-412.

[31 Igor Maria De Rosa, Josè Maria Kenny, Debora Puglia, Carlo Santulli and Fabrizio Sarasini, Morphological, thermal and mechanical characterization of okra (Abelmoschus esculentus) fibres as potential reinforcement in polymer composites, Composites Science and Technology, Vol. 70(1), 2010: pp.116-122.

[32] Januar PS, Md.Sapuan Salit, Md.Zaki Ab, Rahman, and Khairul Zaman Hj. Mohd.Dahlan, Thermogravimetric Analysis TGA) and Differential Scanning Calorimetric (DSC) Analysis of PALF Reinforced High impact polystyrene(HIPS) composites, Pertanika J.Sci. & Technol. Vol 19(1), 2011: pp. 161-170.

[33] Y. Xu, S, Kawata, K. Hosoi, T. Kawai, S. Kuroda, Thermomechanical Properties of the silanized-kenaf/polystyrene composites, eXPRESS Polymer Letters, Vol.3 (10), 2009: pp.657-664.

[34] S. Rassmann, R.G. Reid and R. Paskaramoorthy, Effects of processing conditions on the mechanical and water absorption properties of resin transfer moulded kenaf fibre reinforced polyester composite laminates *Composites Part A: Applied Science and Manufacturing*, Vol. 41(11), 2010: pp.1612-1619.

[35] Rashdi, Mohd. Sapuan Salit, Khalina Abdan, Megat Mohamad Hamdan Megat, Water absorption behavior of kenaf reinforced unsaturated polyester composites and its influence on their mechanical properties, *Pertanika J. Science & Technol,* Vol. 18(2), 2010: pp. 433-440.

[36] Robert G. Reid, Oscar M.L. Asumani and R. Paskaramoorthy, The effect on the Mechanical Properties of Kenaf Fibre Reinforced Polypropylene resulting from Alkali–Silane surface treatment, 16th International Conference on composite Structures ICCS16, AJM Ferreira (Editor), Porto, 2011.

.

Dynamic and static coupled field analysis of a piston In a four-stroke diesel engine using ANSYS

D.K.Nageswara Rao, Prasanna Inaganti, AjayR Kodliwad, B. Rajendra Prasad
Department of MechanicalEngineeringMallareddy College of Engineering, Hyderabad-500100

***Abstract*-Thecomponentpistoninaninternalcombustionengineplaysanimportantroleintransformingthethermalenergydevelopedduringthecombustionintomechanicalenergy.Duringthisprocess,thepistonissubjecttoheat,andpressuresdevelopedinthecombustionaswellasvariationsinpressuresduringvariousstrokesoftheengine.Hence,thereisaneedtostudythebehaviorofthepistontotheloadsactingonit.Inthiswork,thedistributionsofstressandtemperaturesinthepistonarefoundusingfiniteelementanalysispackage,ANSYSUNDERtwoloadingconditionsi.e.onlygaspressure,andcombinationofthermalloadandgaspressure.Designofthepistonhasbeencarriedoutusingstandardproceduresavailableintheliterature.Later,uniaxialtensiontesthasbeenperformedonanAluminiumspecimenandthevaluesfromthestress-traindiagramareimportedtoANSYStodefinethenon-linearbehaviourofthematerial.CADmodelisgeneratedintheANSYSandstaticcouplefieldanalysis(Non-linearstructuralandthermal)isperformedbyapplyingvariousloads(thermalandcombustionpressure)onthepiston.Thestressandtemperaturedistributionsonthepistonare studiedandthe conclusionsare drawn.**

Keywords-dynamicanalysis,staticanalysis,four-strokedieselengine,

I. INTRODUCTION

ApistonisacomponentofreciprocatingIC-engines.Itisthemovingcomponentthatiscontainedbyacylinderandismadegas-ightbypistonrings.Inanengine,itspurposeistotransferforcefromexpandinggasinthecylindertothecrankshaftviaapiston rod.Pistonenduresthecyclicgaspressureand theinertialforcesatwork,and thisworkingconditionmaycausethefatiguedamageofpiston,suchaspistonsidewear,pistonheadcracksandsoon.Sothereisaneedtooptimizethedesignofpistonbyconsideringvariousparametersinthisprojecttheparametersselectedareanalysis ofpistonbyapplyingpressureforceactingatthetopofthepistonandthermalanalysisofpistonatvarioustemperaturesinvariousstroke.Thisanalysiscouldbeusefulfordesignengineerformodificationofpistonatthetimeofdesign.In thisprojectwedeterminethevariousstresscalculationbyusingpressureanalysis,thermalanalysisandthermo-mechanicalanalysis

II. DESIGNOFTHEPISTON

A. AboutPiston

Apistonisacomponentusedinaninternalcombustionengine,whichtransformsthethermalenergygeneratedduring the combustionintomechanicalenergy. Itisconnectedtothecrankshaftviaconnectingrod.Whenthecombustionprocesshappensinsidethecylinder,thegaspressure actingon the pistoncrowntendsto push it downward towardsthecrankcaseanditsreciprocatingmotionisconvertedtorotarymotionofthecrankshaftwiththehelpofconnectingrod.Dependingonthedimensions,thepistonsareclassifiedas:

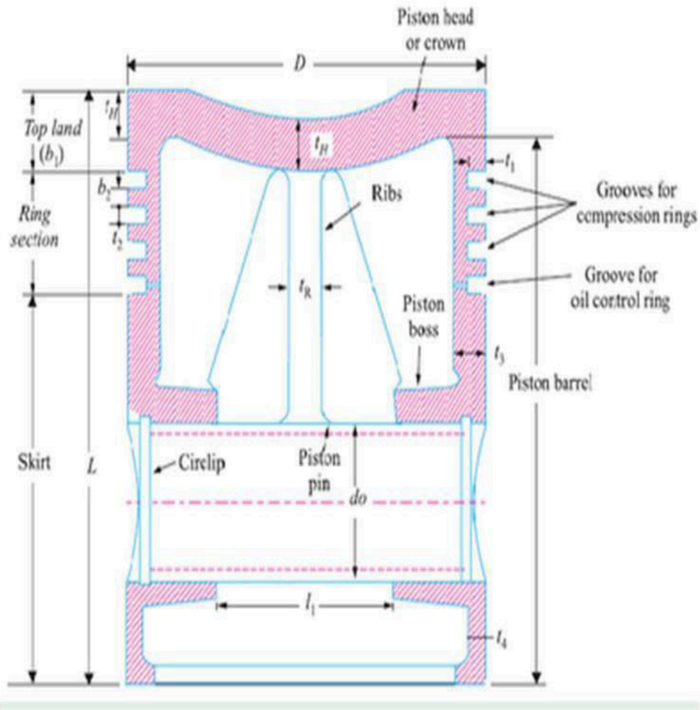


Figure1:Generalviewofpiston

The design procedure adopted in this workispresentedbelowandtheresultsaretabulated:

a)PistonHead:-

Thicknessofpistonheadisdeterminedonbasisofstrengthas wellasonheatdissipation$t_H = D\sqrt{\frac{3P}{16\sigma_t}}$

Cross-sectionalArea,A = $\frac{\Pi}{4} D^2$

IndicatedPower,I.P = $\frac{PLAN}{60}$

P=P_m=indicatedmeaneffectivepressure.

BrakePower,$B.P = I.P * \eta_{mech}$

Heatflowthroughpistonhead,$H = C * H.C_v * m \times B.P$

II. RADIALRIBS:-

Radialribsmaybefourinnumberthethicknessoftheribs varies from $\frac{t_h}{3}$ to $\frac{t_h}{2}$

III. PISTONRINGS:-

Outoffourringsthreearecompressionringsandoneisoilring

Radialthicknessofthepistonrings,t_1

$$t_1 = D\sqrt{\frac{(3P)}{\sigma_t}}$$

Axialthicknessofpistonrings,t_2 $t_2 = 0.7t_1 to t_1$

Distancefromthetopofpistontofirstringgroovei.e.,

Widthofthetopland,b_1 $b_1 = 1.2t_H$

Widthofotherringland,b_2

$$b_2 = 0.75t_2 \ to \ t_2$$

IV. PISTONBARREL:-

Radialdepthofpistonringgrooves(b)is0.4mmmorethanradial thicknessofpiston(t_1).

$$b = t_1 + 0.4$$

Maximumthicknessofbarrelt_3.

$$t_3 = 0.03D + b + 4.5mm$$

Pistonwallthicknesstowardstheopenendt_4.

$$t_4 = 0.25t_3 to t_3$$

V. PISTONSKIRT:-

Maximumgasload= $\frac{\Pi}{4} D^2 P_{max}$

LengthofthepistonL.

L=Lengthofskirt+ Lengthofringsection+Top land

$$L = l + (4t_2 + 3b_2) + b_1$$

VI. PISTONPIN:-

Loadonthepinduetobearingpressure.

=Bearingpressure*Bearingratio*Bearingarea

$$= p_{b1} * d_0 * L_1 \qquad (L_1 = 0.45D)$$

MaximumloadonthepistonduetoGaspressure.

$$= \frac{\Pi}{4} * D^2 * p$$

Table1:CalculatedDesignvalues

S. No	Parameter	Value(mm)
1	Thicknessofpistonhead(t_H)	8.82
2	Radialthicknessofpistonrings(t_1)	2.33
3	Axialthicknessofpistonrings(t_2)	1.76
4	Widthoftopland(b_1)	8.82
5	Widthofotherland(b_2)	1.32
6	Radialdepthofpistongrooves(b)	2.74
7	Pistonwallthicknesstowardstheopenend(t_4)	2.57
8	Lengthof piston(L)	65.68
9	Diameterofpiston(D)	70.56
10	Diameterofpistonpin(d_0)	31.75

4. MODELING

InitiallyCADmodel isgeneratedin theenvironmentofANSYSusingthedimensionsobtainedfromthe designprocedure, tabulatedinTable3.1.The obtainedCADmodelisasshowninthe fig4.1

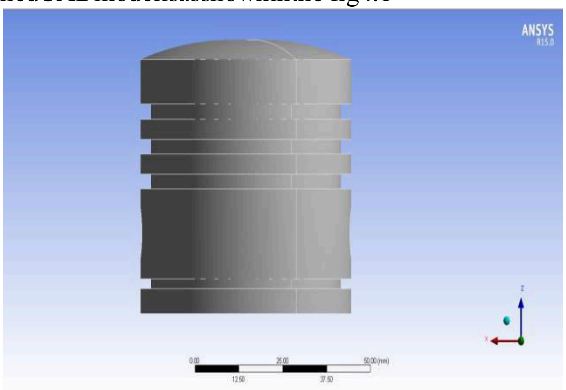


Figure2:CADmodelofPISTONimportedinANSYS

B. ELEMENTTHERMALANALYSISUSEDIN

Theelementtype usedforthermalanalysisis20node90.Itisahigherorder3-Dthermalelement.Theelementhas20nodeswithasingledegreeoffreedom,temperature,ateachnode.Theseelementshavecompatible temperatureshapesandarewellsuitedtomodelcurvedboundaries. Ithas4elementshapes,whicharepresentedinfig4.2.

- 10 node tetrahedron withonedegree of freedomateachnode
- 13nodequadrilateralpyramidwithonedegreeoffreedom ateachnode
- 15nodetriangularprismwithonedegreeoffreedomateachnode
- 20 node quadrilateral prismwithonedegree offreedomateachnode

Inthiswork, weareusing10-nodetetrahedronhavingonedegreeoffreedom.

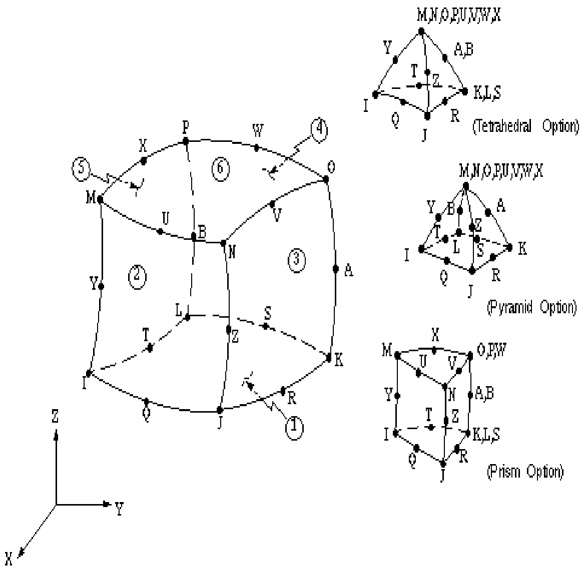


Table2:Materialsandtheirproperties

S.NO	MATERIAL PROPERTIES	AL6061	Al-SiC
1	ElasticModulus(GPa)	71	74.50
2	UltimateTensile Strength(MPa)	320	354
3	Yieldstrength(MPa)	280	193.38
4	Poisson'sRatio	0.33	0.30
5	ThermalConductivity(W/mc)	105	180
6	Density(kg/m^3)	2770	2711.4

C. ELEMENTTYPEFORSTRUCTURALANALYSIS

Theelementtypeusedforstructuralanalysisis20node186.Itisahigherorder3-D20nodeelementthatexhibits quadraticdisplacementbehavior.Theelementisdefined by20nodeshavingthreedegreeoffreedompernode:translationinthenodalX,Y,andZ–directions.TheelementsupportstheplasticityandItisa3-delementhaving20nodesandisahigherorderelementhaving3distinctelementbehaviors.Ithasthreedegreesoffreedom.Theelementbehaviorsare

- 10 nodetetrahedronwith 3degreeoffreedomat eachnode
- 13 node quadrilateral pyramidwith3 degree offreedomateachnode
- 15nodetriangularprismwith3degreeoffreedomateachnode
- 20 node quadrilateral prismwith3 degreeof freedomateachnode

Thiselementiscompatibleforstructuralanalysiswhen20node 95is optedforthermalanalysiswhencoupledfieldanalysisisperformed. Forboththeelements,10nodetetrahedronshapesisoptedhaving4nodesat4cornersand6nodesatthemidpointsoftheedgesofthetetrahedron.

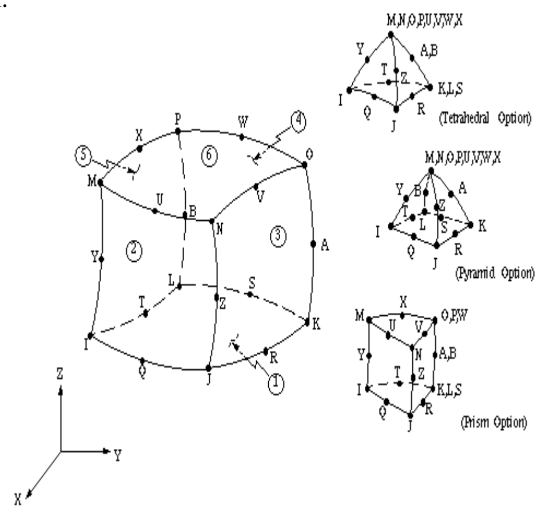


Table3: Materialpropertiesforstructuralanalysis

S.NO	MATERIAL PROPERTIES	AL6061	Al-SiC
1	ElasticModulus(GPa)	71	74.50
2	UltimateTensile Strength(MPa)	320	354
3	Yieldstrength(MPa)	280	193.38
4	Poisson'sRatio	0.33	0.30
5	ThermalCond uctivity(W/mc)	105	180
6	Density(kg/m^3)	2770	2711.4

D. Meshing

Meshingmeansdividingthephysicalobjectwithinfinitedegreesoffreedomintosmallpartshavingfinitedegreesoffreedom.Eachpartisknownaselementandeachelementisconnectedinbetween withendpoints called nodes.In this work,thecoarsemeshisgeneratedwiththe10-node90element.Thegeometryfreeismesheddueto surfaceirregularity

Numberofnodesgenerated=22165
Numberofelementsgenerated=12316

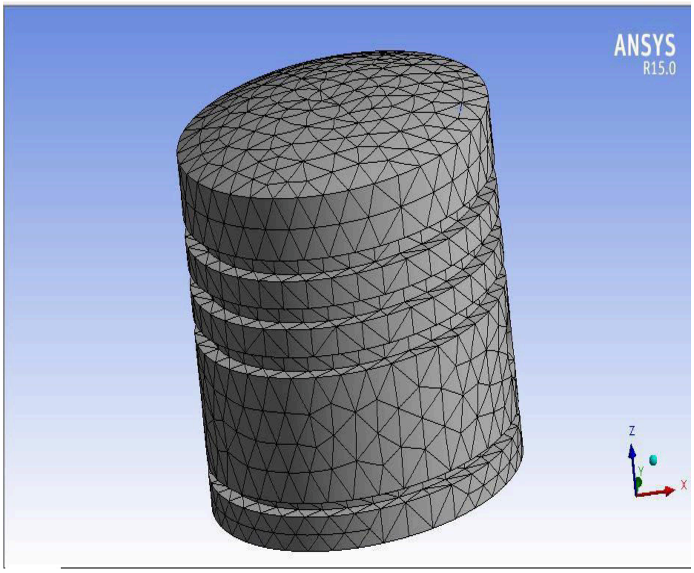


Figure3:MeshedviewofthePiston3.RESULTSA

NDDISCUSSIONS

E. 3.1THERMALANALYSIS

1) 3.1.1 RESULS OF PISTON USING AL6061MATERIAL

Thermalloadof150^{0}Cappliedtothepistoncrown surfaceandconvectionwith1.45e-4w/mm^{20}Cappliedtothepistonsurfaces.Theloads&boundaryconditionsappliedisshown below figure.

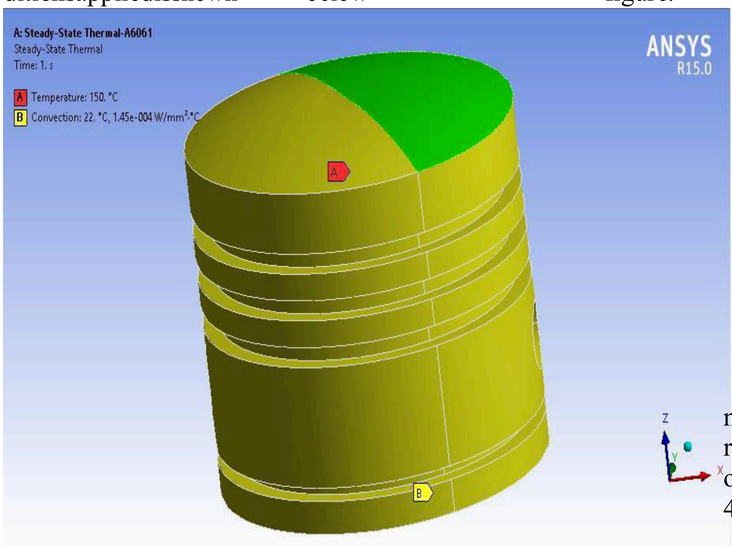


Figure4:Thermalloads&boundaryconditions

Thetemperatureappliedat thetop surfaceofthepiston andthetemperature resultsshowstheflow of temperaturefromtopsurfacetotheotherinthebody.Thebelowfigureshowsthetemperatureresultofthepistonwhenapplied150^{0}C.

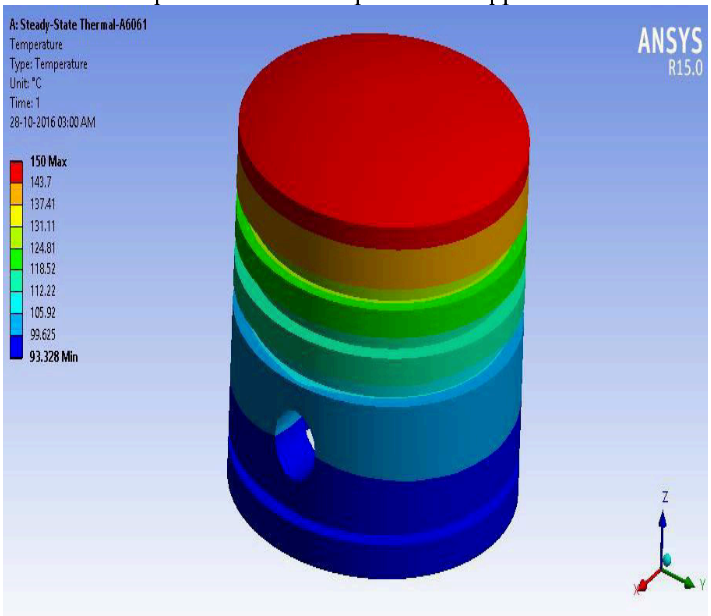


Figure5:TemperatureobtainedforAluminum6061model

HeatTransfercoefficientappliedtothepistonandtheheatfluxresultsshowsthemaximumheatfluxconcentrationinthebody.Thebelowfigureshowstheheatfluxresultofthepistonwhenapplied Heat Transfercoefficientof1.45e-4w/mm^{20}C.

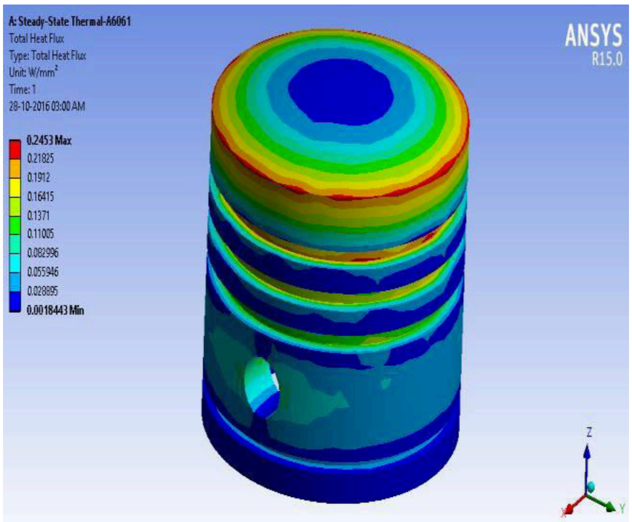


Figure6:HeatfluxgeneraatedfortheAlumininium6061model

Thermalconductivityappliedandtemperaturetothepistonandtheequivalentstressresultsshowsthemaximumstressconcentrationinthebody.Thebelowfigureshowstheequivalentstressresultofthepistonwhenappliedthermalconductivityof1.45e-4w/mm^{20}Candtemperatureof150^{0}C.

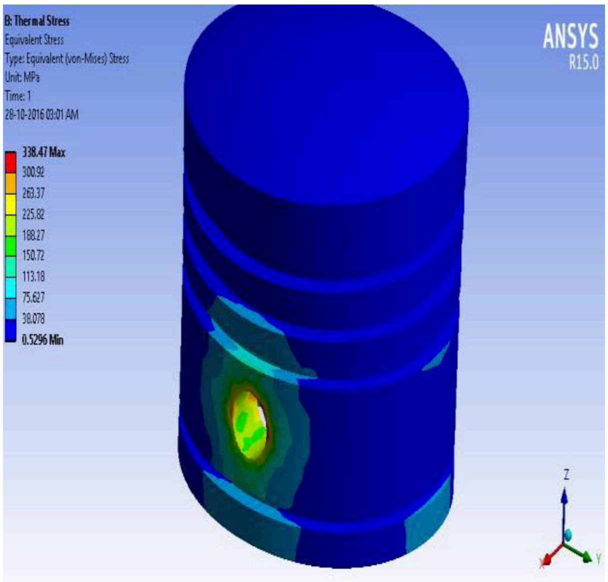


Figure7:ThermalequivalentstressfortheAL6061piston

Thermalconductivityappliedandtemperaturetothepistonandthedeformationshowsbehaviorofthebody.Thebelowfigureshowsthedeformationresultofthepistonwhenappliedthermalconductivityof1.45e-4w/mm^{20}Candtemperatureof150^{0}C.

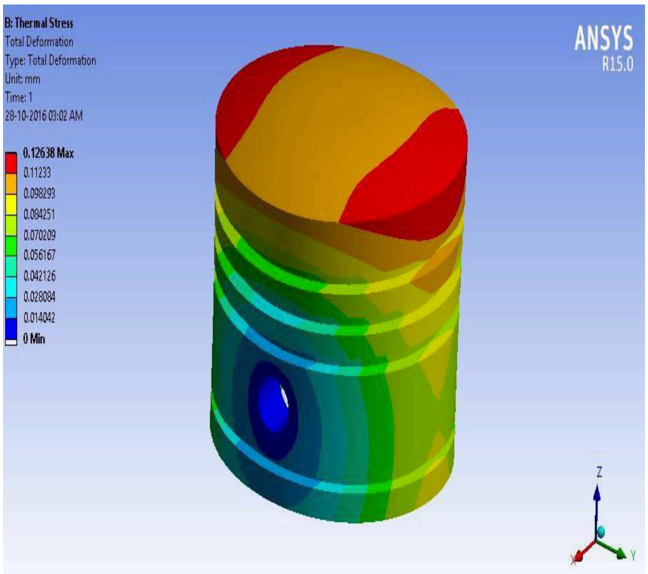


Figure8:ThermaldeformationforAL6061piston

3.1.2RESULSOFPISTONUSINGSILICONCARBIDEMATERIAL

`Thetemperatureappliedatthetopsurfaceofthepistonandthetemperatureresultsshowstheflowoftemperaturefromtopsurfacetotheotherinthebody.Thebelowfigureshowsthetemperatureresultofthepistonwhenapplied150^{0}C.

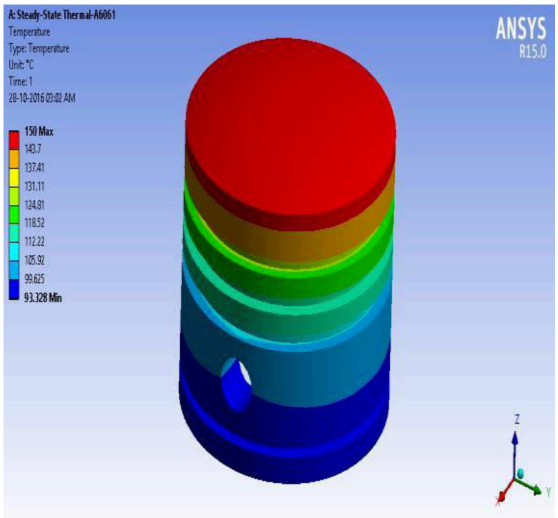


Figure9:TemperatureobtainedforAluminumSiliconCarbidemodel

Thermalconductivityappliedtothepistonandtheheatfluxresultsshowsthemaximumheatfluxconcentrationinthebody.Thebelowfigureshowstheheatflux result of thepistonwhenappliedthermalconductivityof1.45e-4w/mm^{2} ^{0}C.

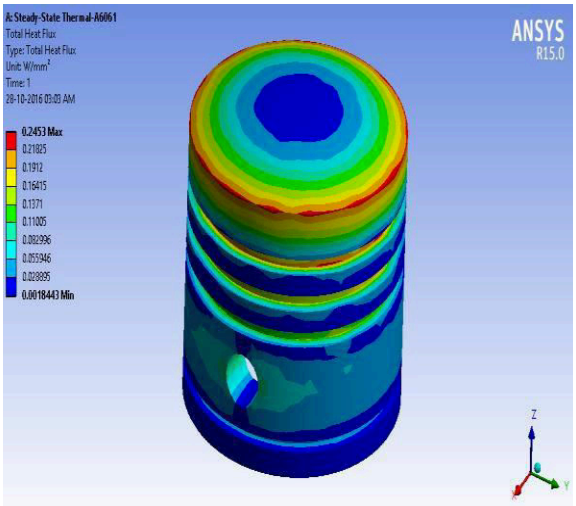


Figure10:HeatfluxgeneratedfortheAluminumSiliconCarbidemodel

Thermalconductivityappliedandtemperaturetothepistonandtheequivalentstressresultsshowsthemaximumstressconcentrationinthebody.Thebelowfigureshowstheequivalentstressresultofthepistonwhenappliedthermal conductivityof1.45e-4w/mm^{20} Candtemperatureof150C.^{0}

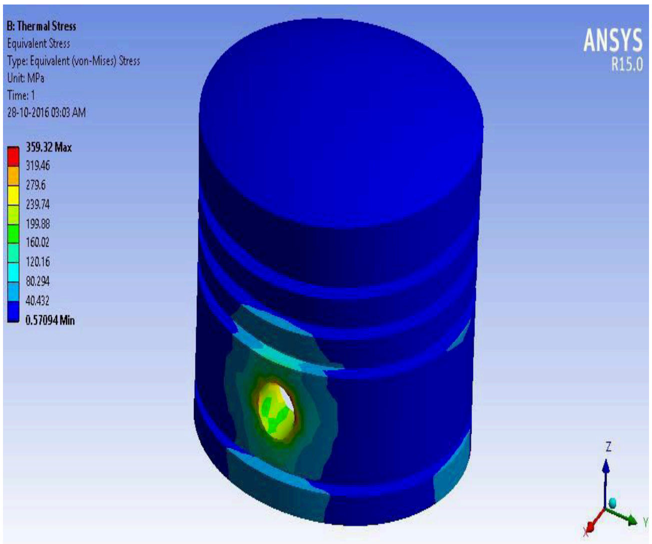


Figure11ThermalequivalentstressfortheAluminum SiliconCarbidepiston

Thermalconductivityappliedandtemperaturetothepistonandthedeformationshowsbehaviorofthebody.Thebelowfigureshowsthedeformationresultofthepistonwhenappliedthermalconductivityof1.45e-4w/mm^{20}Candtemperatureof150^{0}C.

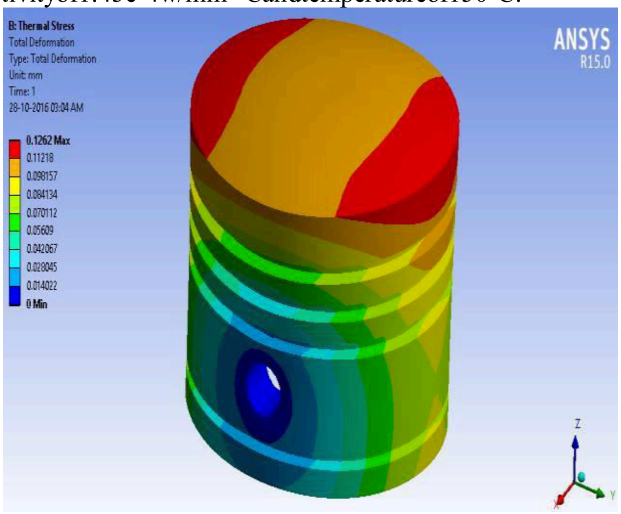


Figure12:ThermaldeformationfortheAluminumSiliconCarbidepiston

F. 3.2STRUCTURALANALYSIS

1) 3.2.1 RESULS OF PISTON USING AL6061MATERIAL

Inadditionaltothethermalanalysisisstaticstructuralanalysisalsoperformedonthepistonbyusing AL6061materialtoanalyzethestructuralbehaviorandstressdevelopedinthebody.Thestaticresultsareshowninbelowimages.

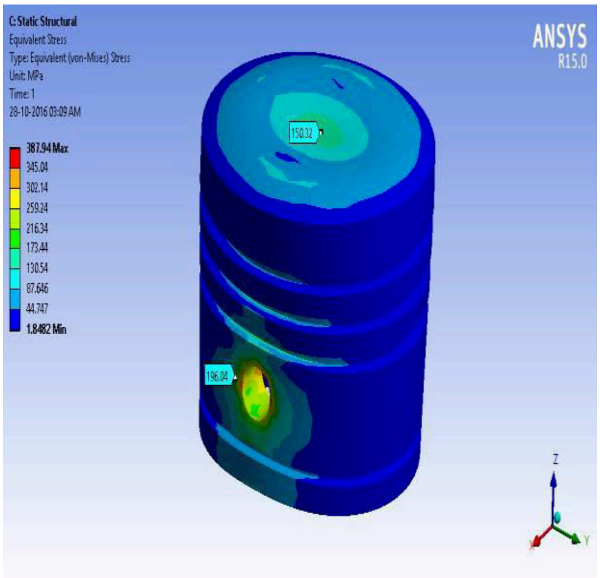


Figure 13:Staticequivalentstressfor al 6061model

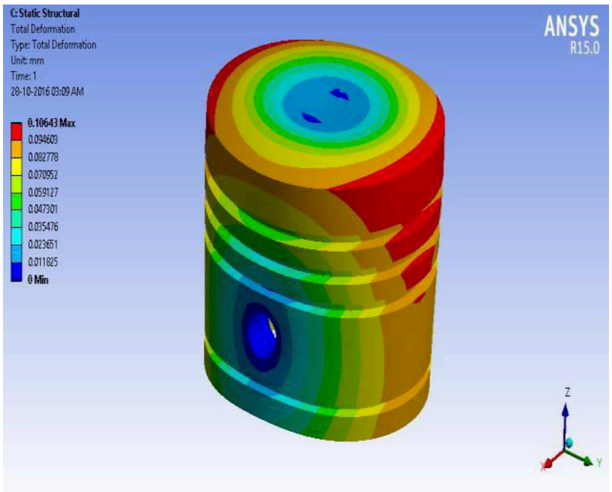


Figure14:STATICDEFORMATIONFORAL6061PISTON

Themaximumstaticequivalantvonmisesstressisobservedattheconstrainedlocationandcanbeignoredandaveragestressobservedis196MPa.Deformationobtainedis0.10643mmusingAL6061material

2) 3.2.2 RESULS OF PISTONUSING ALUMINUMSILICONCARBIDEMATERIAL

InadditionaltothethermalanalysisisstaticstructuralanalysisalsoperformedonthepistonbyusingAluminumSiliconCarbide materialto analyzethe structural behaviorandstressdevelopedinthebody.Thestaticresultsareshowninbelowimages.

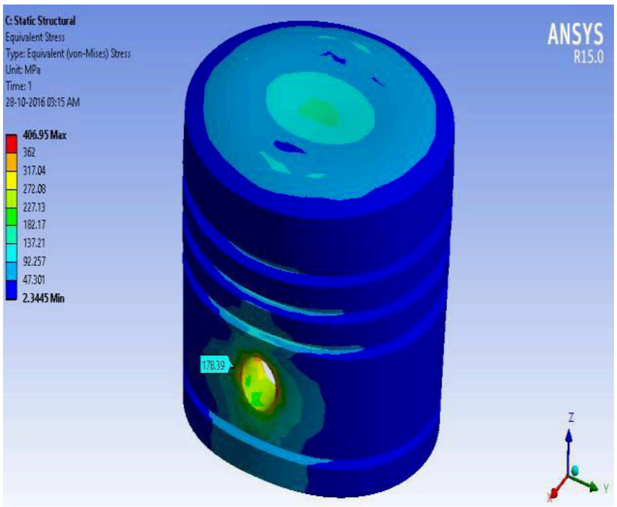


Figure15:Staticequivalentstressforaluminumsiliconcarbidemodel

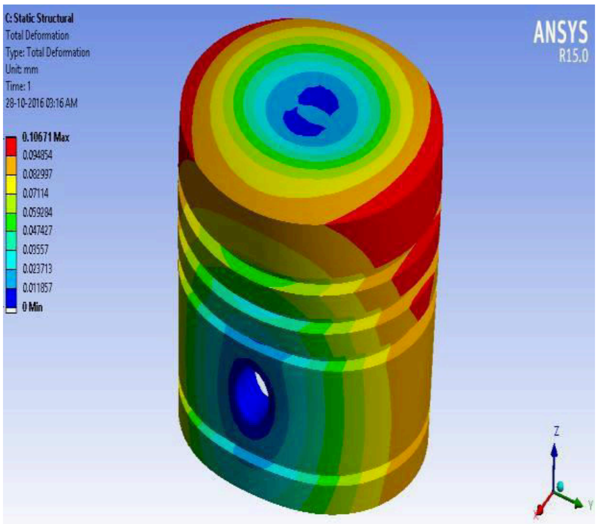


Figure16:StaticDeformationaluminumsiliconcarbidePiston

Themaximumstaticequivalentvonmisesstressisobservedattheconstrainedlocationandcanbeignoredandaveragestressobservedis 178MPa.Deformationobtainedis 0.10671mmusingaluminumsiliconcarbidematerial

G. RESULTSSUMMARY

Table4:ResultsSummary

	AL6061	AL-SIC
HEATFLUX(W/mm^2)	0.2453	0.2453
TEMPERAURE(^c)	150	150
THERMALSTRESS(MPa)	338.47	359.32
THERMALDEFORMATION(mm)	0.1268	0.1262
STATIC STRESS(MPa)	196	178
STATIC DEFORMATION(mm)	0.10643	0.10671

CONCLUSION

Inthecoupledfieldanalysis,combinedgaspressureandthermalload(convectioneffectbythehotcombustiongases)isappliedonthepiston.Ithasbeenobservedthattheeffectofgastemperatureissignificant.Coupledfieldanalysisisperformedbyconsideringtwodifferentaluminumalloyssuchas Al6061andAl-SiC.Thestressesproducedinthepistonwith Al-SiCmaterialarelesswhencomparedto Al6061andthestressvaluesarewithintheallowablelimit.Al-SiCmaterialismorerobustwhencomparedto Al6061

References

1. ElementReference –ANSYS 12.0
2. Heattransfer databook byC.P.Kothandaraman
3. TemperaturefieldanalysistogasolineenginePistonandstructureoptimization,HongyuanZhang,ZhaoxunLin,IianXing,37,Vol.48No.2,JournalofTheoreticalandAppliedInformationTechnology

Design and Comparative Analysis of Different Hydraulic Cylinders by ANSYS

Dr.Sivasankara Gowda, I.Prsasnna, Ajay R. Kodilwad, B. Rajendra Prasad
DepartmentofMechanicalEngineeringMallaReddyCollegeofEngineering,Secunderbad

***Abstract*—** AHydrauliccylinderisamechanicalactuatorthatisutilizedtogiveaunidirectionaldrivethroughaunidirectionalstroke. It hasnumerousapplications,outstandinglyindevelopmentgear,producingapparatusandstructuralbuilding."Hydraulics"byandlargealludestocontroldeliveredbymovingliquids.Modernhydrodynamicsischaracterizedastheutilizationofrestrictedfluidtotransmitcontrol,increasecompel,orcreatemovement.Awaterdrivencylindercomprisesofthesepart- cylinderbarrel,cylindertop,cylinderhead,cylinder,cylinder pole,organand seals.

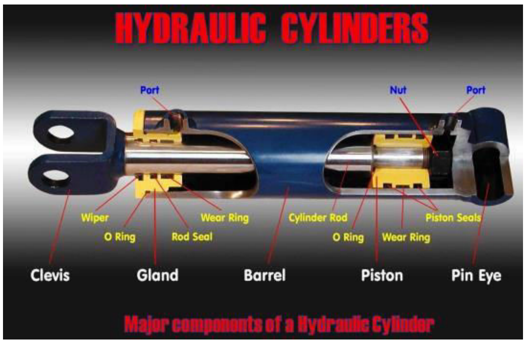
InthepresentworkthegeometricmodelismadeinCATIASoftwareandimportedtohyperworkforfocalizedFiniteelementmethod andexamination.StretchandrelocationsdistinctivewaterdrivencylindersarefiguredbyutilizingAnsysprogramming.

Keywords-Ansys,Hydraulicsystem,Hydrodynamics ,CATIA,Actuator

IINTRODUCTION

1.1. HydraulicCylinder:-Hydraulic

cylinderisamechanical actuator thatisusedtogiveaunidirectionalforcethroughaunidirectionalstroke.



Thepistonpartitionswithinthecylinderintotwochambers, thebasechamber(topend)andthepistonbarsidechamber(poleend/headend).Flanges,trunnions,clevises,Lugs are regularcylindermountingalternatives.Thepistonpolelikewisehasmountingconnectionstointerfacethecylindertotheprotestormachinesegmentthatitispushing/pulling.

Ifweassumethattheoilentersfromcapend,duringextensionstroke,andtheoilpressureintherodend/headendisapproximatelyzero,theforce*F*onthe pistonrodequalsthepressure*P*inthecylindertimesthepistonarea*A*:

$$F=P.A$$

Thehydrauliccylindersaredoubleactingsinglerodpistoncylinder.Itsfeaturesare

1. simpleinstructure,
2. reliableinoperation,
3. Convenientinassembleanddisassembleeasyinmaintenance

Theamazing amount offorceacylinderexerts isduetothesimplemechanicalprincipleofpressureexertedonthesurfaceareaofthe**piston**.Simplyput,thelargerthe diameterofthecylinder,themoreitwilllift.Theformulaforthisis**areaxpsi(***Poundspersquareinch***)=Force.**

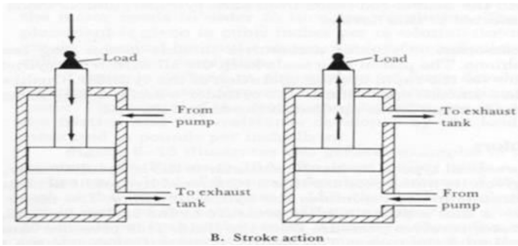


Fig1.HydrulicSystem

Hydraulicdrivenandpneumaticsystemsuppliesaretheessentialsegmentsofdesigningapplications.Particularlywaterdrivenand pneumaticcylindersareutilizedasapartofnumerousdesigningapplicationslike;programmedassemblingandmontagelines,substantialdevelopmentsupplies,controlframeworks,delicateestimationandtest frameworks.Astandoutamongstthemostessentialcomponentsconsideringattheoutlineventureofthesetypesofgearisworkingstatesofcylinder.Cylindershavediverseworkingfrequenciesasindicatedbytheirutilizationfields. Whiletheenormous estimated cylindersutilizedasapartofframeworksthatrequireshigherconstrainandminutesourcesofinfo,worksforthemostpartinlowerfrequencies,thelittlemeasuredcylindersutilizedasapartoftouchyapplicationfieldsliketestand estimationframeworkscanhavehigherworkingfrequencies.Atthelowerworkingrecurrencecircumstances,weightimpactonthecylinderisconsideredasstaticload,andthe waterdrivenframeworktypesofgearareplannedbymodel.Otherthanthis,attheplanmethodofcylinderswithhigher workingfrequencies,thedynamicimpactasforquickchangeofweightmustbecontemplatedandalsothestaticinvestigation.

1.1Pumps:-

Mainpumps:2 variabledisplacementaxialpistontype.
Maximumflow: 2x 121L/min(2x26.6UK GPM).Servopump:Geartype.
Maximumflow: 20L/min(4.4UKGPM).

1.2. **Reliefvalve setting:-**

ARM(4610lbf/sq.in)
Withpower boost 343bar
(4975lbf/sq.in)Swing circuit279bar
(4045lbf/sq.in)Travelcircuit343bar
(4975lbf/sq.in)Pilotcontrol40bar
(569lbf/sq.in)

AseparateCushionControlvalveintheservosystemprovidescushioningoftheboomanddipperspoolsselectionand quickwarm-upofthe servosystem.

1.3DimensionsofHydraulicCylinder:-

BOOM
Bore100mm(3.9in)Rod75mm(3.0in)Stroke1081 mm(42.5in)

III Designand Analysis:-

3.1 CAD/CAM:-

TheModernworldofdesign,development,manufacturingsoon,inwhichwehavesteppedcan’tbeimaginedwithoutinterferenceofcomputer.Theusageofcomputerissuchthat,theyhavebecomeanintegralpartofthesefields.Intheworldmarketnowthecompetitioninnotonlycostfactorbutalsoquality,consistency,availability,packing,stocking,deliveryetc.Soaretherequirements forcing industriestoadoptmoderntechniqueratherthanlocalforcingtheindustriestoadaptbettertechniqueslikeCAD/CAM/CAE, etc.

Thispenetrationoftechniqueconcernhashelpedthe manufacturersto

- Increaseproductivity
- Shorteningthelead-time
- Minimizingtheprototypingexpenses
- ImprovingQuality
- Designingbetterproducts

3.2 FE Analysis:-

Inthelimitedcomponentstrategy,therealcontinuumofgroupofmatterlike strong,fluidorgasisspokentoasacollectionofsubdivisionscalledFinitecomponents.Thesecomponentsarethoughttobeentomb associated atindicated focusesknown as hubsornodalfocuses.Thesehubsasarulelieon thecomponentlimitswhereaneighboringcomponentisthoughttobeassociated.Sincethegenuinevarietyofthefieldfactors(likeDisplacement,stretch,temperature,weightandspeed)insidethecontinuumareisnotknow,weexpectthatthevariety ofthefieldvariableinsidealimitedcomponentcanbeapproximatedbyabasiccapacity.Theseapproximatingcapacities(additionallycalledinsertionmodels)arecharacterizedregardingthequalitiesatthehubs.Atthepointwhenthefield conditions(likebalanceconditions)fortheentirecontinuumarecomposed,thenewobscurewillbethenodalestimationsofthefieldvariable.Bytacklingthefieldconditions,whicharebyandlargeasthegridconditions,thenodalestimationsofthefieldfactorswillbeknown.Oncetheseareknown,the approximatingcapacitycharacterizesthefieldvariableallthroughthecollectionofcomponents.
Itisnecessarytoidentifythetediousandtimeconsumingstepsandtrytoautomatethemtoreducethe FEsimulationtime andtoavoidtheconstantinteractionoftheuserwith theFEtool.Followingthelistofstepsarepresented.

Basicapproachforanyfiniteelementanalysis(FEA)canbedividedintothreeparts

- Pre–processors
- Solver
- Post–Processor

3.3 ANSYS:-

ANSYSdesignoptimizationenablestheengineerstoreducethenumberofcostlyprototypes,tailorrigidityandflexibilitytomeetobjectivesandfindtheproperbalancinggeometricmodifications.

Competitivecompanieslookforwaystoproducethehighest qualityproductatthelowestcost.ANSYS(FEA)canhelpsignificantlybyreducingthedesignandmanufacturingcostsandbygivingengineers addedconfidenceintheproductstheydesign.FEAismosteffectivewhenusedattheconceptualdesignstage.Itisalsousefulwhenusedlaterinmanufacturingprocesstoverifythefinal designbeforeprototyping.

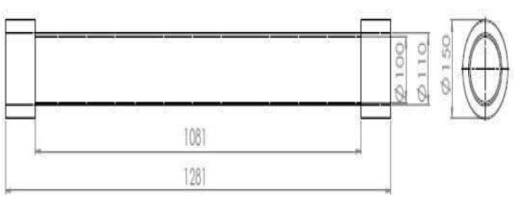
TheANSYSprogramoperatesonPentiumbasedPCsrunningonWndows95orWindowsNTandworkstationsandsupercomputersprimarilyrunningonUNIXoperatingsystem.ANSYSInc.continuallyworkswithnewhardwareplatformsandoperatingsystems.

Analysistypesavailable:

1. STRUCTURALSTATICANALYSIS.
2. STRUCTURALDYNAMICANALYSIS.
3. STRUCTURALBUCKLINGANALYSIS.
   - LINEARBUCKLING
   - NONLINEARBUCKLING
4. STRUCTURALNONLINEARITIES
5. STATICANDDYNAMICKINEMATICSANALYSIS.
6. THERMALANALYSIS.
7. ELECTROMAGNETICFIELDANALYSIS.
8. ELECTRICFIELDANALYSIS
9. FLUIDFLOWANALYSIS
   - COMPUTATIONALFLUIDDYNAMICS
   - PIPEFLOW
10. COUPLED-FIELDANALYSIS
11. PIEZOELECTRICANALYSIS

IV Modelling and Meshing:

4.1 CATIAModelling:



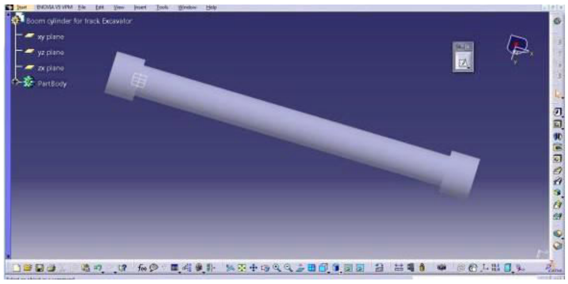


Fig4.1 Hydraulic Cylinder Model

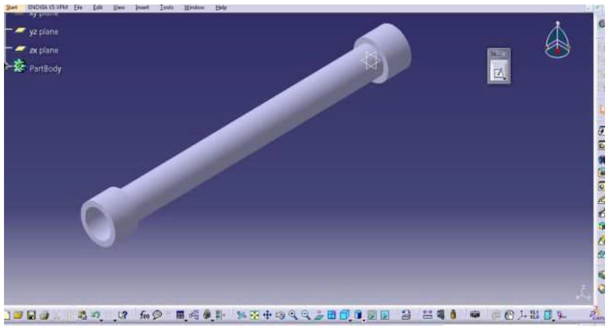


Fig4.2 Hydraulic Cylinder Isometric view

Fig4.3CATIAModelingOfCylinder UsedInMiningRigs:

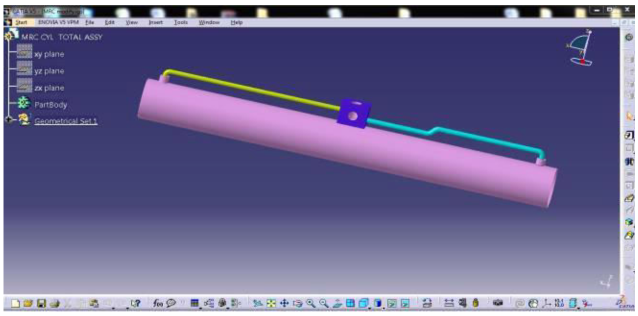
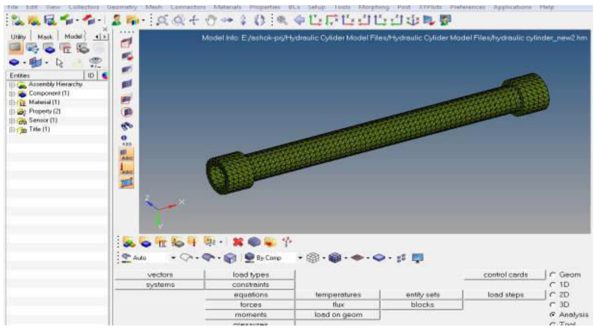


Fig4.4MRCCylinderModel

Meshing:-Meshing isgeneratedbyusing hypermeshsoftware.Meshthegeometrybyusingtetrahedralelements.Elementtype is solid45.



VStatic Analysis:

5.1BoomCylinderForTrackExcavator:

LoadsAndBoundaryConditions: Meshmodelofboom cylinderfortrackexcavatorisconstrained(x,yandz-translations)atrightside.AppliedInternalpressureis40bar.

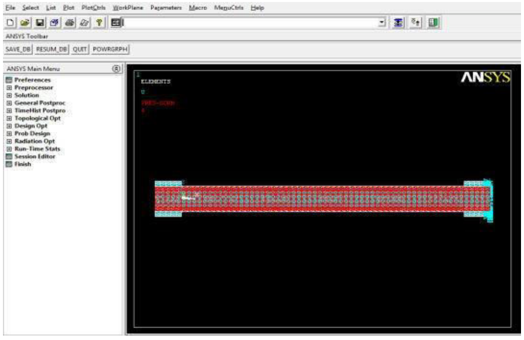


Fig5.1:Loadsandboundary conditionsof boomcylinderfortrackexcavator

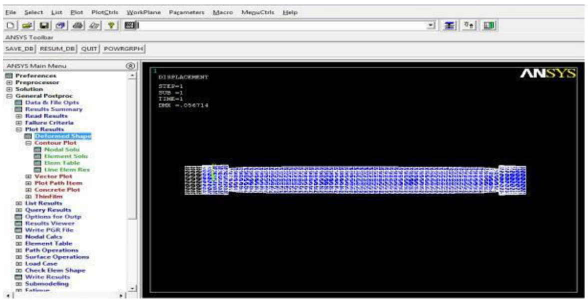


Fig 5.2:Deformed –un deformed ofboomcylinderfortrackexcavator

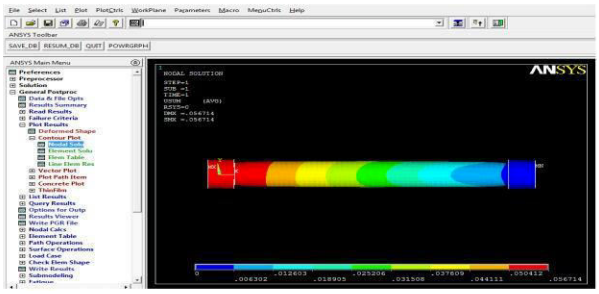


Fig5.3displacementvectorsumofboomcylinderfortrackexcavatoris 0.056mm

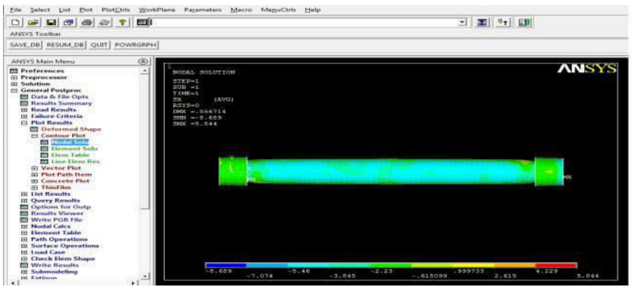


Fig 5.4Stressin x-directionof boomcylinderfortrackexcavatoris 5.84 N/mm^2

Thefollowingtablerepresentsthestressesoftwohydrauliccylindersindifferent

TableforDifferentPressure loads:

Stress(N/m	Boomcylinderfortracvator(pressure40ba	Cylinderusedinminin(pressure80bar)
Stress in x-dire	5 . 8	2 6 . 6
Stress in y-dire	4 2 . 5	1 2 4 .
Stress in z-direc	3 8 . 8	1 1 7 .
Shear stress i	4 . 1	5 3 . 6
Shear stress i	1 9 . 5	5 9 . 5
Shear stress i	3 . 4 8	2 1 . 5
Vonmises str	4 0 . 9	1 2 1 .

VIConclusion

The diversehydraulic cylindersat variousweight burdensweredissectedbyfiniteelementstrategies.Fromtheaboveresultsthe Maximum Vonmisespushforblastcylinderfor trackexcavatorwatchedis40.95N/mm2 andthecylinderutilizedasapartofminingapparatuseswatched is121.83N/mm2.thisesteemisundersafeloadcondition. TheMaximumDisplacementforblastcylinderfortrackwatched is 0.056mm,and thecylinder utilized asapartofminingapparatuseswatchedis0.328. TheStressLevelsforvariouscylinderswascheckedundermax weightstackconditionandturnedouttobeprotectedplan andproposedtouseforlifting ofoverwhelmingburdensandboringapparatusoperations.

Reference

[1]"FEAanalysisofbullockcartaxleunderstaticanddynamicloadingconditio n,"byMulaniNawajAandMirzaMM,atISSN(Print): 2321-5747,Volume-1,Issue-2,2013.

[2]C.Bisua*,L.Olteanua,R.Laheurteb,Ph.Darnisb,O.Cahucb,“Experimentalapproachontorsordynamicanalysisformillingprocessmonitoringand diagnosis”IntelligentComputationinManufacturing Engineering,ProcediaCIRP 12(2013)73– 78 .

[3]HamidM.Sedighi∗,KouroshH.Shirazi,“Bifurcationalanalysisin huntingdynamicalbehaviorinarailwaybogie:Usingnovelexact equivalent functions for discontinuous nonlinearities”, ScientiaIranicaB(2012)19 (6),1493–1501.

Effect of welding properties on strength of the mild Steel-an experimental approach

C. LabeshKumar*,Dr.P.KDash**

*Dept.ofMechanicalEngineering,IARE,Hyderabad.
**Dept.ofAeronauticalEngineering,IARE,Hyderabad.

Abstract

InthispaperanexperimentalverificationofMIGweldingonmildsteelundervariousweldingconditionarestudied.Theweldingtimeandweldingenvironmentarechangedovertherangeofspecimens.IthasbeenobservedthatthereisasignificantstrengthgaininCO_2presencesweldingincomparetoatmosphericweldingalsoweldingspeedsizeablyreducesthespecimenstrengthandcause.Severchangesinthefailuremicrostructureanddensityvariation.

Keywords:Mildsteel,MIGWelding,CO_2,UTM,MicroStructure, Density.

1. Introduction

Weldingisafabricationprocessusedtojoinmaterials,usuallymetalsorthermoplastics,together.Duringwelding,thepiecestobejoined(theworkpieces)aremeltedatthejoininginterfaceandusuallyafillermaterialisaddedtoformapoolofmoltenmaterial(theweldpool)thatsolidifiestobecomeastrongjoint.Incontrast,SolderingandBrazingdonotinvolvemeltingtheworkpiecebutratheralower-melting-pointmaterialismeltedbetweentheworkpiecestobondthemtogether.

ThecurrentworkiscarriedonMIGweldingMIG(MetalInertGas)welding,alsoknownasMAG(MetalActiveGas)andintheUSAasGMAW(GasMetalArcWelding),isaweldingprocessthatisnowwidelyusedforweldingavarietyofmaterials,ferrousandnonferrous.MIGweldingiscarriedouton DCelectrode(weldingwire) positivepolarity(DCEP).HoweverDCENisused(forhigherburnoffrate)withcertainself-shieldingandgasshieldcoredwires.Theoutputofdirectcurrentafterfullwaverectificationfroma3-phasemachineisverysmooth.Toobtainsmoothoutputafterfullwaverectificationwitha 1-phasemachine,alargecapacitorbankacrosstheoutputisrequired.Becauseoftheexpenseofthis,manylowcost1-phasemachinesomitthiscomponentandthereforeprovideapoorerweldcharacteristic.

ThecurrentworkiscarriedoutformildsteelplatesofsimilarsizeswithabuttjointisperformedbyusingMIGweldingunderdifferentweldspeedandenvironmentlaterontestingisperformedontheUTMandrelativeresultsarebeendiscussed.SpecimenisaMildSteelplates withdimensions as mentionedbelow.Theyhavebeen filled atan angleof45^{O}onbothspecimens.Suchspecimensaretakenin3pairsforthisexperiment.

2. Materials

TheMildSteelplates(40x30mmandthickness3.4mm)werejoinedlongthelongersidebytheMIGwelding.TheelectrodeusedhereisaCoppercoatedMildSteelwireofdiameter0.8mm.

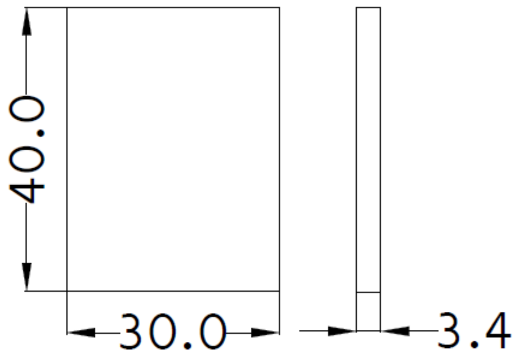


Fig.1MildSteelplateswithDimensions

Fig.2 MildSteelplatesafterfiled at45^{O}

Table1mildsteelcomposition

Element	Percentage
Carbon	0.16-0.18%
Silicon	0.40%max
Manganese	0.70-0.90%
Sulphur	0.040% Max
Phosphorus	0.040% Max

3. ExperimentalSetup

Thisprocessincludestwomildsteelwhicharebeenjoinedbythe MIGwelding.Thebasematerialand filledmaterialareofsameproperties showninthetableofproperties.Theweightofthespecimenis48gramsanditsdensitybeforeweldoftwopiecesis7.85gm/cm^3

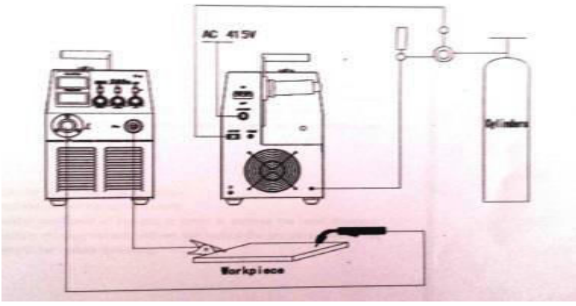


Fig.3MIG setup linediagram

Fig.4AfterWeldMildsteel pieces

Table2MildSteelWeightandDensity

S.No	specimen	Weightofspecimenbeforeweld	Densityof specimen
1	Mildsteelplates	48.00grms	7.85gm/cm^3

4. Resultsand Discussions

Themildsteelpiecesofspecified dimensionsarebeenweldedwith thehelpofMIGwelding.InwhichthesetupcarriedoutinpresenceofCO2andabsenceofCO2withdifferentweldspeeds.ThevariationregardingthedensityisshowingmuchappropriateinpresenceofCO2. Thefillermaterialisofsamecompositionofthebasematerialinordernottodisturbthecontentaftersolidificationofweldpieces.Theweldplatesweretestedbyintermsofdensityandtensileandmicroscopic study.Thetestspecimenwhichhasbeencutoffisgrindedandpolishedwasstudiedundermicroscopewhichshowsnodefeatsafterweld.

Fig. 5 Microscopicimage ofslow weld

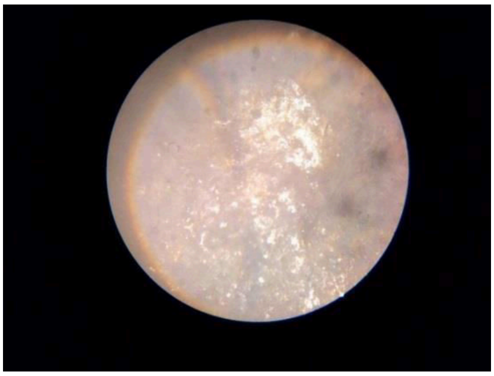


Fig. 6 Microscopicimage offastweld

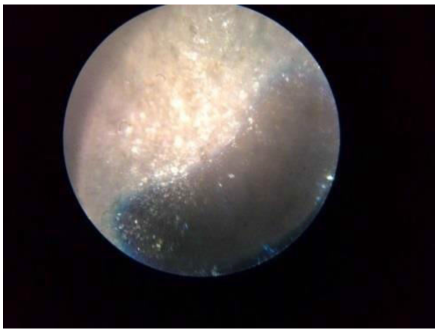
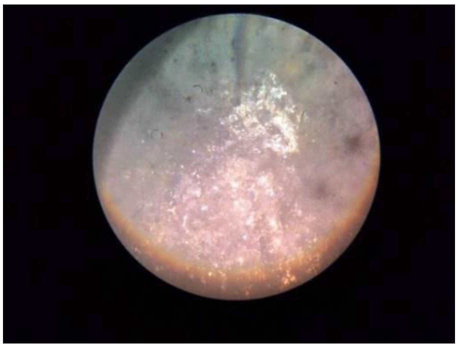


Fig.7Microscopicimage of fastweld inpresenceofCO2



Theweldedzoneundermicroscopeshowsthattheweldedareaisaffectedbyhighheat.Thereisnoeffect ofthisheatonthestructureofthespecimen.Environmentalconditionsshowvastdifferenceintheweld edplates.Thevaluesobtainedisbeentabulatedasperweldspeed,densityofspecimenafterweld,Tensi lestrengthandlastly StandardDeviation.UndertheMicroscopetheweld hasbeenperformedusingthelowspeed

Table3WeldedSpecimenResults

S.No	Specimen	WeldSpeed	DensityofSpec imenafterweld	Tensile Strength	Standard Deviation %
1.	Weldedin presenceofCO2	2 cm/sec	6.97gm/cm^3	3.2 KN	25.581
2.	Weldedwithhighspeed	1.6 cm/sec	6.52gm/cm^3	2.5 KN	41.86
3.	Weldedwithlow speed	1.33 cm/sec	7.85gm/cm^3	2.7 KN	37.20

5. Conclusion

Onthebasesofexperimentalobservationscarriedoutfordifferentweldingspeedsaswellaschangeine nvironmentalparameterslikepresenceofCO2ithasbeenfoundthat

1. Thedensityisreducedwithrespecttoweldingspeedandalsoattributedtotheenvironment.

2. Thetensilestrength of thespecimenishighlydependedonthewelded speed rateand ithasbeenfoundthatthetensilestrengthdecreaseswhenweldspeedincreasesandthestrengthishighly increasedbychoosingtheenvironmentparameterlikeCO2

3. Ithasbeenconcludedasthestandarddeviation observedforhighspeed withCO2presenceisminimumof25.81andreachestomaximumof41.86

6. References

[1] UbertalliGrazino,DonatoFirro,GianmarcoTaveri,Characteristicsofweldingjoints(MIGandSAW)onLDX2101Duplex SS,Procedia engineering109(2015)484-491.

[2] Jean-PierrePlanckaert,El-HabiDjermoune,DavidBrie,FrancisBriandFredericRichard,ModelingofMIG/MAGweldingwithexperimentalvalidationusinganactiveActivealgorithmappliedonhighspeedmovies.AppliedMathematicalModelling34(2010)1004–1020

[3] Y.-S.Kim,MetalTransferinGasMetalArc Welding,Ph.D.Thesis,MassachusettsInstituteofTechnology,June1989.

Static Analysis of milling cutter by Using finite element method

D.K.Nageswara Rao, B.c.Raghu Kumar reddy, R.Indrajayadav, A. Lakshmi Jyothi
Department of Mechanical Engineering, Mallareddy college of Engineering Secunderbad

*ABSTRACT:***Millingmachineisoneoftheimportantmachiningoperations.Inthisoperationtheworkpieceisfedagainstarotatingcylindricaltool.Therotatingtoolconsistsofmultiplecuttingedges(multipointcuttingtool).Normallyaxisofrotationof feedgivento theworkpiece..**

Inthisprojectworkthedesignaspectsofplainmillingcutteris analysed.Theobjectiveconsideredisthedesignandmeshingofplain millingcutterandtoanalysevariousstresscomponentsactingonit.Themodellingandanalysisiscarriedoutusingsoftware ANSYS.

Keywords: static analysis,millingcutter, FEM

I. INTRODUCTION

Millingisaprocessofproducingflatandcomplexshapeswith theuseofmulti-toothcuttingtool,whichiscalledamillingcutterandthecuttingedgesarecalledteeth.Theaxisofrotationofthecuttingtoolisperpendiculartothedirectionoffeed,eitherparallelorperpendiculartothemachinedsurface.Themachinetoolthattraditionallyperformsthisoperationisamillingmachine.Millingisaninterruptedcutting operation:theteethofthemillingcutterenterandexittheworkduringeachrevolution.Thisinterruptedcuttingactionsubjectstheteethtoacycleofimpactforceandthermalshockoneveryrotation.The toolmaterialandcuttergeometrymustbedesignedtowithstandtheseconditions.Cuttingfluidsareessentialformostmillingoperations.Thecutterisliftedtoshowthechips,andthework,transient,andmachinedsurfaces.Thecutterdesignbeingpresentedinthispaperisusefulforsinglepointaswellasformulti-pointcutterssuchasthoseusedforturningandmilling.Infact,thedesignprinciplesforbothsingleandmulti-pointcuttersaresimilar.Thedesignparameterssuchasrakeangle, clearanceangleoftooth,andheightoftootharecommoninbothsinglepointandmulti-pointcutters.Additionally,parameterssuchasspeedofrotation,feed,anddepthofcutarealsosimilar.However,parameterssuchas diameterofthecutter,numberofteethonthecutter,andangularspacingofteethareexclusivelyassociatedwithmillingcutters.Inthefamilyofmillingoperationssuchasplainmilling,slotmilling,side milling,endmilling,facemilling,andformmilling,designparametersdifferonlyintheirnumericalvalues.Ineverycase,theteethof millingcuttershavecuttingedgesandanglesrelatedtoedges.Ineffecteachtoolactslikesinglepointtoolmountedonacylindricalhhub.Theteethonthe millingcuttersaremostlyevenly spaced. There aretwobasictypesofmilling,areasfollowsdown(climb)milling:itistypeofmillinginwhichthecutterrotationisinthesamedirection as themotionof theworkpiecebeingfed.Indownmilling,thecuttingforceisdirectedintotheworktable,whichallowsthinnerworkpartstobemachined.Bettersurfacefinishisobtainedbutthestressloadontheteethis abrupt,whichmaydamagethecutter.Inconventionalmilling,frictionandrubbingoccur astheinsertentersintothecut,resultinginchipweldingandheatdissipationintotheinsertandworkpiece.Resultantforcesinconventionalmillingareagainstthedirectionofthefeed.Work-hardeningisalsolikelytooccur.

II. PROPOSED WORK

Millingoperationisconsideredaninterruptedcuttingoperationteethofmillingcutterenterandexittheworkduringeachrevolution.Thisinterruptedcuttingactionsubjectstheteethtoacycleofimpactforceandthermalshockoneveryrotation.Thetoolmaterialandcuttergeometrymustbedesignedtobeartheabovestatedconditions.Inthisprojectworkthedesignaspectsofplainmillingcutteris analysed.Theobjectiveconsideredisthedesignandmeshingofplainmillingcutterandtoanalysevariousstresscomponentsacting onit.ThemodellingandanalysisiscarriedoutusingsoftwareANSYS.

III. CUTTINGCONDITIONS IN MILLING

Inmilling,eachtoothonatoolremovespartofthestockintheformofachip.Thebasicinterfacebetweentoolandworkpartispicturedbelow.Thisshowsaonlyafewteethofaperipheral millingcutter.

-

teethPlainMillingCutterUsedforPeripheralorSlabMillingCuttingvelocityVistheperipheralspeedofthecutterisdefinedbyV=πDNWhereDisthecutterouterdiameterandNistherotationalspeedofthecutter.Asin thecase ofturning,cuttingspeedVisfirstcalculatedorselectedfrom appropriatereferencesourcesandthentherotationalspeedofthecutterN,whichisusedtoadjustmillingmachinecontrols,iscalculated.Cuttingspeedsareusuallyintherangeof0.1~4 m/s,lowerfordifficult-to-cutmaterialsandforroughcuts,andhigherfornon-ferrouseasy-to-cutmaterialslikealuminiumand forfinishingcuts.

CuttingSpeed

Cuttingspeedofamillingcutterisitsperipherallinearspeedresultingfromoperation.Itisexpressedinmetersperminute. Thecuttingspeedcanbederivedfromtheaboveformula.Spindlespeedofamillingmachineisselectedtogivethedesired peripheralspeed ofcutter.V= (πdn)/1000Where*d* = Diameterofmillingcutterinmm,*V*=Cuttingspeed(linear)inmeterperminute,and*n*=Cutterspeedinrevolutionperminute.

FeedRate

Itistheratewithwhichtheworkpieceunderprocessadvancesunderthe revolvingmillingcutter.Itisknownthatrevolvingcutterremainsstationaryandfeed isgiven to the workpiece throughworktable.Generallyfeedis expressedin threeways

Feed per Tooth

Itisthedistancetravelledbytheworkpiece(itsadvance)betweenengagementbythetwosuccessiveteeth.Itis expressed as mm/tooth(*ft*).

Feed per Revolution

Travelofworkpieceduringonerevolutionofmillingcutter.Itisexpressedasmm/rev.anddenotedby*f*(rev).

Feed per UnitofTime

Feedcanalsobeexpressedasfeed/minuteorfeed/sec.It isthedistanceadvancesbytheworkpiecein unittime(*fm*).

IV. MATERIALSUSED IN MILLING CUTTER

Themillingcuttermaybemadeofhigh-speedsteel,Superhigh-speedsteel;Nonferrouscastalloysorcementedcarbidetipped.The high-speedsteelcuttersarethe mostwidelyusedcutters in generalworkshop..Themainmaterialsbeingusedaresummarizedbelow.

ToolSteel

Itcontainscarboninamountsrangingfrom0.80to1.5%.Disadvantagesof toolsteelsarethattheycomparativelylowheatandwearresistance.Cuttersmadeoftoolsteelarecomparativelycheap,easytoforgeandsimpletoharden.

AlloySteel

Itisthemostimportantandwidelyusedgroupofcuttingtool material.Theyare commonlyknownashighspeedsteelssincetheycanbeoperatedathighspeedoftwoandhalftimesmorethanthoseusedasacarbontoolsteelandretaintheirhardnessuptoabout9000C.Thesearethegeneraltypeofhighspeedsteels,hightungsten,highmolybdenumandhighcobalt.Thesteelcontaining18%tungsten4%chromiumand1%vanadiumisconsideredtobeoneofthebest of all-purposetoolsteel.Insomesteels ofsimilarcompositionthepercentageofvanadiumisslightlyincreasedtoobtainbetterresultinheavy-dutywork.Thissteelcontaining6 % molybdenum 6 % tungsten 4 % chromiumand2%vanadiumhaveexcellenttoughnessandcuttingability.Cobalthigh-speedsteelcalledsuperhighspeedsteel.Cobaltisaddedfrom2-15%toincreasehothardnessandwearresistance.Onealloyofthis steelcontains20%tungsten4%chromium20%vanadiumand12%cobalt.

Stellites

Itisthetradenameofnon-ferrouscastalloycomposedof40-80%cobalt,30-35%chromiumand12-19%tungsten.Inadditiontooneormorecarbideforming elements, carbonisaddedinamountsof1.8to2.5%stellitespreservehardnessupto10000Candcanbeoperatedonsteelathighspeedtwotimeshigherthanforhigh-speedsteel.

CementedCarbides

Thesearecomposedprincipallyofcarbonmixedwithotherelements.Thebasicingredientsofmostcementedcarbidesaretungstencarbidewhichisextremelyhard.Carbidetoolsaremadebybrazing orsilversolderingthe formedinsertsontheendsofcommercialsteelholders.Themostimportantpropertiesofcementedcarbidesaretheirveryhighheatandwearresistance.Cementedcarbide tippedcutterscanmachinemetalevenwhentheircuttingelements areheatedtoatemperatureof10000C.Theycanwithstandcutting speedformorethansixtimeshigherthantoolsofhigh-speedsteel.Cementedcarbideisthehardestmanufacturedmaterialandhasaextremelyhighcompressive strength,howeveritisverybrittle,lowresistancetoshock.

Ceramics

Ceramicsarethelatestdevelopmentinthemetalcuttingtoolsuses Aluminiumoxide,generallyreferredtoasceramics.Compacting aluminiumoxidepowerinamouldmakesceramiccutters.Theceramiccuttersaremadeintheformoftipsandaretobeclampedonmetal shanks.

V. RESULTSAND DISCUSSIONS

GENERALPOSTPROCEDURE → PLOTRESULTS → DEFORMED SHAPES→OK

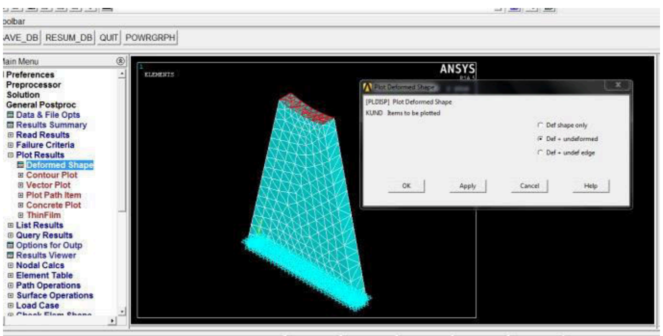


Fig . Showsthedeformedshapeofmillingcutter

CONTOUR PLOT→NODALSOLUTION→ DOFSOLUTION→ X-COMPONENT→ OK

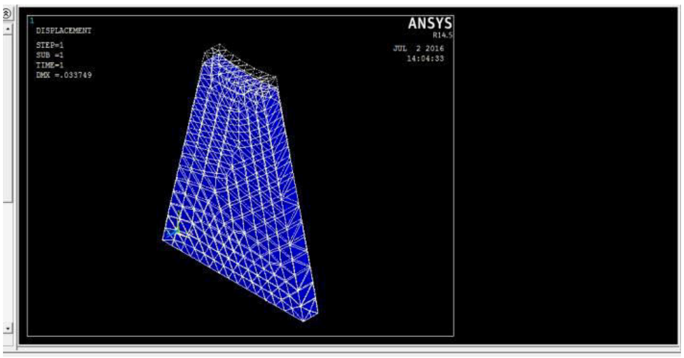


Fig .ShowstheNodalSolution on X-COMPONENT

CONTOUR PLOT→NODALSOLUTION →

DOFSOLUTION→ Y-COMPONENT→OK

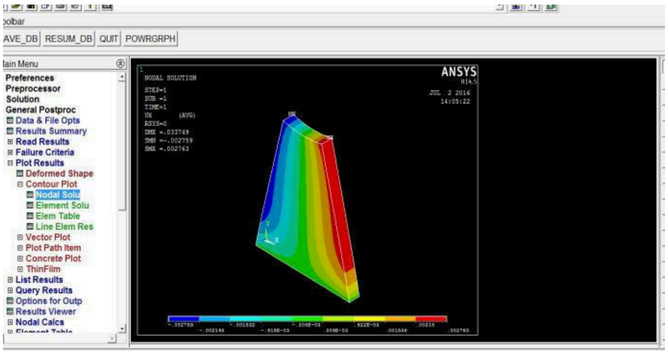


Fig .ShowstheNodalSolution onY-COMPONENT

NODALSOLUTION → STRESS →X-

COMPONENT→

OK

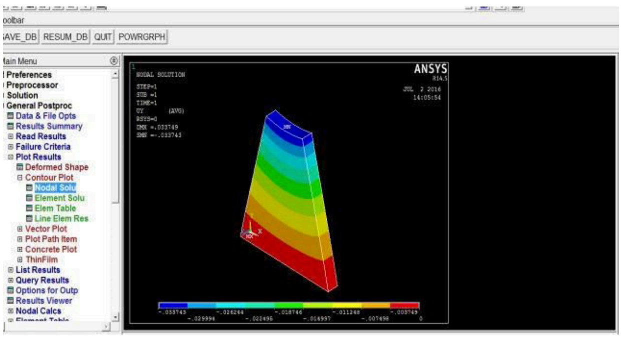
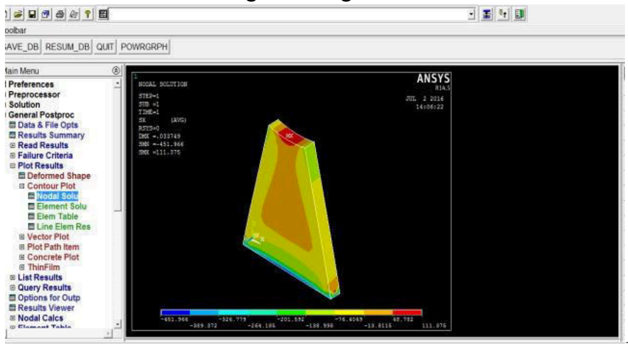


Fig.Shows theStressonX-COMPONENT

NODALSOLUTION → STRESS → Y-

COMPONENT→ OK



Fi

g .Showsthe StressonY-COMPONENT

NODALSOLUTION → VON MISESSTRESS →

OK

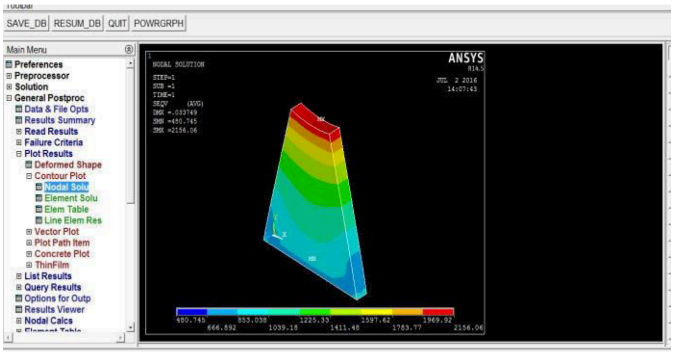


Fig .Showsthe Von misesStressofmillingcutter

PLOTCONTROLS→ANIMATE→

DEFORMEDSHAPE→

OK

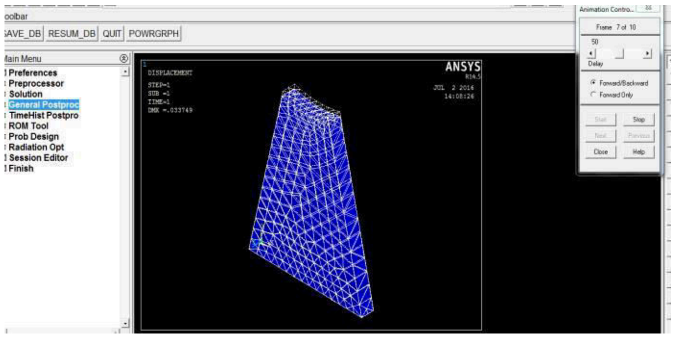


Fig.Shows theDeformed Shape

ofmillingcutterinanimatedview

VI. CONCLUSION

Millingoperationisconsideredaninterruptedcuttingoperationteethofmillingcutterenterandexittheworkduringeachrevolution.Thisinterruptedcuttingactionsubjectstheteethtoacycleofimpactforceandthermalshockoneveryrotation.

Dynamicanalysisof millingcutter can beperformed.

REFERENCE

[1]ElementReference –ANSYS 12.0
[2]Heattransfer databook byC.P.Kothandaraman
[3]TemperaturefieldanalysistogasolineenginePistonandstructureoptimization,HongyuanZhang,ZhaoxunLin,IianXing,37,Vol.48 No.2,JournalofTheoreticaland AppliedInformationTechnology
[4]SimulationAndAnalysisOfThermo-MechanicalCouplingLoadAndMechanicalDynamicLoadForAPiston,YanxiaWang,YongqiLiu,HaiyanShi,SecondInternationalConferenceOnComputerModelingAndSimulation,2010,IEEE.
[5]ComputerAidedDesignandAnalysisofPistonMechanismofFourStrokeS.I.Engine,1Er.JadhavRajendraB,2Dr.G.J. VikhePatil,2010 IEEE
[6]SimulationInvestigationontheThermo-mechanical Coupling oftheQT300Piston,YanxiaWang,YuzhenDong,YongqiLiu,2009SecondInternationalConferenceonInformationandComputing Science,IEEE
[7]StudyonInfluenceofTemperatureonICEngineVibration-AFiniteElementApproach,VinayV.Kuppast,S.N.Kurbet,AravindYadawad,BasavarajKambale,InternationalJournalofEngineeringResearchandApplications(IJERA),Vol.1,Issue4,pp.1893-1897.
[8]Thermo-Mechanical Fatigue LifeAssessmentof aDiesel EnginePistonM.R.Ayatollahi,F.MohammadiandH.R.Chamani,InternationalJournalofAutomotiveEngineeringVol.1, Number4,October 2011
[9]Thermomechanicalanalysisofdieselenginepistonusingceramiccrown, VinodJunju,M.V.MallikarjunandVenkataRameshMammilla,InternationalJournalofEmergingTrendsInEngineeringAndDevelopment(IJETD),issue2,vol.5(July2012).

Design of an Automotive Exhaust Thermoelectric Generator

KaleruSaiKiran[1],M.SureshBabu[2],Dr.V.V.PrathibhaBharathi[3]
[1]Student, Department of Mechanical Engineering,MallaReddy CollegeofEngineering,Hyderabad,Telangana,India.
mail[1]:sai9030286126@gmail.com E-mail[2]:Suresh4you247@gmail.comE-mail[3]:Prathibhaseenu@gmail.com

Abstract-- **Todesignandanalyseamodelthatcanutilizethewasteheatenergyfromvarioussourceslikeheatenergyobtainedthecarenginesexhaustsystemandto convertobtainedheatenergyintoelectricityformultipurposeuseinautomobiles.Manyconsiderationshavebeentakentomakethissystemeconomical,easyto implementanddoesnotproduceanyburdenoncarefficiencyorengine efficiency.Themodelhasbeendevelopedtosimulatecoupledthermalandelectricalenergytransferprocessesinathermoelectricgenerator(TEG)designedforautomotivewasteheatrecoverysystems.Conventionalbismuthtellurideisconsideredforthermoelectricmodules(TEMs)forconversionofwasteheatfromexhaustintousableelectricalpower.Heattransferbetweenthehotexhaustgasandthehotsideofthe TEMs isenhancedwiththeuseofaplate-finheatexchangerintegratedwithintheTEGandusingforcedconventionalcoolingonthecoldside.TheTEGisdiscretizedalongtheexhaustflowdirectionusingafinite-volumemethod.Detailedresultsareprovidedforlocalandglobalheattransferandelectricpowergeneration.Duringtheresearch,thermoelectricdeviceistestedina varietyofconfigurations withthegoalofdemonstratingathermoelectric-poweredfan.**

Keywords:Thermo-ElectricModule,PeltierEffect,ExhaustSystem,BismuthTelluride,Plate-FinHeatExchanger,Thermoelectric-PoweredFan

I. INTRODUCTION

Ouraddictiontoelectricityhasgeneratedaconcurrentaddictiontofossilfuels.However,thereservesoffossilfuelswill soonbedepleted,sinceoil isalimitedresource.Overtheyears,thecostofelectricityhasrisento unprecedentedlevelsduethelimitedsupply ofoilandeconomicandpoliticalfactors.Thus,renewableenergyis amoreattractivealternativetoelectricitygeneration,asitwillalsoprovideacleanerenvironmentforfuturegenerations.Intheworldtoday,therearemanygreatsolutionstorenewableenergy,butsomeareunfeasible.Inthis proposed project,adevicewillbecreatedtointroduceawayforhumanstocreaterenewableenergyusingthermoelectricdevices.

Thisprojectaimstoprovideasourceofrenewableenergythatovercomesthelimitationsofcurrentmethods.Athermoelectricdeviceconvertsthermalenergytoelectricalenergybyusinganarrayofthermocouples.Thisdeviceisareliablesourceof powerforsatellites,spaceprobes,andevenunmannedfacilities.Satellitesthatflytowardplanetsthatarefarawayfromthesuncannotrely exclusivelyonsolarpanelstogenerateelectricity.Thesesatelliteswillhavetouseanalternativeenergysource,suchasthermoelectricdevices,to generatetheirpower.Thermoelectricdevicesfordeep-spacemissionsusearadioactivematerial,likeplutonium,togenerateheat,andthermocouplestoconverttheheattoelectricity.Sincethermoelectricdevicehasnomovingparts,it is reliableandcangenerateelectricity formanyyears.Studieshavebeendoneonimprovingtheefficiency ofthermoelectricgeneratorbyincorporatingothertechnologies,likenanotechnology.By achievingabetterefficiency,thermoelectricdevices wouldneedlessradioactivematerialtoproducethesameamountof power,makingthepowergenerationsystemlighter.Lessradioactivematerialwillalsodecreasethecostofspaceflightlaunches.

II. DESIGNCONSTRAINTS

Essentiallythegoalis toremovesufficientheatfromthedevicesothatitdoesnotoverheat, whileretainingthelargesttemperatureatthehotsideoftheTEmoduletogeneratepower.Therearetwobroadcategoriesintermsofgeometricalconfigurations:thethermoelectricmodulecaneitherbethermallyinseriesorinparallelwiththemainheatsink.Furthermore,flowconditionsconsideredforthechosengeometrymustincludeboth forcedconvectionforthesteadystateandnaturalconvectionforthestart-uptransient.Thefollowingconstraintsarerequired:

- Constraint1:Maximumjunctiontemperatureof125^{0}C
- Constraint2:Createthelargestpossibletemperaturedifferenceacrossthermoelectricmodulegivenconstraint1
- Constraint3:Thermalcontactcanonlybemadeononesideofthedevice(usuallythecaseforpowerdevices)

Aneasywaytocomplywiththeconferencepaperformattingrequirementsistousethisdocument asatemplateandsimplytype yourtextintoit.

III. THERMALCIRCUITANDFEMSIMULATION

Athermallyseriesconfiguration,asshowinfigure1,isnotfeasiblesimplybecause,whileitwouldprovidethelargesttemperaturedifferenceacrossthethermoelectricmodule,thethermalresistanceoftheTEmoduleissolargethatefficientheatremovalisimpossible,even withforcedconvection.

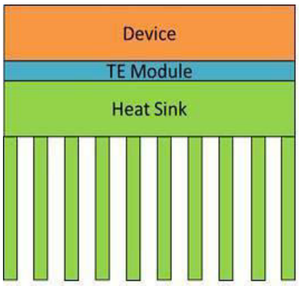


Figure1: ThermallySeriesConfiguration

Thisleavesaparallelconfigurationastheonlyalternative.Regardlessoftheexactgeometry,thegeneralsimplifiedDCthermalcircuitforanyparallelconfigurationwillhavethesamestructureinsteadystate.

InthisDCthermalcircuit,R_{te},thethermoelectricmodule'sthermalresistance,canbeassumedtobemuchlargerthanthecombinedthermalresistanceoftheotherbranch,sothatverylittleheatpassesthroughthethermoelectricbranch.R_{hs}dependsonthegeometryandheatsinkmaterial,whileR_{hsair}dependsonthesurfaceareaofthefinsandairspeedintheforcedconvectioncase.WealsoassumethatwehavenocontroloveriR_{te},sincethesurfaceareaavailablefortheTEmodulewillnecessarilybeontheorderofthesizeofthedevice.Withtheseassumptions,theoriginaldesignconstraintsamounttoamaximizationofthehighsidetemperatureuptoT$_{junct}$byincreasingR_{hs1}andR_{hsair1}whileminimizingtheheatsinkresistancesinthetopbranchsothatasmuchofthetemperaturedifferenceaspossibleappearsacrossR_{te}.Weproposeonepossibleconfiguration,showninfigure2,whichallowsustomodifytheseparameters.

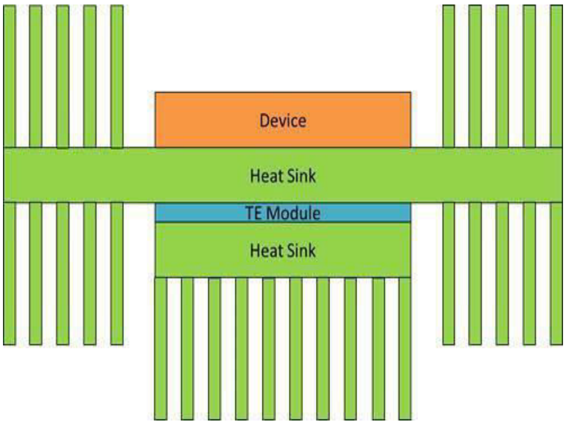


Figure2: ThermallyParallelConfiguration

Intheproposedconfiguration,theTEmoduleisplacedatthehottest pointof theheatsink,sothataslong asconstraint1ismet,constraint2isalsomet.R_{hsair}canbemodifiedbychangingthenumberoffinsinthemainheatsinkandthethermoelectricheatsink,andR_{hs1}andR_{hs2}canbechangedbyalteringthedimensionsofthemainheatsink.
Inthesimulation,thedeviceisavolumetricheatsourceproducing2000Wandthethermoelectricmodulehasthesamelengthandwidthasthedevice,withathicknessof3.4mm(roughly the thicknessof acommercial
Peltiercooler).Inaccordancewiththeassumptionthatheatcanonlyberemovedfromonesideofthedevice,thetopsurfacehasathermalinsulationboundarycondition.

Thedeviceisimmersedinaboxofairinwhichrepresentsopenspace. Theheatequationissolvedonthesolidandcoupled to the incompressibleNavier-Stokes equations onthefluiddomainviacontinuityforheatandtheno-slipconditionforfluidflow.Theno-slipboundaryconditiononwallsisacommonapproximationmadeincomputationalfluiddynamicsforlowand intermediatevelocities, and greatlysimplifiesthecomputationaslongasthensarenotcloseenoughtogetherthatboundaryoverlapeffectsoccur.

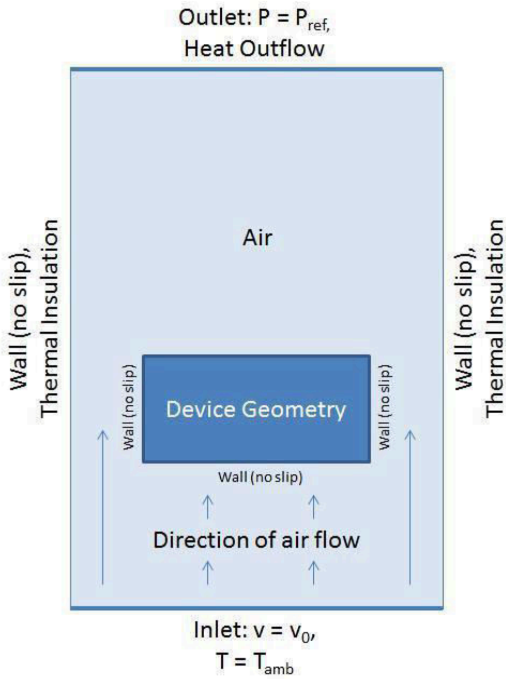


Figure3:showstheboundaryconditionsforthesteady-stateforcedconvectionsimulations.

Theinletboundaryconditionsareconstanttemperatureandvelocityprofileandtheoutletboundaryconditionsareconstantpressureandheatoutflow.TheheatoutflowconditioninCOMSOLisidenticaltothermalinsulationandstatesthattheonlyheattransferisbyconvection.Thesidewallsofthefluiddomainalsohavethethermalinsulationconditionandno-slipwallswhich,foralargeenoughboxapproximatesalargeopendomain.

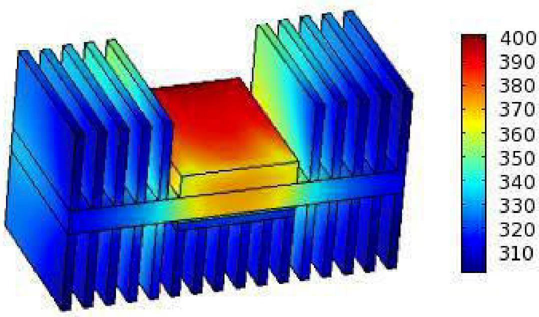


Figure4: SurfaceTemperature,ForcedConvection

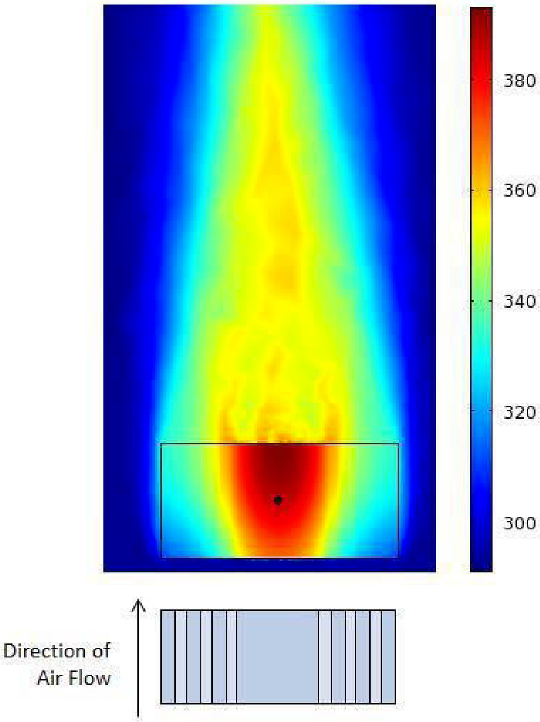


Figure5: CrossSectionalTemperature,ForcedConvection

Therectangularoutlineinfigure5representsthepositionofthedevice,andthepointdenotestheaxisalongwhichfigure6,thetemperatureprofile,isplotted.Theorientationoftheinfigure 5 isthesame asinfigure 5. Infigure 6, the temperatureprofilegoeslinearlyfromx=0mm,thetopoftheIGBT(Insulatedgatebipolartransistor)tox=16mm,thetipofthethermoelectricheatsink'sfins.

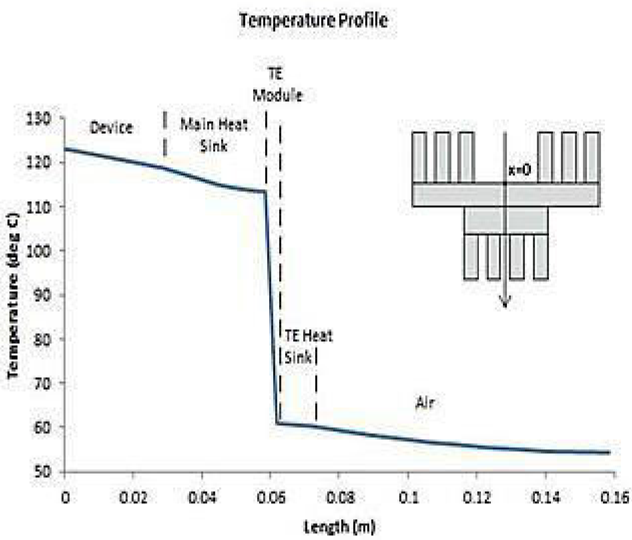


Figure6: TemperatureProfile,ForcedConvection

Withaninlet velocityof 2m/s,weseea dropofapproximately60^{0}Cacrossthethermoelectricmoduleinsteadystate,quitegoodconsideringthehighesttemperatureinthesystemisjustunder125^{0}C.IntegratingtheheatfluxintotheTEmoduleresultsinavalueof250W.Assumingan averageefficiencyof4%forthethermoelectricmodule,around10 Wofpowerwillberecovered.

Integratingthepressuredropovertheinletand multiplyingbytheinletvelocity,wecalculatethefanpowerrequired tocooltheheatsinktobeabout5W.Intheorythen,itappearsthatbyusinganoptimizedgeometryandwithanefficientthermoelectricmaterial,usingthe recoveredheat topowerthecoolingfaninclosedloopispossible,atleastinsteadystate.Atradecanbemadebetweenoutputpowerandfanspeed(andhence,devicetemperature)sinceincreasingfanspeedlowerstheaveragetemperatureofthesystem. Figures7 and8showthetotalheatfluxthroughthethermoelectricmoduleand temperature,respectively,asfunctionsoffanspeed.

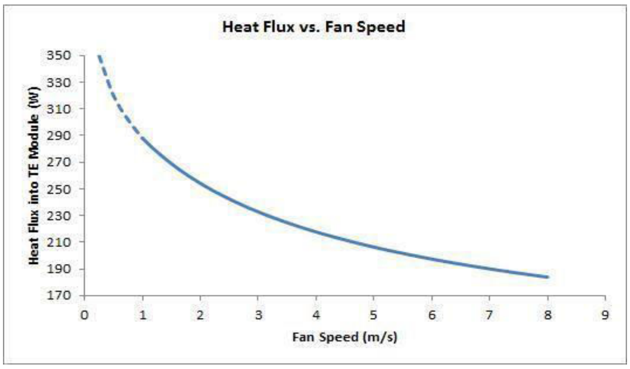


Figure7: HeatFluxvs.FanSpeed

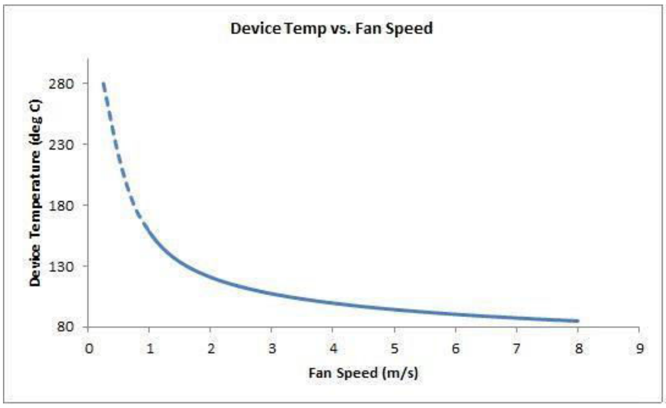


Figure8: DeviceTemperaturevs.FanSpeed

Theheatflux-vs.-fanspeed(Figure7)anddevicetemperature-vs.-fanspeed (Figure 8) areextrapolated below1m/sbecausetheforcedconvectionmodeldoesnottakeintoaccountnaturalconvection.Atlowfanspeeds,thesteady-statesolutionapproachesasituationwheretemperatureisuniformandnoheatflowsthrougheitherbranch,whichisunrealistic.Ifthefan power-vs.-fanspeedcharacteristicisknown,thentheintersectionbetweenthefanpower-vs.-fanspeedandpowergenerated-vs.-fanspeedcurvesdenotesthesteadystateoperatingpointof thesystemwithoutanycontrol,asshowninfigure9.

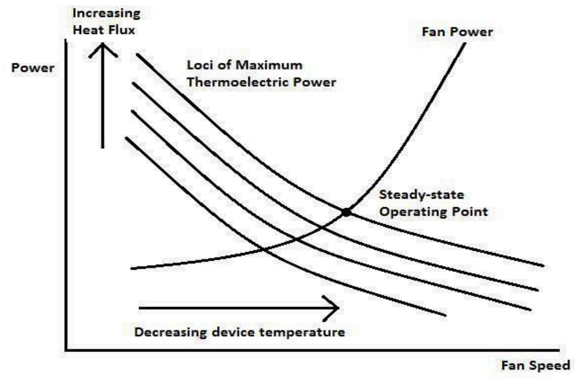


Figure9: OperatingPoint

Thelocusesofmaximumthermoelectricpowerrepresentthepeakpowerpointsasfunctionsofinputheatandfanspeed,withreferencetoFigure7,sincethepeakpowergeneratedwillbeafixedpercentageofthetotalheatfluxthroughthethermoelectric legofthegeometry.Thepoint showninfigure9istheoperatingpointwiththeleastavailablepower output.Therefore,anyoperatingpointtotheleftofthesteady-stateoperatingpoint along thefanpowercurveis possiblewith theappropriatecontrolsystem,tradingpoweroutputfordevicetemperaturewhilegeneratingexcesspower.

Thecomponentsofthecontrolsysteminfigure10are:

Plant:Theplantincludestheheatsinksandthermoelectricmodule, whichmaybeobtainedusingtheappropriatemodel,forinstancetheonedevelopedinthispaper.

Maximumpowerpointtracker(MPPT):Acontrollerwhichmeasurestheinputvoltageandcurrentandaltersthedutycycleofadc/dcconvertertomaintaintheinstantaneouspowerVIatamaximum.ThisensuresthatthepowerbeingoutputbytheTEmoduleremainsonthelocusofpeakpowerpoints.

VoltageRegulatorandBus:Createsaconstantvoltagebustopowerthefanandtodistributeexcesspowerifthefanisnottaking100%ofthepowergenerated.

FanController:Measuresfancurrentandspeedinordertoregulatefanspeed.Thefanspeedcommandcanbe(1)setbasedonthedifferencebetweenthemeasuredthermoelectricpower and a reference power,(2) setata constantvalue or (3)beallowedtoreachthesteadystateoperatingpoint.ThefancontrollerthensendsthePWMsignalstotheinverterwhichpowersthefan.

Fan:Asynchronousmotorwhichcoolsthedeviceandheatsinks.

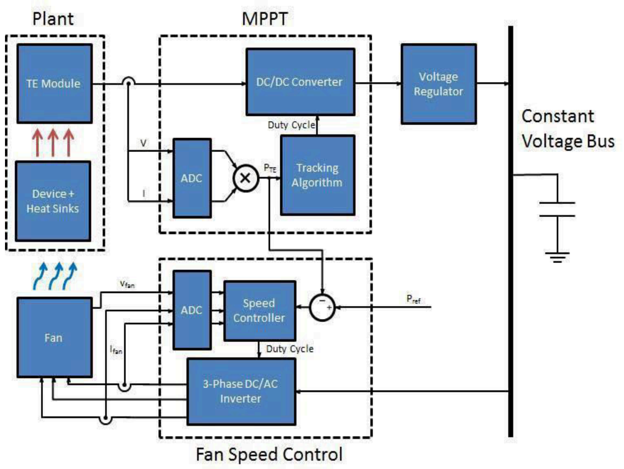


Figure10: ControlSystem

Thefinalthingtoconsideristhestart-upbehaviourofsuchacoupledsystem.Sincewehavealreadydesignedforthesystemto have themaximumallowedjunctiontemperatureinordertorecoverthelargestamountofenergy,havingthesystemstartinnaturalconvectionwillshootT_{junct}past125^{0}C.Assumingthefangetsenoughpowertoturnonatexactly125^{0}C,itisofinteresttosimulateexactlyhowmuchhigherthetemperaturerisesandforhowlong.Forthispurposewedesignedanothersimulationwithnatural convectionconditions,ranthatsimulationuntilT_{junct}reached125^{0}C,andusedthestateatthat pointastheinitialconditionsforaforcedconvectionsimulation.Theresultisshowninfigure11. Theresultsofthesimulationshowthatforourtestcase,thetemperatureovershootisontheorderofafewdegreesoveratimescaleoftensofseconds.

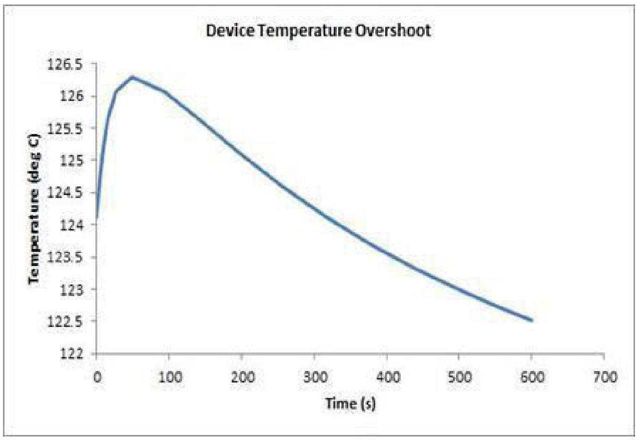


Figure11: TemperatureOvershoot

Thepercentovershootwoulddependonthegeometryoftheheatsinkand theamountofheatbeinggenerated bythedevice,buttheseresultsshowanytransienttemperaturerisedduringstart-upislimitedinbothmagnitudeandduration.

IV. CONCLUSION

Thesteadystateandtransientbehaviourofthesampledesignwasinvestigated,anditwasfoundthatasteadystatesolutionwhereafanwasbeingdrivenbypowergeneratedfromwasteheatwastheoreticallypossible,andthatthetemperatureovershootassociatedwithstart-upwasrelativelyminor.Apossiblecontrolstructureforthesystem wasalsoconsidered.

V. REFERENCES

[1]A.W.Crook(ed).Pro_tingFromLow-GradeWasteHeat.London:InstituteofElectricalEngineers,1994.
[2] D.M.Rowe(ed).CRCHandbookofThermoelectrics. Danvers,MA:CRCPress,1995.
[3]SimonLineykinandSamBen-Yaakov.\AnalysisofThermoelectricCoolersbyaSPICE-CompatibleEquivalentCircuitModel".In:(2005).
[4]R.C.O'Brienaetal.\Saferadioisotopethermoelectricgeneratorsandheatsourcesforspaceapplications".In:(2009).
[5]GangChen.NanoscaleEnergy Transport andConversion.Oxford:OxfordUniversityPress,2005.

Improvement of Heat Transfer using Nano Fluids

Ramesh, G.
Malla ReddyCollege ofEngineering,
JNTUHyderabad,
Telangana,India.
Email:shivashanker350@gmail.com

Mrs.A.LakshmiJyothi
Malla ReddyCollege ofEngineering,
JNTUHyderabad,
Telangana,India.
Email:jyothi_avvaru@yahoo.com

Kaleru Sai Kiran
Malla ReddyCollege ofEngineering,
JNTUHyderabad,
Telangana,India.
Emai0l:sai9030286126@gmail.com

Dr.V.V.Prathibha Bharathi
Malla ReddyCollege ofEngineering,
JNTUHyderabad,
Telangana,India.
Email:Prathibhaseenu@gmail.com

ABSTRACT

Inthisstudy,thermalandflowbehaviormodelsforcircularmicrochannelusingwateranditsnanofluidswithaluminaasacoolantfluidinsingle phase flowhavebeendeveloped.A finitevolume-basedCFDtechniqueisusedandmodelsaresolvedby usingFluentSolver.The2Daxissymmetricgeometrywithstructuredmeshand100x18nodesareusedforsinglephaseflowwithAl_2O_3nanoparticlesof23nmaveragediameter.Viscouslaminarandstandardk-εmodelsareusedtopredictthesteadytemperatureinlaminarandturbulentzone.Theheattransferenhancementupto83%inlaminarandturbulentzonesareobtainedwiththeRerangingfrom5to11980andparticlevolumeconcentrationfrom0to5%.EventhoughthepressuredropincreaseswithincreaseinRe,itiscomparativelylesscomparedtothecorrespondingdecreaseintemperature.Theincreasein temperaturedepends onRe andPe(ThePecletnumberistheproductoftheReynoldsnumberandthePrandtlnumber);butthetemperaturedistributionisfoundtobeindependentofradialpositionevenforverylowPe.Comparisonwithanalyticalresultsbothinlaminarandturbulentzoneisprovidedtojustifytheassumptionsintroducedinthemodelsandverycloseagreementisobservedstatistically.Nusseltnumber canwellpredictthe analytical data

INTRODUCTION

Nanofluidsareengineeredcolloidsmadeupofabasefluidandthenanoparticles.Theintroductionofnanoparticlesenhancestheheattransferperformanceofthebasefluidssignificantly.Thebasefluidsmaybewater,organic liquids (e.g.,ethylene,tri-ethylene-glycols,refrigerants,etc.),oilsandlubricants,biofluids,polymericsolutions,andothercommonliquids.Thenanoparticlematerialsincludechemicallystablemetals(e.g.,gold,copper),metaloxides(e.g.,alumina,silica,zirconia,andtitania),oxideceramics(e.g.,Al_2O_3,andCuO),metalcarbides(e.g.,SiC),metalnitrides(e.g.,AIN,SiN),carboninvariousforms(e.g.,diamond,graphite,carbonnanotubes,andfullerene),andfunctionalized nanoparticles Thebenefitsofusingnanofluidscomparedtotheconventionalbasefluidsare asfollows.

1. Theamountofheattransferincreasesasaresultofincrease intheheattransfer surface area betweenthe particlesandfluids.
2. Thepumpingpowerrequiredfortheequivalentheattransfer is less thanthatcompared topure liquids.
3. Thepropertieslikethermalconductivity,density,andso forthmaybevaried byvaryingparticleconcentrations tosuit different applications

Therearethree approaches to FluidMechanics– Experimental, Theoretical and Computational. Experimentalapproach is the oldestapproach,perhapsalsoemployedbyArchimedeswhenhewas toinvestigate a fraud.It isa verypopularapproachwhereyouwillmakemeasurementsusingawindtunnelorsimilarequipment.But thisis a costly ventureand is becomingcostlierdayby day.Thenwehavethetheoreticalapproachwhereweemploythemathematicalequationsthatgoverntheflowandtrytocapturethefluidbehaviorwithinaclosedformsolutioni.e.,formulasthat canbe readilyused. Thisis perhaps the simplestof theapproaches,butitsscopeissomewhatlimited.Noteveryfluidflowrenders itselftosuchan approach. Theresulting equationsmaybetoocomplicatedto solveeasily.Thencomesthe third approach-Computational.Herewetryto solvethe complicatedgoverningequations by computingthem using a computer.Thishas theadvantagethatawidevarietyoffluidflowsmaybecomputedandthatthecostofcomputingseemstobegoingdowndaybyday.WiththeresulttheemergingdisciplineComputationalFluidDynamics,CFD,hasbecomeaverypowerfulapproachtodayinindustryandresearch.

COMPUTATIONAL FLUID DYNAMICS

Overthepasthalf-century,wehavewitnessedtheriseinthenewmethodologyforattackingcomplexprobleminfluidmechanics,heattransferandcombustion.Ithascometothestatethatwhereverthereisaflow,computercanhelptounderstandandanalyzethesame.Thisnewmethodologyofsolvingaflow problemusingacomputerisgiventhenameCFD.ComputationalFluidDynamicsorCFDistheanalysisofsystemsinvolvingfluidflow,heattransferandassociatedphenomenasuchaschemicalreactionsbymeansofcomputer-basednumericalapproach,Inthisnumericalapproach,theequations(usuallyinpartialdifferentialform)thatgovernaprocessofinterestaresolvednumerically.Thetechniqueisverypowerfulandspansawide range ofindustrial and non-industrial applicationareas.
Therearethreemethodstoanalyzeafluidflowproblem.

1. Experimental
2. Theoretical
3. Computational(CFD)

SIMULATIONOFFLUIDFLOW INA CIRCULAR MICROCHANNEL

It is wellknownthat nanoparticleshaveveryhighthermal conductivitycomparedtocommonlyusedcoolant.Thus,thethermalconductivityandotherfluidpropertiesarechangedbymixingtheparticleinfluid.ThechangedpropertiesoftheNanofluidsdeterminetheheattransferperformanceofthemicrochannelheatexchangerwithnanofluids.Thispointisillustratedinthischapterbydoingthecomputationalfluiddynamics(CFD)analysisofthehydrodynamicsandthermalbehaviourofthesinglephaseflowthrougha circularmicrochannel

SPECIFICATIONOFPROBLEM:

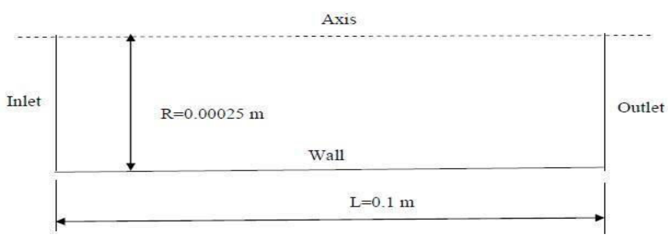
Consider a steadystatefluidflowing througha circularmicrochannelofconstantcrosssectionasshowninFigure.6.1(LeeandMudawar,2007).Thediameterandlengthofcircularmicrochannelare0.0005mand0.1mrespectively.Theinletvelocityisu(m/s),whichisconstantovertheinletcross-section.Thefluidexhaustsintotheambientatm2osphere which isat a pressure of1atm.

Fluidflowthrougha circularmicrochannel ofconstant cross-section

GEOMETRYIN ANSYSWORKBENCH

TheComputationaldomainofcircularmicrochannelisrepresentedintwodimensional(2D)formbyarectangleanddisplayedinFigure.

6.2. Thegeometryconsistsofawall,acenterline,andaninletandoutletboundaries.Theradius,Randthelength,Lofthepipearespecifiedinthe figure



MATERIAL PROPERTIES

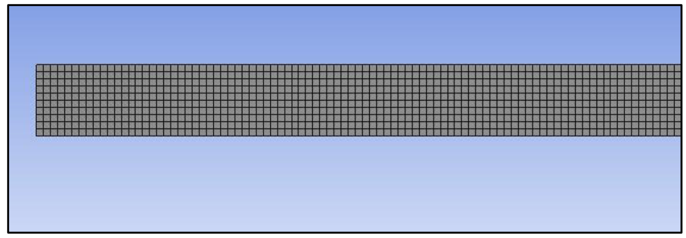
PurewaterisusedasbaseworkingfluidandAlumina(Al_2O_3)istakenasnanoparticles.Thedensity,heatcapacityandthermalconductivityofaluminaare 3,600kg/m^3,765J/kgKand36W/mKrespectively.Thepropertiesofnanofluids(nf)aregiveninTable6.2at30^{o}Ctemperature and100kPapressure.Table 4.2Waterbasefluidproperties withdifferentconcentrationofalumina nanoparticles

	0%	1%	2%	3%	4%	5%
k (w/mK)	0.603	0.62	0.638	0.656	0.675	0.693
ρ(kg/m^3)	995.7	1021.7	1047.7	1073.8	1099.8	1125.9
μ(kg/ms)	7.97E-04	8.17E-04	8.38E-04	8.57E-04	8.78E-04	8.97E-04
Cp(kJ/kg K)	4.183	4.149	4.115	4.081	4.046	4.012

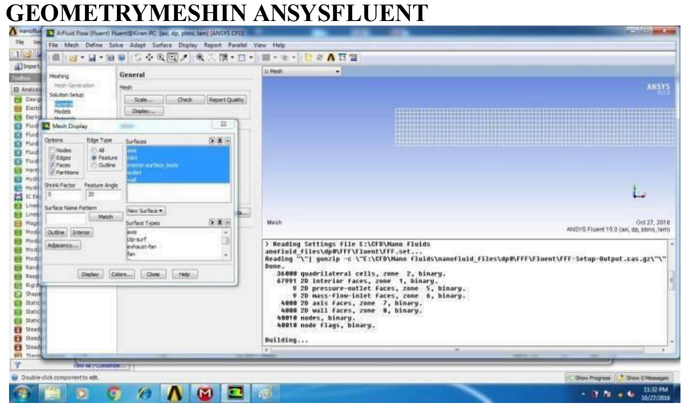
BOUNDRYCONDITIONS

Anoslipboundaryconditionwasassignedforthenonporouswallsurfaces,wherebothvelocitycomponentsweresettozeroatthatboundary i.e.$\upsilon_x=\upsilon_r=0$.Aconstantheatflux(100W/m^2)isappliedonthechannelwall.Axissymmetrywasassignedatcenterline.Auniformmassflowinletandaconstantinlettemperaturewereassignedat the channelinlet.Atthe exit,pressure wasspecified

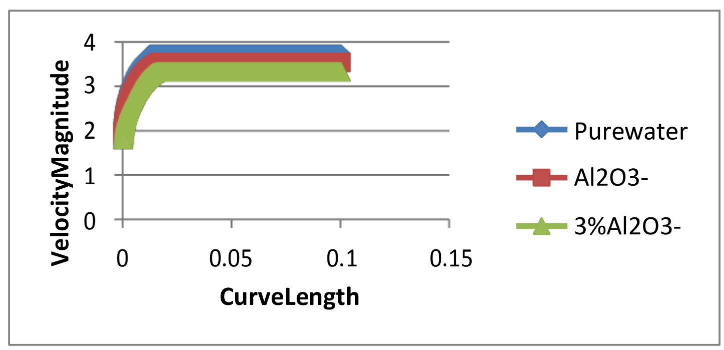
MESHEDMODEL



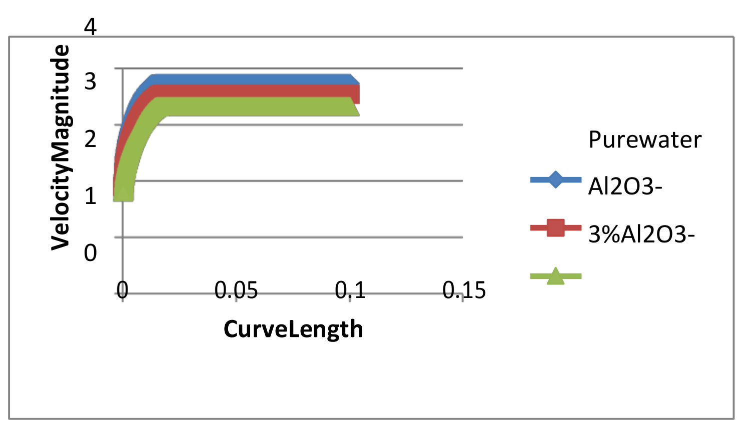
GEOMETRYMESHIN ANSYSFLUENT



VELOCITYPROFILEATCENTERLINEINTHECIRCULARMICROCHANNEL AT RE =1278 FOR LAMINAR

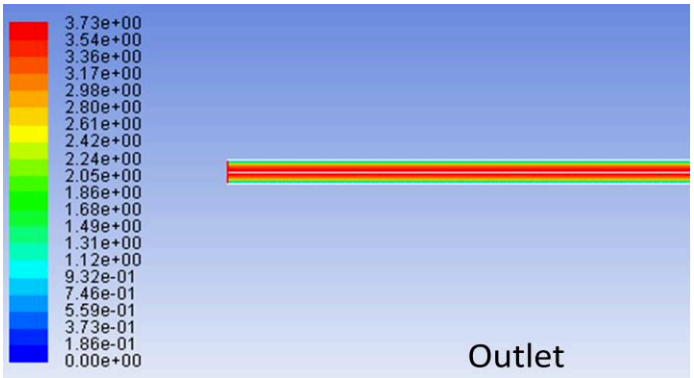


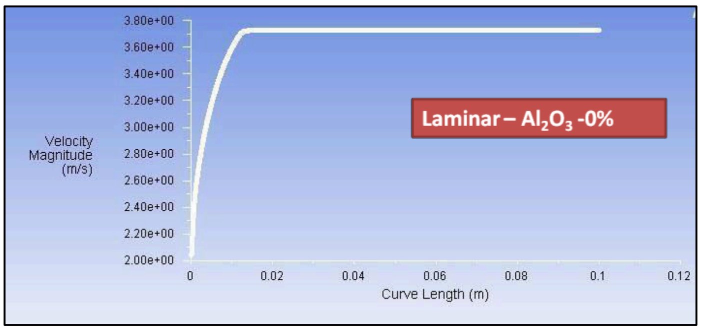
VELOCITYPROFILEATCENTERLINEINTHECIRCULARMICROCHANNEL AT RE =6390 FOR TURBULENT



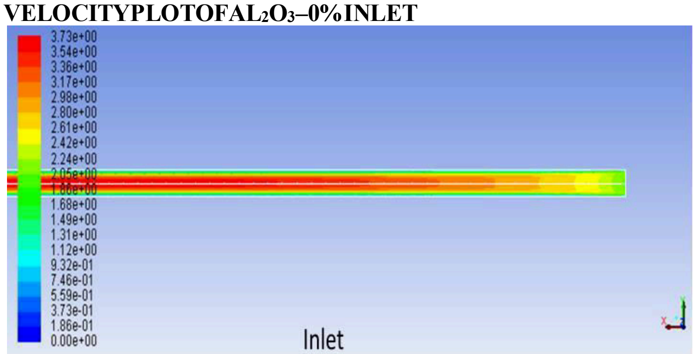
LAMINAR

VELOCITYPLOTOFAL_2O_3–0%OUTLET



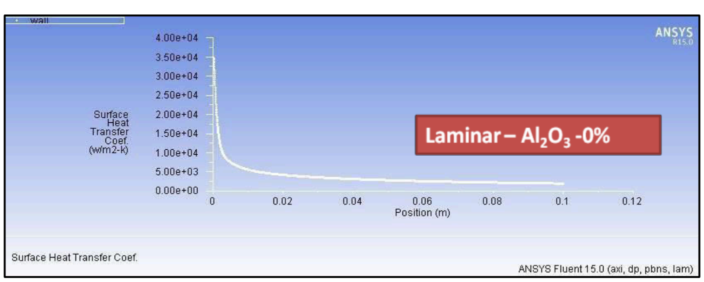


VELOCITYPLOTOFAL_2O_3–0%INLET

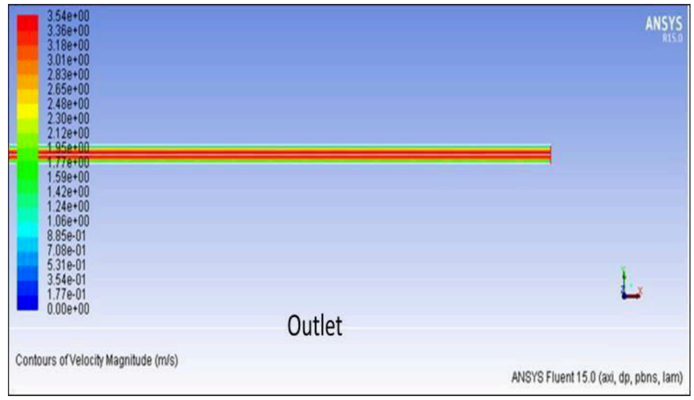


VARIATIONOFVELOCITYOFWATERINRADIALDIRECTIO NATDIFFERENTVALUESOFXFORAL$_2$O$_3$-0%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER

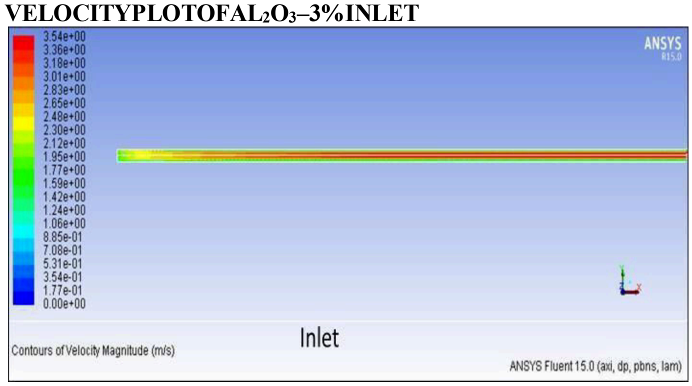
VARIATIONOFHEATTRANSFERCOEFFICIENTOFWATERI NRADIALDIRECTIONATDIFFERENTVALUESOFXFORAL$_2$O$_3$-0%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



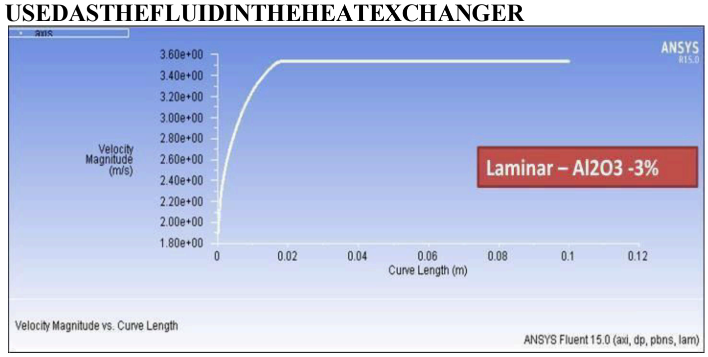
VELOCITYPLOTOFAL_2O_3–3%OUTLET



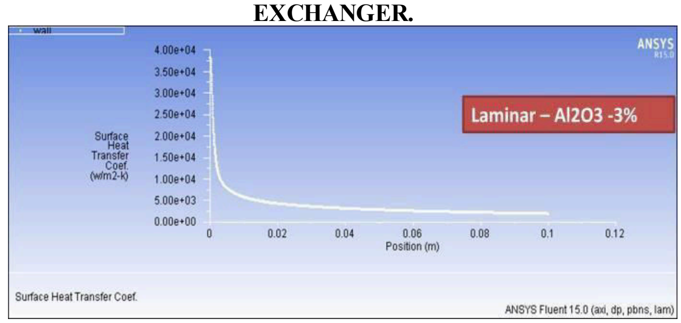
VELOCITYPLOTOFAL_2O_3–3%INLET



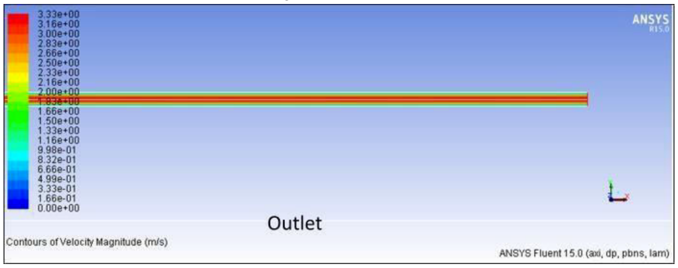
VARIATIONOFVELOCITYOFWATERINRADIALDIRECTIO NATDIFFERENTVALUESOFXFORAL$_2$O$_3$-3%WATERIS USEDASTHEFLUIDINTHEHEATEXCHANGER



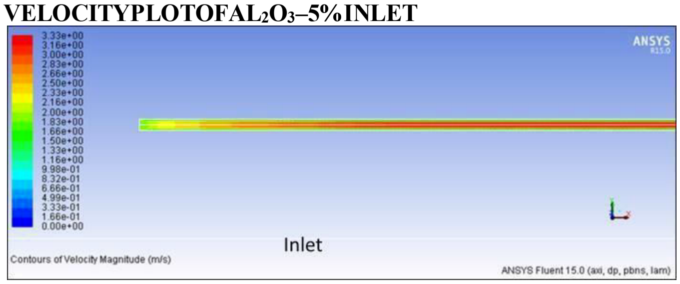
VARIATIONOFHEATTRANSFERCOEFFICIENTOFWATERI NRADIALDIRECTIONATDIFFERENTVALUESOFXFORAL$_2$ O$_3$-3%WATERISUSEDASTHEFLUIDINTHE HEAT EXCHANGER.



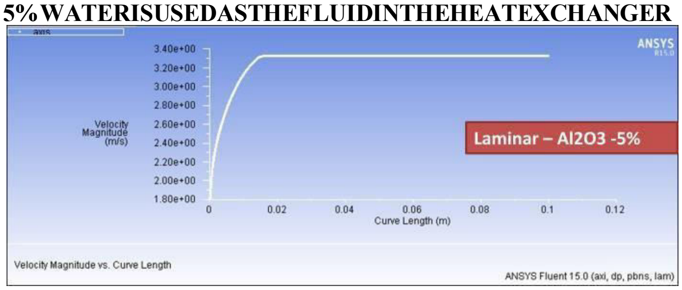
VELOCITYPLOTOFAL_2O_3–5%OUTLET



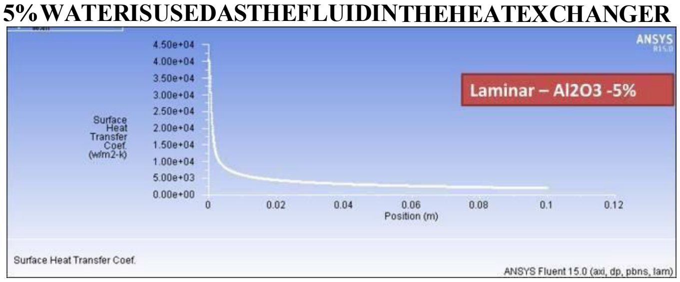
VELOCITYPLOTOFAL_2O_3–5%INLET



VARIATIONOFVELOCITYOFWATERINRADIALDIRECTIO NATDIFFERENTVALUESOFXFORAL$_2$O$_3$-5%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER

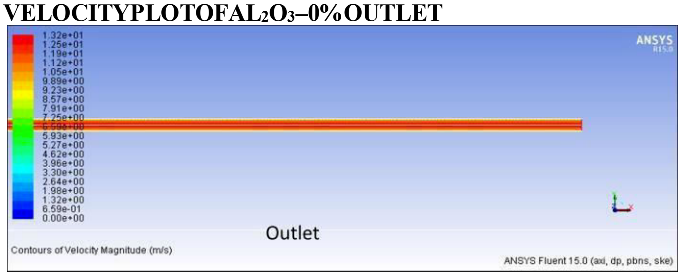


VARIATIONOFHEATTRANSFERCOEFFICIENTOFWATERI NRADIALDIRECTIONATDIFFERENTVALUESOFXFORAL$_2$O$_3$-5%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER

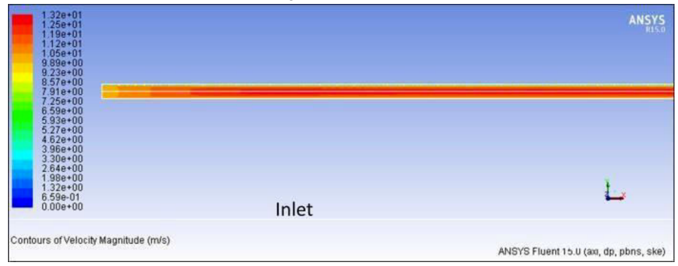


TURBULENT

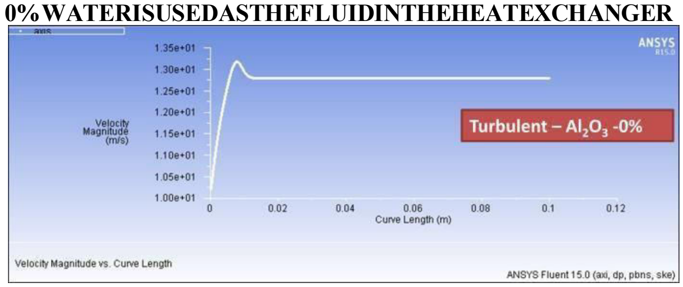
VELOCITYPLOTOFAL_2O_3–0%OUTLET



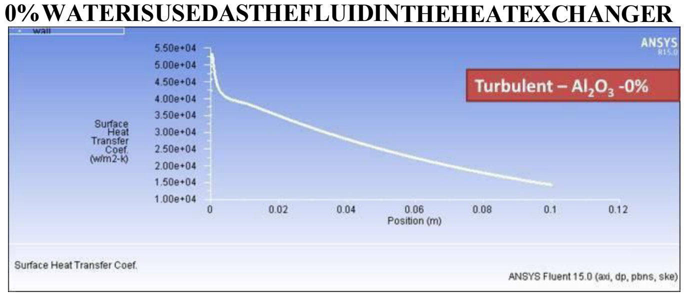
VELOCITYPLOTOFAL_2O_3–0%INLET



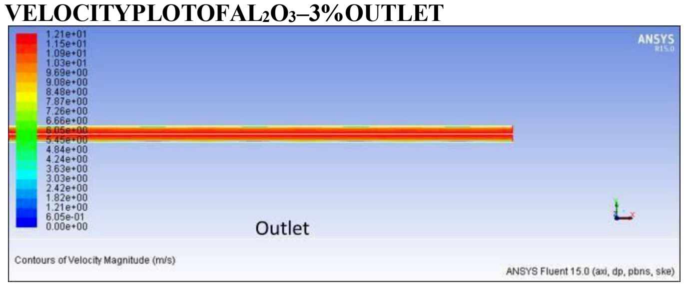
VARIATIONOFVELOCITYOFWATERINRADIALDIRECTIO NATDIFFERENTVALUESOFXFORAL$_2$O$_3$-0%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



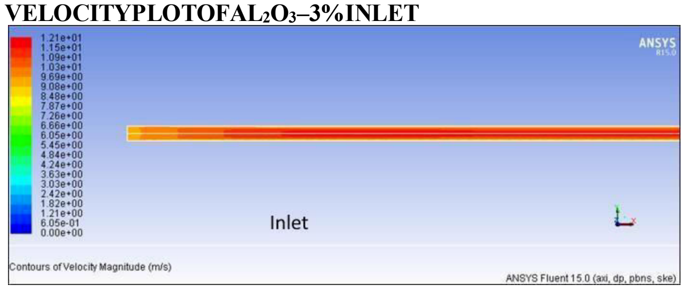
VARIATIONOFHEATTRANSFERCOEFFICIENTOFWATERI NRADIALDIRECTIONATDIFFERENTVALUESOFXFORAL$_2$O$_3$-0%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



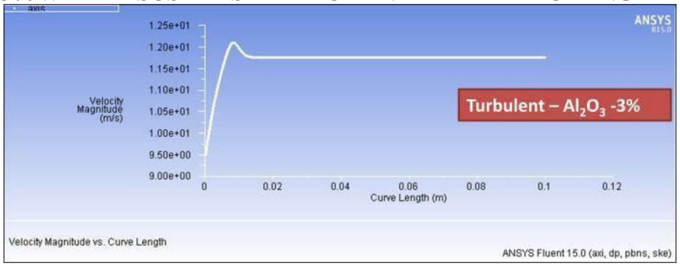
VELOCITYPLOTOFAL_2O_3–3%OUTLET



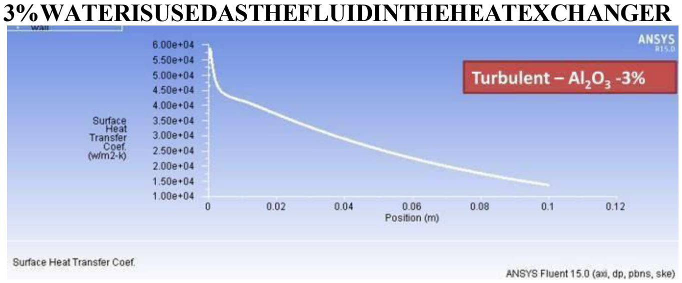
VELOCITYPLOTOFAL_2O_3–3%INLET



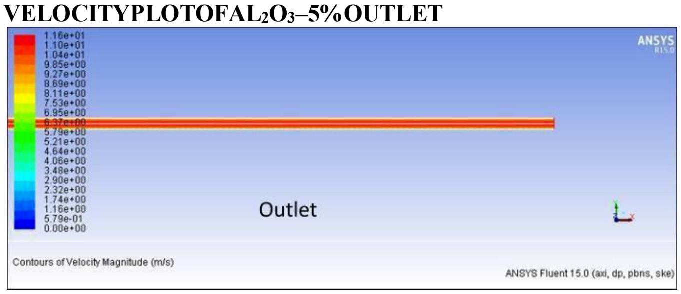
VARIATIONOFVELOCITYOFWATERINRADIALDIRECTIO NATDIFFERENTVALUESOFXFORAL$_2$O$_3$-3%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



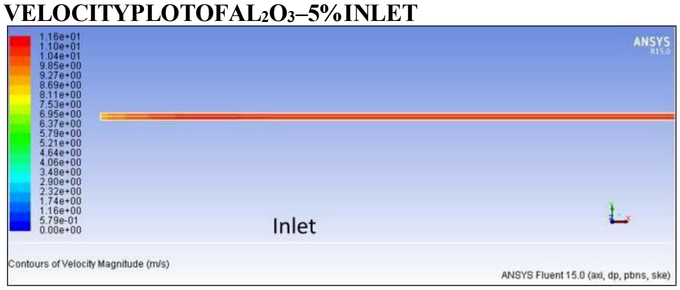
VARIATIONOFHEATTRANSFERCOEFFICIENTOFWATERI NRADIALDIRECTIONATDIFFERENTVALUESOFXFORAL2 O3-3%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



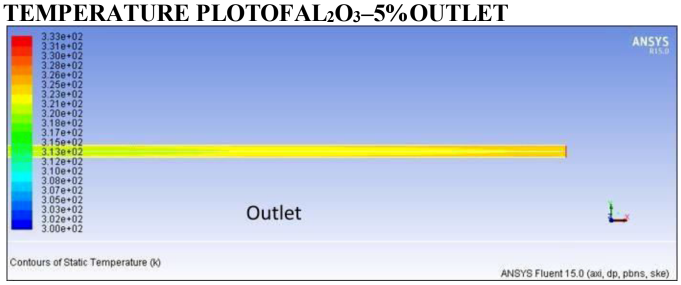
VELOCITYPLOTOFAL$_2$O$_3$–5%OUTLET



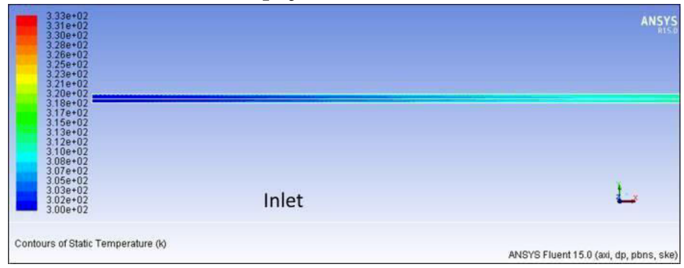
VELOCITYPLOTOFAL$_2$O$_3$–5%INLET



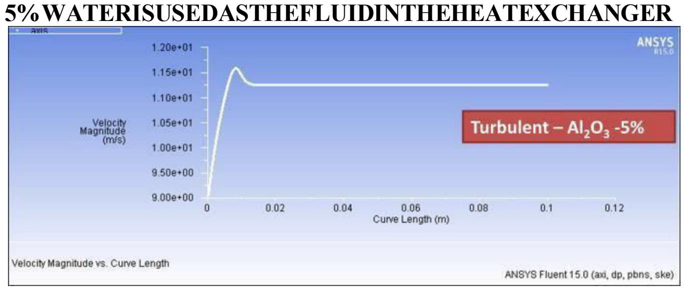
TEMPERATURE PLOTOFAL$_2$O$_3$–5%OUTLET



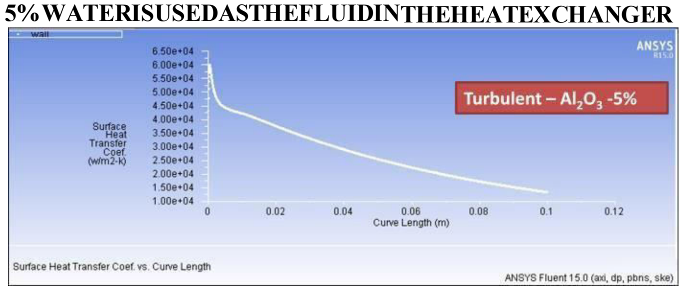
VELOCITYPLOTOFAL$_2$O$_3$–5%INLET



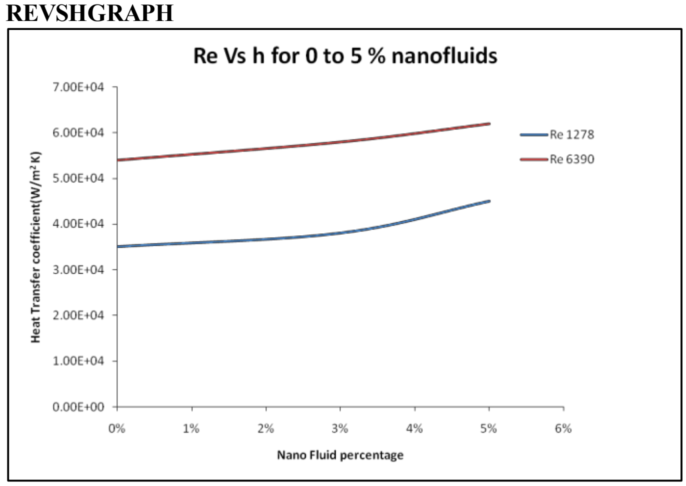
VARIATIONOFVELOCITYOFWATERINRADIALDIRECTIO NATDIFFERENTVALUESOFXFORAL$_2$O$_3$-5%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



VARIATIONOFHEATTRANSFERCOEFFICIENTOFWATERI NRADIALDIRECTIONATDIFFERENTVALUESOFXFORAL$_2$O$_3$-5%WATERISUSEDASTHEFLUIDINTHEHEATEXCHANGER



REVSHGRAPH



CONCLUSIONS

Inthisstudy,thethermalandflowbehaviourmodellingofcircularmicrochannelhasbeenperformed.Velocity,temperatureandheattransfercoefficienthavebeenformulated.Theheattransferduringlaminarandturbulentregimehasbeensolvedusingtheviscouslaminar andstandardk-εmethods.The results showthat:

Thermallydevelopingconditionsforaparticularreandnanofluidconcentrationwithhigherheattransfercoefficientmostlyinentrancesregionofmicrochannels.Astheconcentrationofnanoparticleincreases,heattransfercoefficientalsoincreases.Withincrease inre,heattransfercoefficientalsoincreases.

Theenhancementofheattransferinturbulentnanofluidflowisgreaterascomparedtolaminarnanofluidflowwithrespecttoitsbasefluid.Velocityandtemperaturecontoursrepresentsuccessfullythehydrodynamic andthermal behaviourofthe microchannelsystem.

Eventhoughaxialvelocitydecreasewithincreaseinnanofluidconcentrationforlaminarandturbulentzones,novariationisfoundataparticularconcentrationexceptfortheentrancelength.Velocityprofileisflatatverylowreand parabolicathigherre.Walltemperatureatanaxialpositiondecreasewithrespecttoincreaseinnanofluidconcentration.Butthereisnonanofluidtemperaturevariationwithradialposition

FUTURESCOPE

Here,CFDanalysisisdonethenanofluidAl2O3indifferentpercentage usedinmicrochannel.

Thestudycanbeextendedforwardbyconductinganalysisondifferentavailablenanofluidscan be usedforextendedstudy.

REFERENCES

1. Wang,B.X.,Zhou,L.P.,Peng,X.F.,2003.Afractalmodelforpredictingtheeffectivethermalconductivityofliquidwithsuspensionofnanoparticles.InternationalJournalofHeat andMassTransfer 46,2665–2672.
2. Fedorov,A.G.andRaymond,V.2000.Three-dimensionalconjugateheattransferinthemicrochannelheatsinkforelectronicpackaging.InternationalJournalofHeatandMassTransfer.43399-415
3. Jiang,P.,Fan,M.,Si,G.andRen,Z.2001.Thermal–hydraulicperformanceofsmallscalemicro-channelandporous-mediaheat-exchangers.InternationalJournalofHeat andMassTransfer,44,1039-1051.
4. Chein,R.andChuang,J.2007.Experimentalmicrochannelheatsinkperformancestudiesusing nanofluids.International JournalofThermalSciences.46,57-66.
5. Allen,P.W.2007.ExperimentalandNumericalInvestigationofFluidFlowandHeatTransferinMicrochannels.MscThesis,MechanicalEngineeringDepartment,Louisiana StateUniversity.
6. Kandlikar,S.G.,Garimella,S.,Li,D.,Colin,S.andKing, M.R.2006.HeatTransferandFluidFlowInMinichannelsandMicrochannels,Elsevier
7. Gherasim,I.,Roy,G.,Nguyen,C.T.andVo-Ngoc,D.2009.Experimentalinvestigationofnanofluidsinconfinedlaminarradialflows.InternationalJournalofThermalSciences.48,1486–1493.
8. Hetsroni,G.,Mosyak,A.,Pogrebnyak,E.andYarin,L.P.2005.Fluidflowinmicrochannels.InternationalJournalofHeat andMassTransfer.48,1982–1998.
9. Bachok,N.,Ishak,A.andPop,I.2011.Flowandheattransferoverarotatingporousdiskinananofluid.PhysicaB.406,1767– 1772.
10. Das,S.K.,Putra,N.,Roetzel,W.,2003a.Poolboilingcharacteristicsofnano-fluids.InternationalJournalofHeatandMassTransfer 46,851–862.
11. .ANSYSFluent12.0TheoryGuide,April,(2009).

Analysis of bevel gears using FEA

B.Rajendra Prasad, L. Priyanka, Siva sankara Gowda
Department of Mechanical Engineering Mallareddy college of Engineering

Abstract—**Gearsareanintegralandnecessarycomponentinourdaytodaylives.Theyarepresentinthesatelliteswecommunicatewith,automobilesandbicycleswetravelwith.Gearshavebeenaroundforhundredsofyearsandtheirshapes,sizes,andusesarelimitless.Forthevastmajorityofourhistorygearshavebeenunderstoodonlyfunctionally.Thatistosay,thewaytheytransmitpowerandthesizetheyneedtobetotransmitthatpower havebeenwell knownformanyyears.It was notuntilrecentlythathumansbegantousemathematicsandengineeringtomoreaccuratelyandsafelydesignthesegears.Bevelgearsarewidelyusedbecauseoftheirsuitabilitytowardstransferringpowerbetweennonparallelshaftsatalmostanyangleorspeed.TheAmericanGearManufacturingAssociation(AGMA)hasdevelopedstandardsforthedesign,analysis,andmanufactureofbevelgears.Thebendingstressequationforbevelgearteethisobtainedfromthe Lewisbendingstressequationforabeamandbendingstress valuederive forthespiralbevelgear,straightteethbevelgearandzerolbevelgear.Forabovementionedgearcomparisonbetweenanalyticalvalue andvalueobtainbytheANSYSWorkbench15.0.**

Keywords:CATIA,ANYSYS,BevelGear,GearNomenclature,deformation,von missesstressetc..

I INTRODUCTION

Powertransmissionisthemovementofenergyfromitsplaceofgenerationtoalocationwhereitisappliedtoperforminguseful work.Powertransmissionisnormallyaccomplishedbybelts,ropes, chains,gears,couplingsandfrictionclutches.

1.1 GEAR

Atoothedwheelthatengagesanothertoothedmechanismi nordertochangethespeedordirectionoftransmittedmotion.

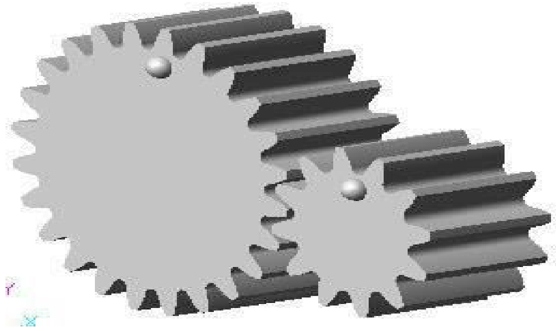


Fig1.1:Gear

Agearisacomponentwithinatransmissiondevicethattransmitsrotationalforcetoanothergearordevice.Agearisdifferentfromapulleyinthatagearisaroundwheelwhichhaslinkages("teeth"or"cogs")thatmeshwithothergearteeth,allowingforcetobefullytransferredwithoutslippage.Depending on their construction andarrangement, geared devices cantransmitforces atdifferentspeeds,torques,or inadifferentdirection,fromthepowersource.Themostcommonsituationisforageartomeshwithanothergear Gear'smostimportant feature isthatgearsofunequalsizes(diameters)canbecombinedtoproduce amechanicaladvantage,sothattherotationalspeedandtorqueofthesecondgeararedifferentfromthatofthefirst.Toovercometheproblemofslippageasinbeltdrives,gearsareusedwhichproducepositivedrivewithuniformangularvelocity.

1.2 GEARCLASSIFICATION

Gearsortoothedwheelsmaybeclassifiedasfollows:

1. Accordingtothepositionof axesoftheshafts.

Theaxesofthetwoshaftsbetweenwhichthemotionistobetransmitted,maybe

a. Parallel
b. Intersecting
c. Non-intersectingandNon-parallel

1.3 Generalnomenclature

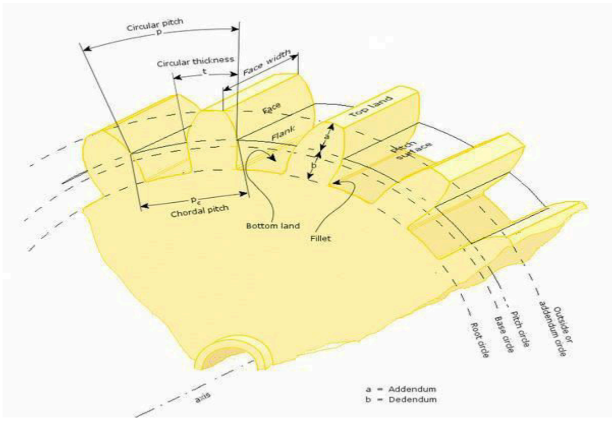


Fig1.2:GearNomenclatureRotationalf

requency,n
Measuredinrotationovertime,suchasRPM.

Angularfrequency,ω
Measuredinradianspersecond

$$1\,\mathrm{RPM} = \pi/30 \text{ rad/second}$$

Numberofteeth,N
Howmanyteethagearhas,aninteger.Inthecaseofworms,itisthe numberofthreadstartsthatthe wormhas.

Gear,wheel
Thelargeroftwointeractinggearsoragearonitsown.

Pinion
Thesmalleroftwointeractinggears.

Pathofcontact
Pathfollowedbythepointofcontactbetweentwomeshinggearteeth.

Lineofaction,pressureline

Linealongwhichtheforcebetweentwomeshinggearteeth isdirected.Ithasthesamedirectionastheforcevector.Ingeneral,thelineofactionchangesfrommomenttomomentduringtheperiodofengagementofapairofteeth.Forinvolutegears,however, the tooth-to-tooth forceisalwaysdirectedalongthesameline—thatis,thelineofactionisconstant.Thisimpliesthatforinvolutegearsthepathofcontactisalsoastraightline,coincidentwiththelineofaction—asisindeedthecase.

Axis

Axisofrevolutionofthegear;centerlineoftheshaft.

Pitchpoint,p

Pointwherethelineofactioncrossesalinejoiningthetwogearaxes.

Pitchcircle,pitchline

Circlecenteredonandperpendiculartotheaxis,andpassingthrough thepitchpoint.Apredefined diametricpositiononthegearwherethecirculartooththickness,pressureangleandhelixanglesaredefined.

Pitchdiameter,d

A predefineddiametralpositiononthegearwherethecirculartooththickness,pressureangleandhelixanglesaredefined.Thestandardpitchdiameterisabasicdimensionandcannotbemeasured,butisalocationwhereothermeasurementsaremade.Itsvalueisbasedonthenumberofteeth,thenormalmodule(ornormaldiametralpitch),andthehelixangle.Itiscalculatedas:

$$d = \frac{N m_n}{\cos\psi}$$ inmetricunitsor

$$d = \frac{N}{P_d \cos\psi}$$ inimperialunits.

Module,m

Ascalingfactorusedinmetricgearswithunitsinmillimeterswhoseeffectistoenlargethegeartoothsizeasthemoduleincreases and reducethesizeasthe moduledecreases.Modulecanbedefinedinthenormal(m_n),thetransverse(m_t),ortheaxialplanes(m_a)dependingonthedesignapproachemployedandthetypeofgearbeingdesigned.Moduleistypicallyaninputvalueintothegeardesignandisseldomcalculated.

Operatingpitchdiameters

Diametersdeterminedfromthe numberofteethandthe centerdistanceatwhichgearsoperate.Exampleforpinion:

$$d_w = \frac{2a}{u+1} = \frac{2a}{\frac{z_2}{z_1}+1}.$$

Pitchsurface

Incylindricalgears,cylinderformedbyprojectingapitchcircleintheaxialdirection.Moregenerally,thesurfaceformedbythesumofallthepitchcirclesasonemovesalongtheaxis.Forbevelgears itisacone.

Angleofaction

Anglewithvertexatthegearcenter,onelegonthepointwherematingteethfirstmakecontact,theotherlegonthepointwheretheydisengage.

Arcofaction

Segmentofapitchcirclesubtendedbytheangleofaction.

Pressureangle, θ

Thecomplementoftheanglebetweenthedirectionthattheteeth exertforceon each other,andthelinejoining thecentersofthetwogears.Forinvolutegears,theteethalwaysexertforcealongthelineofaction,which,forinvolutegears,isastraightline;and thus, for involute gears, the pressureangleisconstant.

Outsidediameter, D_o

Diameterofthegear, measuredfromthetopsoftheteeth.

Rootdiameter

Diameterofthegear, measuredatthebaseofthetooth.

Addendum,a

Radialdistancefromthepitchsurfacetotheoutermostpointofthetooth.$a = (D_o - D)/2$

Dedendum,b

Radialdistancefromthedepthofthetoothtroughtothepitchsurface.

$$b = (D - \text{root diameter})/2$$

Wholedepth, h_t

The distancefromthe top of the tooth to the root;itisequaltoaddendumplusdedendumortoworkingdepthplus clearance.

Clearance

Distancebetweentherootcircleofagearandtheaddendumcircleofitsmate.

Workingdepth

Depthofengagementoftwogears,thatis,thesumoftheiroperatingaddendums.

Circularpitch,p

Distancefrom onefaceofatoothtothecorrespondingfaceofanadjacenttoothonthesamegear,measuredalongthepitchcircle.

Diametralpitch, p_d

Ratioofthenumberofteethtothepitchdiameter.Couldbemeasuredinteethperinchorteethpercentimeter.

Basecircle

Ininvolutegears,wherethetoothprofileistheinvoluteofthebasecircle.Theradiusofthebasecircleissomewhatsmallerthanthatofthepitchcircle.

Basepitch,normalpitch, p_b

Ininvolutegears,distancefromonefaceofatoothtothecorrespondingfaceofanadjacenttoothonthesamegear,measuredalongthebasecircle.

Interference

Contactbetweenteethotherthanattheintendedpartsoftheirsurfaces.

Interchangeableset

Asetofgears,anyofwhichwillmateproperlywithanyother.

HelicalgearnomenclatureHelix angle, ψ
Anglebetweenatangenttothehelixandthegearaxis.Itiszerointhe limitingcase ofaspur gear, albeititcanconsideredasthehypotenuseangleaswell.

Normalcircularpitch, p_n
Circularpitchintheplane normaltotheteeth.

Transversecircularpitch,p
Circularpitchintheplaneofrotationofthegear.Sometimesjustcalled"circularpitch"

$$p_n = p\cos(\psi)$$

Severalotherhelixparameterscanbeviewedeitherinthenormalortransverseplanes.Thesubscriptnusuallyindicatesthenormal.

1.4 Typesofgears

1. SpurGear
2. HelicalGear
3. HerringboneGear
4. BevelGear
5. WormGear
6. RackandPinion
7. InternalandExternalGear
8. FaceGear
9. Sprockets

IIBEVELGEAR

Bevelgearsare gearswheretheaxesofthetwoshaftsintersectandthetooth-bearingfacesofthegearsthemselvesareconicallyshaped.Bevelgearsaremostoftenmountedonshaftsthatare90degreesapart,butcanbedesignedtoworkatotheranglesaswell.[1]Thepitchsurfaceofbevelgearsisacone.Twoimportantconceptsingearingarepitchsurface andpitchangle. Thepitchsurface ofagearistheimaginarytoothlesssurfacethatyouwouldhavebyaveragingoutthepeaksandvalleysoftheindividualteeth.Thepitchsurfaceofanordinarygearistheshapeofacylinder.Thepitchangleofagearistheanglebetweenthefaceofthepitchsurfaceandtheaxis.

Themostfamiliarkindsofbevelgearshavepitchanglesoflessthan90degreesandthereforearecone-shaped.Thistypeofbevelgeariscalledexternalbecausethegearteethpointoutward.Thepitchsurfacesofmeshedexternalbevelgearsarecoaxialwiththegearshafts;theapexes of thetwosurfacesareatthepointofintersectionoftheshaftaxes.Bevelgearsthathavepitchanglesofgreaterthanninetydegreeshaveteeththatpointinwardandarecalledinternal bevelgears.Bevelgearsthathavepitchanglesofexactly90degreeshaveteeththatpointoutwardparallelwiththeaxisandresemblethepointsonacrown.That'swhythistypeofbevelgeariscalledacrown gear.Mitergearsarematingbevelgearswithequalnumbersofteethand withaxesatrightangles.
Skewbevelgearsare thoseforwhichthe correspondingcrowngearhasteeththatarestraightand oblique.

2.1 TypesofBevelgears

Bevel gearsare classified indifferent types according togeometry:

- Straightbevelgearshaveconicalpitchsurfaceandteetharestraightandtaperingtowardsapex.
- Spiral bevel gears havecurved teeth at anangleallowingtoothcontacttobegradualandsmooth.
- Zerolbevelgears areverysimilartoabevelgearonlyexceptionistheteethare curved:theendsofeachtootharecoplanarwiththeaxis,but themiddleofeachtoothissweptcircumferentiallyaroundthegear.Zerolbevelgearscanbethoughtofasspiralbevelgears,whichalsohavecurvedteeth,butwithaspiralangleof zero,sotheendsoftheteethalignwiththeaxis.
- Hypoidbevelgearsaresimilartospiralbevelbutthepitchsurfacesarehyperbolicandnotconical.Pinioncanbeoffset above,orbelow,thegearcentre,thusallowinglargerpiniondiameter,andlongerlifeandsmoothermesh,withadditionalratiose.g.,6:1,8:1,10:1.Inalimiting caseofmaking the"bevel"surfaceparallelwiththeaxisofrotation,thisconfigurationresemblesawormdrive.Hypoidgearswerewidelyusedinautomobilerearaxles.

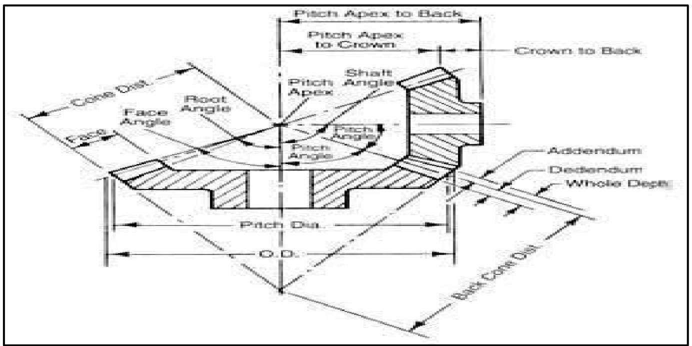
2.2 GeometryofaBevelGear

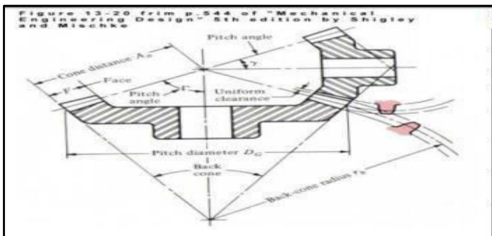
Thecylindricalgeartoothprofilecorrespondstoaninvolute,whereasthebevelgeartoothprofileisanoctoid.Alltraditionalbevelgeargenerators(suchasGleason,Klingelnberg,Heidenreich&Harbeck,WMWModul)manufacturebevelgearswithanoctoidaltoothprofile.IMPORTANT:For5-axismilledbevelgearsetsitisimportanttochoosethesamecalculation/layoutliketheconventionalmanufacturingmethod.Simplifiedcalculatedbevelgearsonthebasisofanequivalentcylindricalgearin normalsectionwithaninvolutetoothformshowadevianttoothform withreducedtoothstrengthby10-28%withoutoffsetand45%withoffset[Diss.Hünecke, TUDresden].Furthermorethose"involutebevelgearsets"causesmorenoise.

ListofDrawingSymbols

- **Np**-Numberofteethonpinion
- **Ng**-Numberofteethongivengear
- **Dg**-Pitchdiameterofgivengear
- **Dp**-Pitchdiameterofgivenpinion
- **F**-Face width(lengthofsingletooth)
- **γ**-Pinionpitchangle(radians)
- **Γ**-Gearpitchangle(radians)
- **Ao**- Conedistance (distance from pitch circle tointersectionofshaftaxes)
- **rb**-Back-coneradius
- **P**-Diametricalpitch(teethper inchofpitchdiameter(N/D))
- **p**-Circularpitch(inchesofcircumferencepertooth (Π/P))

Thetoothshapeforbevelgearsisdeterminedbyscalingspurgeartoothshapesalongthefacewidth.Thefurtherfromtheintersectionofthegearandpinionaxes,thebiggerthetoothcross sections are.Ifthetoothfacewere to extend allthewaytotheaxesintersection,theteethwouldapproachinfinitesimalsizethere.Thetoothcross-sectionatthelargestpartofthetoothisidenticaltothetoothcross-sectionofatoothfromaspurgearwithPitchDiameterof2*rb,ortwicetheBack-ConeRadius,andwithanimaginarynumber ofteeth(N')equalto2πtimesthe Back-Cone Radius(rb) dividedbytheCircularPitchofthebevelgear(p).Thismethodofobtainingthedimensions andshape ofthe largest toothprofileisknownasthe"Tredgold"tooth-shapeapproximation.RefertotheprofilesshownneartheBack-coneradiusdimensioninthedrawingabove





Drawings
List of symbols

N_P	Number of teeth on Pinion
N_G	Number of teeth on Gear
D_G	Pitch Diameter of Gear
D_P	Pitch Diameter of Pinion
F	Face Width (Length of one tooth)
γ	Pinion Pitch Angle (Radians)
Γ	Gear Pitch Angle (Radians)
A_o	Cone Distance (Distance from pitch circle to intersection of shaft axes)
r_b	Back-Cone Radius
P	Diametrical Pitch. Teeth per inch of Pitch Diameter (N/D)
p	Circular Pitch. Inches of circumference per tooth (П/P)

Toothshapeforbevelgearsisdeterminedbyscalingspurgeartoothshapesalongthefacewidth.Thefurtherfromtheintersectionofthegearandpinionaxes,thebiggerthetoothcross sections are.Ifthetoothfacewere to extend allthewaytotheaxesintersection,theteethwouldapproachinfinitesimalsizethere.Thetoothcross-sectionatthelargestpartofthetoothisidenticaltothetoothcross-sectionofatoothfromaspurgearwithPitchDiameterof2*rb,ortwicetheBack-ConeRadius,andwithanimaginarynumber ofteeth(N') equalto2*ПtimestheBack-ConeRadius(rb) divided bytheCircularPitchofthebevelgear(p).Thismethodofobtainingthedimensions andshape ofthe largest toothprofileisknownatthe"Tredgold"tooth-shapeapproximation.RefertotheprofilesshownneartheBack-coneradiusdimensioninthedrawingabove.

2.3 ManufacturingBevelGear

Materialsusedingearmanufacturingprocess
Thevariousmaterialsusedforgearsincludeawidevarietyofcastirons,nonferrousmaterialandnon–metallicmaterials.Theselectionofthegearmaterialdependsupon:

- Typeofservice
- Peripheralspeed
- Degreeofaccuracyrequired
- Methodofmanufacture
- Requireddimensionsandweightofthedrive
- Allowablestress
- Shockresistance
- Wearresistance.Some

materialschoseninclude:

- Castiron,whichispopularduetoitsgoodwearingproperties,excellentmachinabilityandeaseofproducingcomplicatedshapesbythecasting method.Itissuitablewherelargegearsofcomplicatedshapesareneeded.
- Steel,whichissufficientlystrong&highlyresistanttowearbyabrasion.
- Caststeel,whichisusedwherestressonthegearishighanditisdifficulttofabricatethegears.
- Plaincarbonsteels,whichfindapplication forindustrialgearswherehightoughnesscombinedwithhighstrength.
- Alloysteels,whichareusedwherehightoothstrengthandlowtoothweararerequired.
- Aluminum,whichisusedwherelowinertiaofrotatingmassisdesired.
- Gearsmadeofnon–metallicmaterialsgivenoiselessoperationathighperipheralspeeds.

2.4 Applications

The bevelgearhasmany diverseapplicationssuch aslocomotives,marineapplications,automobiles,printingpresses,coolingtowers,powerplants,steelplants,railwaytrackinspection machines,etc.
Forexamples,seethefollowingarticleson:

- Bevelgearsareusedindifferentialdrives,whichcantransmitpowertotwoaxlesspinningatdifferentspeeds,suchasthoseonacorneringautomobile.
- Bevel gearsare usedasthemainmechanismforahanddrill.Asthehandleofthedrillisturnedinaverticaldirection,thebevelgearschangetherotationofthechucktoahorizontalrotation.Thebevelgearsina handdrillhave theaddedadvantageofincreasingthespeedofrotationofthechuckandthismakesitpossibletodrillarangeofmaterials.
- Thegearsinabevelgearplanerpermitminoradjustmentduringassemblyandallowforsomedisplacementduetodeflectionunderoperatingloadswithoutconcentratingtheloadontheendofthetooth.
- Spiral bevel gearsare important componentsonrotorcraftdrivesystems.These components are

required tooperateathighspeeds, highloads,and foralargenumberofloadcycles.Inthisapplication,spiralbevelgearsareusedtoredirecttheshaftfromthehorizontalgasturbineenginetotheverticalrotor.

2.5 Advantages

- Thisgearmakesitpossibletochangetheoperatingangle.
- Differingofthenumberofteeth(effectivelydiameter)oneach wheelallowsmechanicaladvantagetobechanged.Byincreasingordecreasingthe ratioofteethbetweenthedrive and driven wheelsonemaychangetheratioofrotationsbetweenthetwo,meaningthattherotationaldriveandtorqueofthesecondwheelcanbechangedinrelationtothefirst,withspeedincreasingandtorquedecreasing,orspeeddecreasingandtorqueincreasing.

2.6 Disadvantages

- Onewheelofsuchgearisdesignedtoworkwithitscomplementarywheelandnoother.
- Mustbepreciselymounted.
- The shafts'bearingsmust be capable ofsupportingsignificantforces.

IIIMETHODS

3.1 CAD/CAM/CAE

TheModernworldofdesign,development,manufacturingsoon,inwhichwehavesteppedcan'tbeimaginedwithoutinterferenceofcomputer.Theusageofcomputerissuchthat,theyhavebecomeanintegralpartofthesefields.Intheworldmarketnowthecompetitioninnotonlycostfactorbutalsoquality,consistency,availability,packing,stocking,deliveryetc.SoaretherequirementsforcingindustriestoadoptmoderntechniqueratherthanlocalforcingtheindustriestoadaptbettertechniqueslikeCAD/CAM/CAE,etc.

ThePossiblebasicwaytoindustriesistohavehighqualityproductsatlowcostsisbyusingthecomputerAidedEngineering(CAE),ComputerAidedDesign(CAD)AndComputerAidedManufacturing(CAM)setup.Furthermanytoolsisbeenintroducedtosimplify&servetherequirementCATIA,PRO-E,UGaresomeamongmany.

This penetration of technique concernhas helpedthemanufacturerstoIncreaseproductivityShorteningthelead-timeMinimizingtheprototypingexpensesImprovingQualityDesigning better products andComputerAided Designing(Technology to create, Modify,Analyzeor Optimize thedesignusingcomputer.

CAE: ComputerAidedEngineering(Technologytoanalyze,SimulateorStudybehaviorofthecadmodelgeneratedusingcomputer.

CAM: ComputerAidedManufacturing(TechnologytoPlan,manageorcontroltheoperationinmanufacturingusingcomputer.

3.1.1 NeedforCAD,CAE&CAM

TheusageofCADCAE&CAMhavechangedtheoverlookoftheindustriesanddevelopedhealthy&standardcompetition,ascouldachievetargetinleantimeandultimatelytheproductreachesmarketinestimatedtimewithbetterqualityandconsistency.Ingeneralview,ithasleadtofastapproachandcreativethinking.

3.2 CATIA

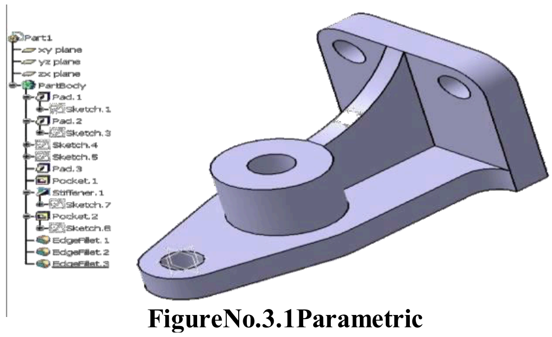
CATIAisarobustapplicationthatenablesyoutocreaterichandcomplexdesigns.ThegoalsoftheCATIAcoursearetoteachyouhowtobuildpartsandassembliesinCATIA,andhow-tomakesimpledrawingsof thosepartsandassemblies.Thiscoursefocusesonthefundamentalskillsandconceptsthatenableyoutocreateasolidfoundationforyour designs.

WhatisCATIA

CATIAismechanicaldesignsoftware.It is afeature-based,parametricsolidmodelingdesigntoolthattakesadvantageof theeasy-to-learnWindowsgraphicaluserinterface.Youcancreatefullyassociative3-Dsolidmodelswithorwithoutconstraintswhileutilizingautomatic oruser-definedrelationstocapturedesignintent.Tofurtherclarifythisdefinition,theitalictermsabove willbefurtherdefined.

Feature-based

Likeanassemblyismadeupofanumberofindividualparts, aCATIAdocumentismadeupofindividualelements.Theseelementsarecalledfeatures.Whencreatingadocument,youcanaddfeaturessuchaspads,pockets,holes,ribs,fillets,chamfers,anddrafts.Asthefeaturesarecreated,theyareapplieddirectlytotheworkpiece.Featurescanbeclassifiedassketched-basedordress-up:Sketched-basedfeaturesarebasedona2Dsketch.Generally,thesketchistransformedintoa3Dsolidbyextruding,rotating,sweeping,orlofting.Dress-upfeaturesarefeaturesthatarecreateddirectlyonthesolidmodel.Filletsandchamfersareexamplesofthistypeoffeature.



FigureNo.3.1Parametric

The dimensions andrelationsusedtocreatea featurearestoredinthemodel.Thisenablesyoutocapturedesignintent, andtoeasilymakechangestothemodelthroughtheseparameters.

• Drivingdimensionsare thedimensionsusedwhencreatingafeature.Theyincludethedimensionsassociatedwiththesketchgeometry,aswellasthoseassociatedwiththefeatureitself.Consider,forexample,acylindricalpad.Thediameterofthepadiscontrolledbythediameterofthesketchedcircle,andtheheightofthepadiscontrolledbythedepthtowhichthecircleisextruded. Thistypeofinformationistypicallycommunicatedondrawingsusingfeaturecontrolsymbols.Bycapturing thisinformationinthe sketch, CATIAenablesyouto fully captureyourdesignintentupfront.

SolidModeling

Asolidmodelis themost complete type of geometricmodelusedinCADsystems.Itcontainsallthewireframeandsurfacegeometrynecessarytofullydescribetheedgesandfacesofthemodel.Inadditiontogeometricinformation,solidmodelsalsoconveytheir―topology‖,whichrelatesthegeometrytogether.Forexample,topologymightincludeidentifyingwhichfaces(surfaces)meetatwhichedges(curves).Thisintelligencemakesaddingfeatures easier.Forexample, ifamodelrequires afillet,yousimplyselectanedgeandspecifyaradiustocreateit.

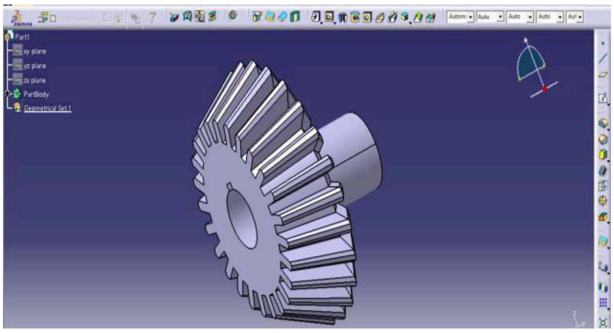
FullyAssociative

ACATIAmodelisfullyassociativewiththedrawingsandpartsorassembliesthatreferenceit.Changestothemodelareautomaticallyreflectedintheassociateddrawings,parts,and/orassemblies.Likewise,changesinthecontextofthedrawingorassemblyarereflectedbackinthemodel.

Constraints

Geometricconstraints(suchasparallel,perpendicular,horizontal, vertical,concentric,andcoincident)establishrelationshipsbetweenfeaturesinyourmodelbyfixingtheirpositionswithrespecttooneanother.Inaddition,equationscanbeusedtoestablishmathematicalrelationshipsbetweenparameters.Byusingconstraintsandequations,youcanguaranteethatdesignconceptssuchasthroughholesandequalradiiarecapturedandmaintained.

3.3 COMPLETEDESIGNOFABEVELGEAR



3.4 DESIGNMODELER

3.4.1 AnsysDesignmodelerGUINavigation

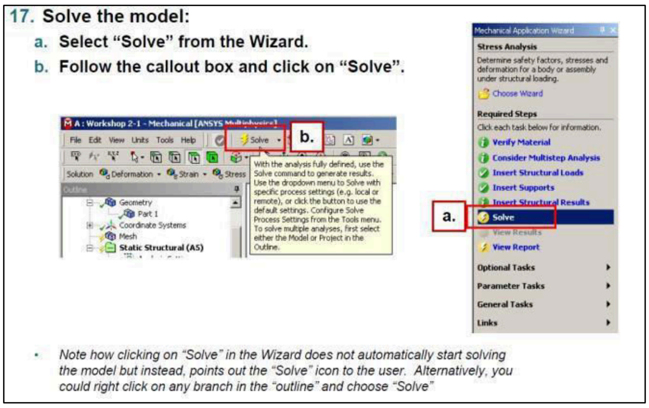


Fig3.2AnsysMechanical–Solution

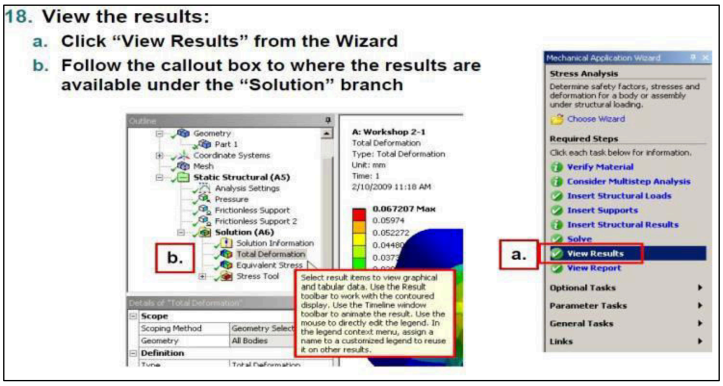


Fig3.3AnsysMechanical–Results

3.5 Objectiveofthepresentwork

Theobjectivesoftheprojectareasfollows

- Todevelopstructuralmodelingofbevel gear rodusingCATIA.
- ToperformfiniteelementanalysisofbevelgearbyusingAnsys15forstructuralsteelmaterial
- InvestigatethemaximumstressofbevelgearusingANSYS15software
- Resultsdescription interms of factorof safety,stiffens,deformationandstress.

VRESULTS

5.1ANALYSIS&RESULTSOFTHEBEVELGEAR

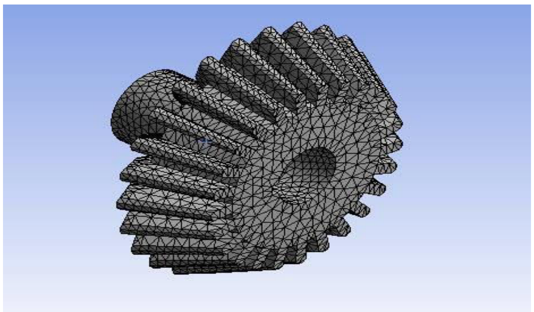


Fig5.1MeshingofBevelgearinTetrahedral

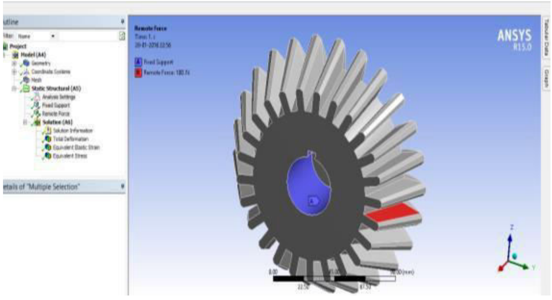


Fig5.2LoadsandBoundaryConditions

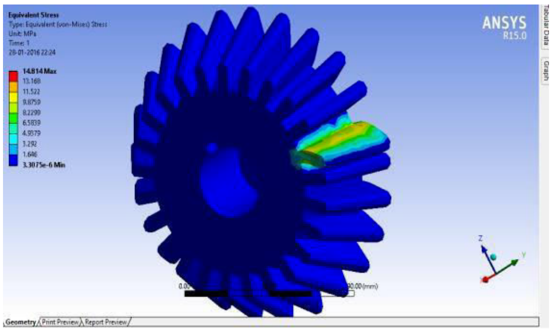


Fig5.3EquivalentStress

VICONCLUSION&SCOPEOFPROJECT

ThecompletedesignofabevelgearinCATIAV5usingfeaturesofthesoftwareandanalysedongearssuchasstaticstructural analysisorworkedinAnsys15.0andcompleteanalysisresultsareobtainedsuchasvonmisesstress,Totaldeformationareobtained.Thesstressresultsareobservedarewithintheallowablelimitofmaterialyieldstrengthsothedesignisinsafecondition.Beforeperformingthetopologyoptimization,thestructuralmodelingofthebevelgearneedstobedevelopedbyusingCATIAsoftware.Thestructuralmodelingthenimportedintothecomputer-aidedengineering(CAE)andbeganthemeshingonthebevelgear.Thefiniteelementmodeling(FEM)processeswereperformedbyusingAnsys14.5.Theboundarycondition(BC)andloadingselectedandplaceatthebevelgear.Thefiniteelementanalysis(FEA)thencarriedoutatthebevelgear.TheAnsys15usedtosolvetheanalysisequationthus,producingtheresultofstress,strainanddisplacementwhereitwillbeusedtoanalyzethecriticalareaofthebevelgear.FinallyResultsdescriptionintermsoffactorofsafety,stiffens,deformationandstress

REFERENCES

1. *Howstuffworks"TransmissionBasics"2*
. *Norton2004,p.462*
3. *Lewis,M.J.T.(1993)."GearingintheAncientWorld".Endeavour**17**(3):110–1110].doi:10.1016/0160-9327(93)90099-O.*
4. 0 *^"TheAntikytheraMechanismResearchProject:Whyisitsoimportant?",Retrieved2011-01-10Quote:"TheMechanismisthoughttodatefrombetween150and100BC"*
5. *^abcdANSI/AGMA1012-G05,"GearNomenclature,DefinitionofTermswithSymbols".*
6. *Khurmi,R.S,TheoryofMachines,S.CHAND*
7. *Schunck,Richard,"Minimizinggearboxnoiseinsideandoutsidethebox.",MotionSystemDesign.*
8. *DoughtieandVallancegivethefollowinginformationonhelicalgearspeeds:"Pitch-linespeedsof4,000to7,000fpm[20to36m/s]arecommonwithautomobileandturbinegears,andspeedsof12,000fpm[61m/s]havebeensuccessfullyused."–p.281.*

Static analysis of airfoil

C. Shashikanth, Dr.Sivasankara Gowda, A. Lakshmi Jyothi, Dr.V.V.Prathibha Bharathi
Department ofMechanicalEngineering MallareddycollegeofEngineeringSecunderbad

***Abstract*—**Inthisproject, theAirfoil isconsideredandFiniteElementAnalysis(FEM)isdonetoanalyse itsperformanceandbasedonit,willbetrytoincreasetheefficiency. TheFEMprincipleswhicharemadeuseinthisprojectareeffectiveandappropriatemethodsthat usingfiniteelementmethodstosolvetheprocessesthatconsistoftransportphenomena.TheAirfoilmodeledandmeshedinANSYS.In ordertoavoidthedatalossthenecessarynumericalcomputationsareaccomplishedbyANSYS(theelementsolverprogram)andtheresultsaregivenintabularrepresentation. Thisanalysis is done foranexistingAIRFOILwiththespecifiedconditionsandfinallythedeformations,stressesvonmisesstreses and the respectivedeformations ,stressesovertheAirfoilisplottedandconclusionarepresented.

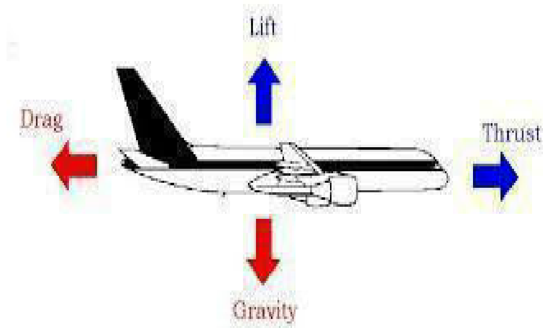
Keywords—Fem,Vonmisesstreses,Airfoil

I INTRODUCTION

In theearliestdays,whenmanwasyetlivingin thelapofnature,theonlymeansoflocomotionwashislegs.Gradually,wehave achievedfasterandmore luxuriouswaysoftravelling,latestbeingtheairtransport.Since,itsinventionaeroplaneshavebeengettingmoreandmorepopularityasitisthefastestmodeoftransportationavailable.Ithasalsogainedpopularityasawarmachine sinceworldwar II. Thispopularityofairtransporthasledtomanynewinventionsandresearchtodevelop fasterandmoreeconomical planes.Thisprojectissuchanattempttodeterminehowwecanderivemaximumperformanceoutof an airfoilsection.

Anairfoilisacross-sectionofwingoftheplane.It'smainjobistoprovidelifttoan aeroplaneduringtakeoffandwhileinflight.But,ithasalsoasideeffectcalledDragwhichopposesthemotionoftheaeroplane.Theamountoflift neededbyaplanedependsonthepurposefor whichitistobeused.Heavierplanes requiremoreliftwhilelighterplanesrequirelessliftthan the heavier ones.Thus,depending upontheuseofaeroplane,airfoilsectionisdetermined.Liftforcealsodeterminestheverticalaccelerationoftheplane, whichinturnsdependsonthehorizontalvelocityoftheplane.Thus,determiningthecoefficientofliftonecancalculatetheliftforceandknowingtheliftforceandrequiredverticalaccelerationonecandeterminetherequiredhorizontalvelocity.

Anairfoil(inAmericanEnglish)oraerofoil(inBritish English)isthestateofawingoredgeorcruiseasseenincross-area.Anairfoil-formedbodytraveledthroughafluidhandlesanaerodynamicenergy.Thesegmentofthispowerperpendiculartothecourseofmovementiscalledlift.Thesegmentparalleltothebearingofmovementiscalleddrag.Subsonicflightairfoilshaveatrademarkshapewithanadjustedheadingedge,emulatedby asharptrailingedge,regularlywithunevencamber.Foilsofcomparativecapacitycomposedwithwaterastheworkingfluidarecalledhydrofoils.Theliftonanairfoilisfundamentally theconsequenceofitsapproachand shape. At thepointwhenarrangedatasuitableedge,theairfoildivertstheapproachingair, bringingaboutan energyonthe airfoilintheheadinginversetothediversion.



SometermsrelatedtoAirfoilare:Leadingedge :- Itistheedgeoftheairfoilfacingthedirectionofmotionof plane.Itisgenerallyroundishinshapeanddeflectstheai rinsucha waythathe velocity

II Historyof AirfoilDevelopment

Theearliestseriousworkonthedevelopmentofairfoil sectionsbeganinthelate1800's.Althoughitwasknow nthatflatplateswouldproduceliftwhen setatan angle ofincidence,somesuspectedthatshapeswithcurvatur e,thatmorecloselyresembledbirdwingswouldprodu cemoreliftordosomoreefficiently.H.F.Phillipspaten tedaseriesofairfoilshapesin1884aftertestingthemin oneoftheearliestwindtunnelsinwhich"artificialcurr entsofair(were)producedfrominductionbyasteamje tinawoodentrunkorconduit."OctaveChanutewrites in 1893, "...itseemsverydesirablethatfurtherscientificexperi mentsbebemadeonconcavo-convexsurfacesofvaryingshapes,foritisnotimpossi blethatthedifferencebetweensuccessandfailureofap roposedflyingmachinewilldependuponthesustainin geffectbetweenaplanesurfaceandoneproperlycurve dtogetamaximumof'lift'."AtnearlythesametimeOtt oUpperSurface:

Theuppersurfacepressureis lower (plottedhigheronthe usualscale) thanthelowersurface Cpinthiscase.Butitdoesn'thave to be.

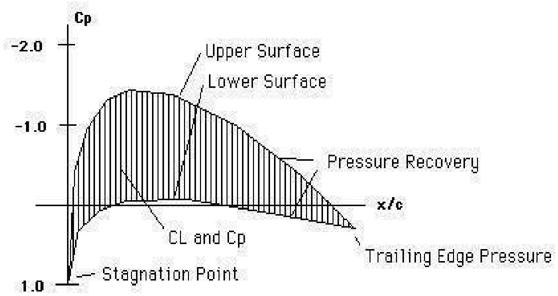
LowerSurface :

Lilienthalhadsimilarideas.Aftercarefullymeasuring theshapesofbirdwings,hetestedtheairfoilsbelow(re producedfromhis1894book,"BirdFlightastheBasis ofAviation")ona7mdiameter"whirlingmachine".Li lienthalbelievedthatthekeyto successfulflightwaswingcurvatureorcamber.Heals oexperimentedwithdifferent noseradiiandthicknessdistributions.

Airfoilsusedby theWrightBrotherscloselyresembledLilienthal'ssectio ns:thinandhighlycambered.Thiswasquitepossiblybec auseearlytestsofairfoilsectionsweredoneatextremelyl owReynoldsnumber,wheresuchsectionsbehavemuch betterthanthickerones.Theerroneousbeliefthatefficien tairfoilshadtobethinandhighlycamberedwasonereaso nthatsomeofthefirstairplaneswerebiplanes.Theuseof suchsectionsgraduallydiminishedoverthenextdeca de.

Awiderangeofairfoilsweredeveloped,basedpri marilyontrialanderror.Someofthemoresuccess fulsectionssuchastheClarkYandGottingen398 wereusedasthebasisforafamilyofsectionstested bytheNACA in the early1920's.

AirfoilPressureDistributions



The lowersurfacesometimescarriesapositive pressure, but at many design conditionsis actuallypullingthe wingdownward. In this case, some suction

III AIRFOILDESIGN METHODS

Theprocessofairfoildesignproceedsfromaknowledgeoftheboundarylayerpropertiesandtherelationbetweengeometryandpressuredistribution.Thegoalofanairfoildesignvaries.Someairfoilsaredesignedtoproducelowdrag(andmaynotberequiredtogenerateliftatall.)Somesectionsmayneedtoproducelowdragwhileproducingagivenamountoflift.Insomecases,thedragdoesn'treallymatter-itismaximumliftthatisimportant.Thesectionmayberequiredtoachievethisperformancewithaconstraintonthickness,orpitchingmoment,oroff-designperformance,orotherunusualconstraints.Someofthesearediscussedfurtherinthesectiononprevioussectionofhistoricalexamples. One approachtoairfoil designisto useanairfoilthatwasalreadydesignedbysomeonewhoknewwhatheorshewasdoing.This"designbyauthority"workswellwhenthegoalsofaparticulardesignproblemhappentocoincidewiththegoalsoftheoriginalairfoildesign.Thisisrarelythecase,althoughsometimesexistingairfoilsaregoodenough.

Thedesignofanairfoilusuallystartswiththedefinitionofthedesiredorrequiredcharacteristics.Thesecanbeacertainrangeofliftcoefficients,Reynolds-orMachnumbers,wheretheairfoilshouldperformbest,stallcharacteristics,momentcoefficient,thickness,lowdrag,highlift,cavitation(forhydrofoils),insensitivitywithregardtodustanddirt,easytobuild(flatbottom)oranycombinationof suchrequirements.Whentheserequirementshavebeen writtendown,thenextstepwouldbetolookaround,what's available.Ifthereisan airfoil

(negativeCp->downwardforceonlowersurface)ispresentneartthemid-chord.

available,whichperfectlyfitsthedesiredconditions,whycreateanewone?Oftenthereisnoexistingairfoil,whichfulfillsallrequirements,orthedesignerbelieves,thathecandesignsomethingnewwithimprovedperformance.Startingfromthispoint,eachdesignerhashisownwayandhispreferredtoolstoproceed.SomeliketouseaninversedesigncodeliketheEpplercode)toprescribeflowparameters andgettheresultinggeometry(airfoil) fromthe code. Otherslike to useastartingairfoilanduseanalysiscodes(orawindtunnel)tocontinueinatrialanderrorstyle(albeitwithalotofexperience)tofindabetterairfoilshape.Thissecondmethodisoftenusedincombinationwithanumericaloptimizationcode:acomputertrieshundredsoreventhousandsofdifferentairfoilshapemodificationsuntilitcannotfindfurtherimprovements.Adrawbackofthenumericaltrialanderroroptimizationprocessisthatitcantakealongtime,andthattheoptimizationprogramstendtomoveintoacornerofthe requirements:theresultingairfoilmightindeedhavealowdragandhighlift,butmaybeonlyinaverysmalloperatingrangeanditmayhavecatastrophicstall characteristics.It isverydifficult totell acomputer,whatthedesiredstallcharacteristicsshouldlooklike,orwhatyouexpect fromdifferentflapsettings.Currentlyagooddesignerisstillnecessarytogetgoodresults,buthecanusethecomputerandnumericaloptimizationasatooltoperformtimeconsumingpolishingworkortogethintsonpossibleimprovements.Theselectionofanairfoilforamodelaircraftdependsmainlyontheliftanddragcharacteristicsoftheairfoil.Ifnoexperimentaldataareavailable,theoreticalmethodscanbeusedtogetanapproximationofthesedata.Whereastheliftcanbecalculatedreasonablewellfromthefrictionlesspressure-respectivelyvelocitydistributionontheairfoilsurface,thefrictiondragcanbedeterminedbyananalysisoftheboundarylayerwithalesserdegree ofaccuracy.

Epplerdevelopedaveryfastandelegantdesignmethod,basedonconformalmapping,whichistheheartofhiscomputercode.Becauseanairfoilalsohastooperateoutsideofitsdesignpoint(s),afastintegralboundarylayermethodand(fortheanalysisofgivenairfoils)anaccuratethirdorderpanelmethod(parabolicvelocityvariation)wasadded.Furthermorethecodeofferspossibilitiestomodifythegeometry,tocalculatedragpolars,andvariousplottingoptions. Duetoitsearlyroots,thecomputercodehasbeendevelopedasabatchcode.Textualandgraphicaloutputisdirectedtofiles,whichmakesthe*FORTRAN77*codeeasilyportableandsystemindependent.Ontheotherhand,theinputfilesarequitecrypticandhardtohandleforbeginners.Theelaboratedescriptionoftheoryand codeevencontainsan(nowoutdated)versionoftheFORTRAN-IVprogram.

Thestrengthofthecodeisthe*design*partandthefastanalysispart,whichmakesitverywellsuitedforthedesigntask.Theresultsoftheintegralboundarylayermethodagreeastonishinglywellwithexperiments,iftheReynoldsnumbersareabove500'000.Thedesignmodulecanbeusedtodesignverysmoothairfoilsshapes,includingtheleadingedgeregion,whichisoftendifficultwithothercodes.Ontheotherhand,thedesignmethodisquiteabstractand difficult tohandlefor beginners.

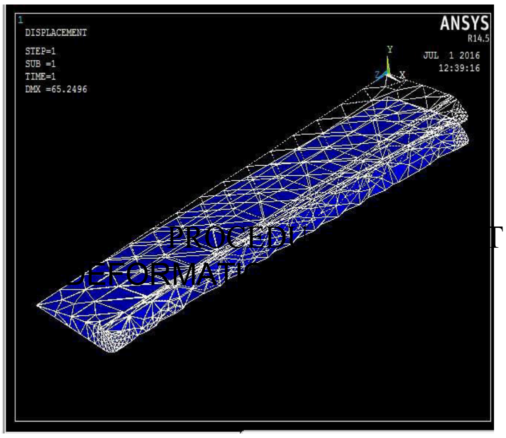
Theboundarylayeranalysisisperformedusingthecalculated,inviscid(withoutfriction)velocitydistributionsasinput;thereisnodirectcouplingbetweenboundarylayerflowandtheexternalflowfield.Transitionpredictionisperformedbytestingtheboundarylayerparametersagainstasetofempiricallyderivedtransitionrelations,whichworkquitewellforattachedflowinawide range ofReynoldsnumbers.

InthelowReynoldsnumberregimetheresultsareusuallynotveryaccurateifalaminarseparationbubbleorlargerseparatedflowregionsoccur.Thisisaresultoftheintegralboundarylayermethod,whichsimplycannotmodelseparation(thiswouldrequiresomesortofcouplingbetweenboundarylayeranalysisand thecalculation oftheexternalflow).Thecodehasaoptiontoperformadisplacementiterationinordertotakethedisplacementeffectsoftheboundarylayerintoaccount,

IV RESULTS

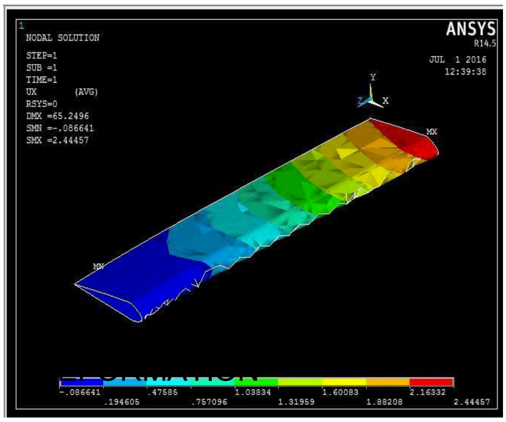
DEFORMEDSHAPE

STRESS
YCOMPONENT



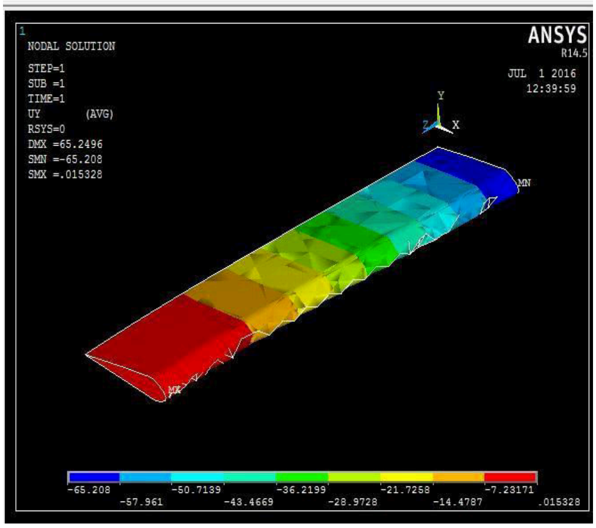
PROCEDU T RESULTS
EFORMATI

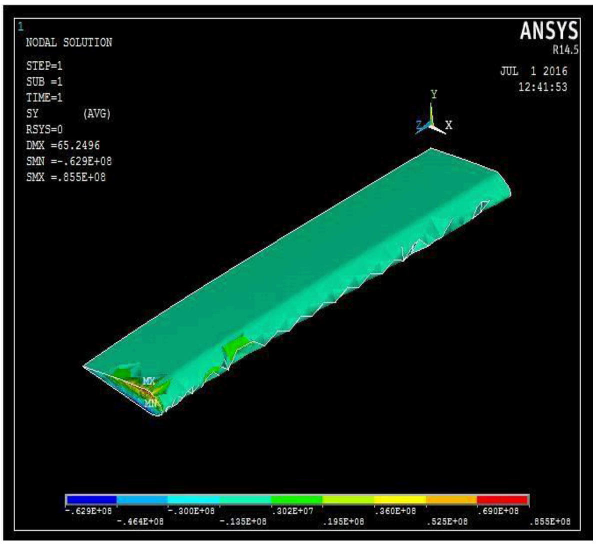
YCOMPONENT
PLOTRESULTS – CONTOUR PLOT



X COMPONENT
PLOTRULTS– CONTOUR PLOT

STRESS
X COMPONENT





V CONCLUSION

Aerodynamicsisanextensionofsciencewhichis concernedwith concentratingonthemovementofair,especiallywhenassociatingwithansolidobject,suchasanairfoil. GeneallyAerodynamics is asub-fieldoffluidprogressandgasmotion,andnumerouspartsofaerodynamicshypothesisareregulartothesefields.Inthisprojecttheairfoilismodeledwiththerespectivedimensionsanddonethestaticanalysis.Foundoutthedeformationsofthebodyandcontouredalongwith Vonmisesstresses in components and graphs w

.REFERENCE

[1] ElementReference– ANSYS12.0[2] HeattransferdatabookbyC. P. Kothandaraman

[3]Temperaturefieldanalysistogasolineenginepistonandstructureoptimization,HongyuanZhang,ZhaoxunLin,IianXing,37, Vol.48No.2,Journal of TheoreticalandAppliedInformationTechnology

[4]SimulationAndAnalysisOfThermo-MechanicalCouplingLoadAndMechanicalDynamicLoadForAPiston,YanxiaWang,YongqiLiu,HaiyanShi,SecondInternationalConferenceOnComputerModelingAndSimulation,2010,IEEE.

Finite Element Analysis of Aircraft Wing for Strength Enhancement

D. K. Nageswara Rao, I.Prasanna, g.Ramesh, Sivasankara Gowda
DepartmentofMechanicalEngineering,MRCE,JNTU Hyderabad.

ABSTRACT

Awingisatypeoffinwithasurfacethatproducesaerodynamic forceforflightorpropulsionthroughtheatmosphere,orthroughanothergaseousorliquidfluid.Assuch,wingshaveanairfoil shape,astreamlinedcross-sectionalshapeproducinglift.Awing'saerodynamicqualityisexpressedasitslift-to-dragratio.Theliftawinggeneratesatagivenspeedandangleofattackcanbeonetotwoordersofmagnitudegreaterthanthetotaldragonthewing.Ahighlift-to-dragratiorequiresasignificantlysmaller thrust topropelthewingsthroughtheairatsufficientlift.

I.INTRODUCTION

In the1960s,everlargeraircraftweredevelopedtocarrypassengers.Asenginetechnologyimproved,thejumbojetwasengineeredandbuilt.Stillprimarilyaluminumwithasemimonocoquefuselage,thesheersizeoftheairliners ofthedayinitiatedasearchforlighterandstrongermaterialsfromwhichtobuildthem.Theuseofhoneycombconstructedpanelsin Boeing'sairlineseriessavedweightwhilenotcompromisingstrength.Initially,aluminumcorewithaluminumorfiber glassskinsandwichpanels were used on wingpanels,flightcontrolsurfaces,cabinfloorboards,andotherapplications.Asteadyincreaseintheuseofhoneycombandfoamcoresandwichcomponentsandawidevarietyofcompositematerialscharacterizesthestateofaviationstructuresfromthe1970stothepresent.Advancedtechniquesandmaterialcombinationshaveresultedinagradualshiftfromaluminumtocarbonfiberandotherstrong,lightweightmaterials.Withsome airframesapproaching100percent.Theterm "verylight jet"(VLJ)has cometodescribeanewgenerationofjetaircraftmadealmostentirelyofadvancedcompositematerials

2.AIRFOILS

Anairfoilsshapeisdefinedbyseveralparameters,whichareshowninthefigurebelow.

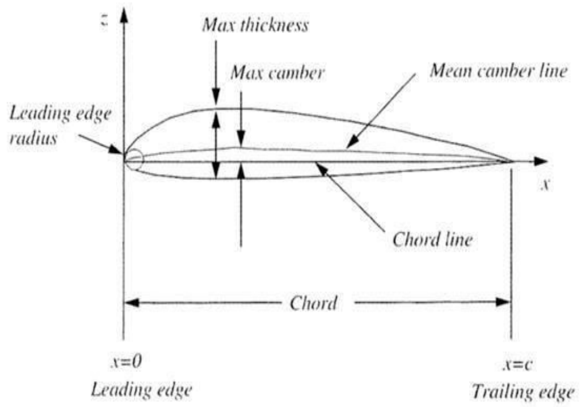


Fig2.1Airfoilshapeparameters

AirfoilDefinitions:

ChordLine: Straightlinedrawnfromtheleadingedgetothetrailingedge

ChordLength(c): Lengthofthechordline

MeanCamberLine: Curvedlinefromtheleadingedgetothetrailingedge,whichisequidistantbetweentheupperandlower surfacesoftheairfoil

Maximum(orJust)Camber: Maximumdistancebetweenthechordlineandthemeancamberline.

MaximumThickness: Maximumdistancebetweentheupperandlowersurfacesoftheairfoilnormaltothechordline.

Span: Widthoftheairfoil.

AngleofAttack: Anglebetweenthechordlineandthestreamwiseflowdirection.

ZeroLiftAngleofAttack: AngleofAttackthatwillproducenolift.Foroursymmetricwedgethiswouldbeanangleofattack ofzero.

StallAngleofAttack: Angleofattackatwhichthereismaximumlift(orliftcoefficient)

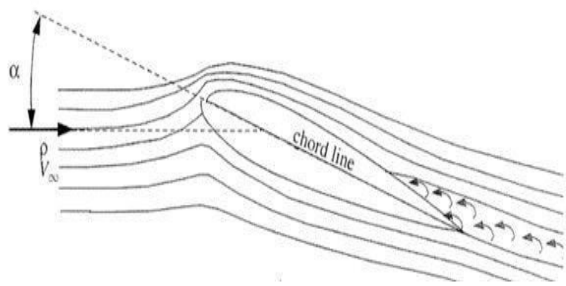


Fig2.2StallAngleofAttack

SymmetricorUncamberedAirfoil: Upperandlowersurfaces aremirrorimages,whichleads tothemeancamberlinetobecoincidentwiththechordline.Asymmetricairfoilwillalsohaveajustcamberofzero.

CamberedAirfoil: Anasymmetricairfoilforwhichthemean camberline willbeabovethechordline.

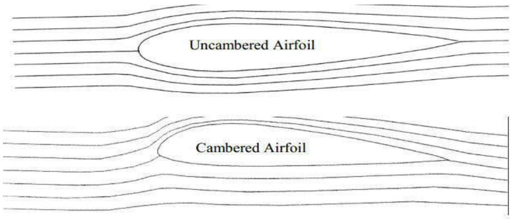


Fig2.3SymmetricorUncamberedAirfoilandCamberedAirfoil

PitchingMoment: Torqueormomentcreatedonthewingduetonetliftanddragforces.Tendstorotatetheleadingedgeeitherupordown.

PitchingMomentCoefficient:

$$c_m = \frac{m}{\frac{1}{2}\rho V^2 S c}$$

where
m:pitching moment(willdepend on themomentreferencecenter)
c:chordlength

Center ofPressure: Themomentreferencecenterforwhichthemomentis zero.Dependsontheangleofattack.

AerodynamicCenter:Themomentreferencecenterforwhich the momentdoesnotvarywithangleofattack.

3.DESIGN&ANALYSISOFAIRCRAFTWING

3.1 NACA63-209series

X1.	Y0.0	Z
00000	0000	0
0.95009	0.00512	0
0.90019	0.01067	0
0.85027	0.01663	0
0.80032	0.02267	0
0.75034	0.02861	0
0.70033	0.03430	0
0.65029	0.03958	0
0.60022	0.04429	0
0.55012	0.04834	0
0.50000	0.05159	0
0.44986	0.05391	0
0.39971	0.05518	0
0.34956	0.05530	0
0.29940	0.05414	0
0.24925	0.05169	0
0.19912	0.04792	0
0.14901	0.04263	0
0.09894	0.03539	0
0.07394	0.03077	0
0.04897	0.02510	0
0.02408	0.01765	0
0.01170	0.01255	0
0.00680	0.00973	0
0.00436	0.00796	0
0.00000	0.00000	0
0.00563	-0.00696	0
0.00820	-0.00833	0
0.01330	-0.01041	0
0.02592	-0.01393	0
0.05103	-0.01878	0
0.07606	-0.02229	0
0.10106	-0.02505	0
0.15099	-0.02917	0
0.20088	-0.03200	0
0.25075	-0.03379	0
0.30060	-0.03470	0
0.35044	-0.03470	0
0.40029	-0.03376	0
0.45014	-0.03201	0
0.50000	-0.02953	0
0.54988	-0.02644	0
0.59978	-0.02287	0
0.64971	-0.01898	0
0.69967	-0.01486	0
0.74966	-0.01071	0
0.79968	-0.00675	0
0.84973	-0.00317	0
0.89981	-0.00033	0
0.94991	0.00120	0
1.00000	0.00000	0

Lengthofthe wingis=5733.84mmThicknessofthe wing=7mmWidthofthesmallend=802.28mmWidthofthebigend=1264.84mm

3.2 MODELING

3.2.13DMODELSINPRO/ENGINEERORIGINALMODEL:

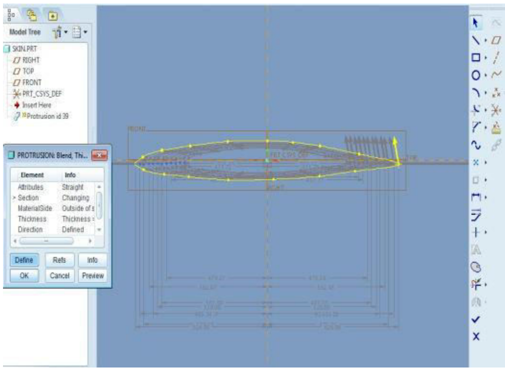


Fig3.1:OriginalmodelsketchORIGINAL MODAL (WITHOUT RIBS ANDSPARS)

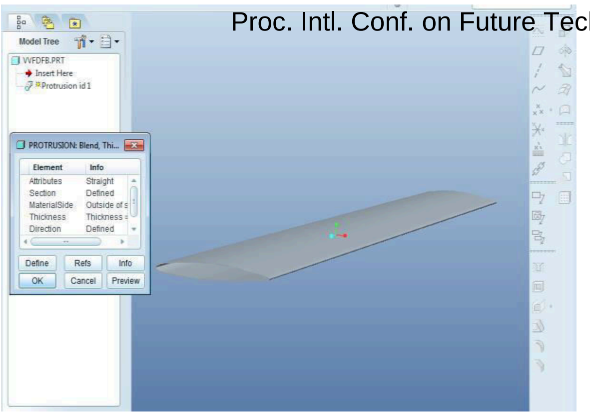


Fig3.2:OriginalmodelMODIFID MODEL(WITHRIBSANDSPARS)MATERIAL PROPERTIES

	S–GLASS	Aluminum7075-T651	Graphite/EpoxycompositeMaterial
DENSITY (Kg/m^3)	2490	1440	1820
YOUNG'S MODULUS (MPa)	89000	179000	241000
POISSON'S RATIO	0.19	0.36	0.3
STRENGTH(MPa)	4750	2733	3600

Table1:Materialproperties

3.3 ANALYSISOFAIRCRAFTWING

3.3.1 STATICANALYSISOFORIGINALMODEL

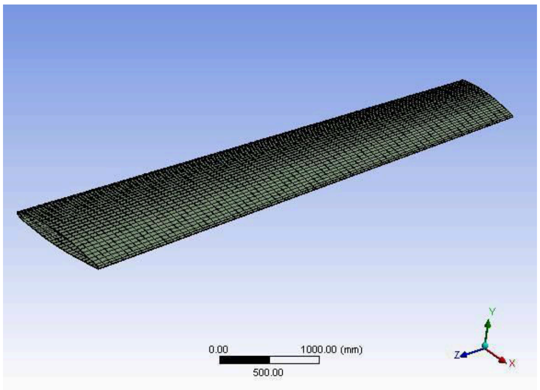


Fig3.3:Meshedmodel

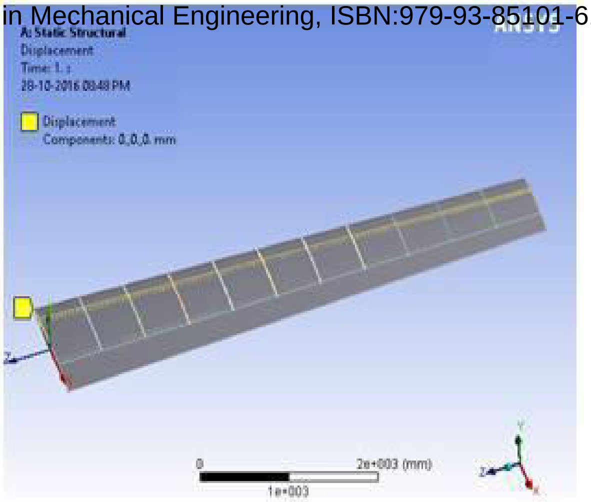


Fig3.4:Displacement

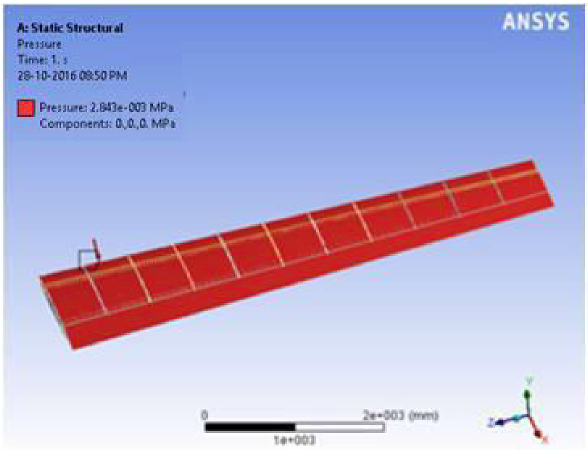


Fig3.5:PressureS GLASS

DEFORMATION:

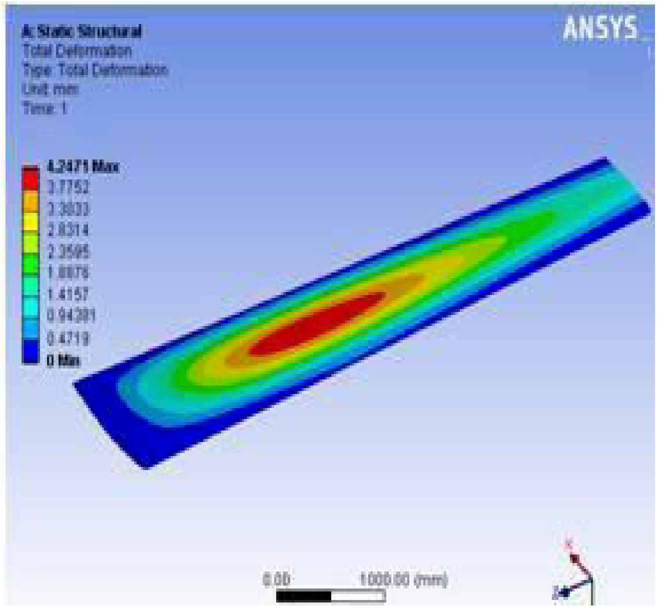


Fig3.6Deformation

From fig3.11whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformationvalueis4.2471mm

STRESS:

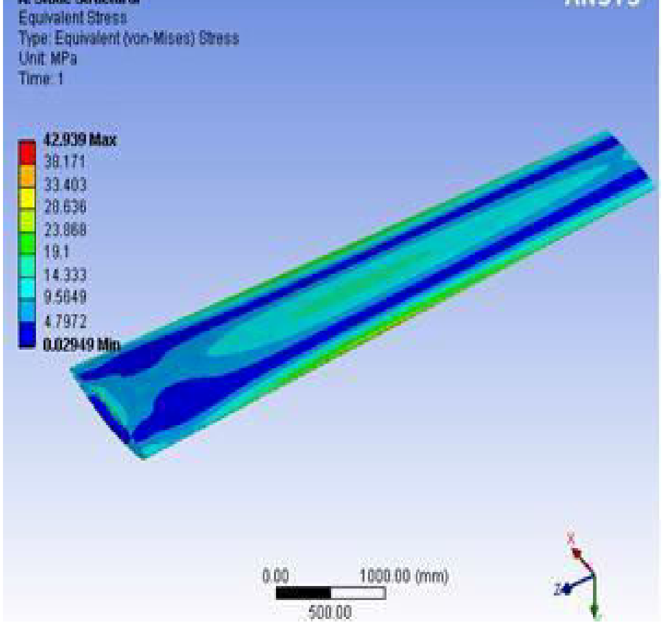


Fig3.7Stress

From fig3.12whentheloadsappliedonwing ofS-glassmaterial,themaximumstressvalueis42.939Mpa

ALUMINUM7075-T651DEFORMATION:

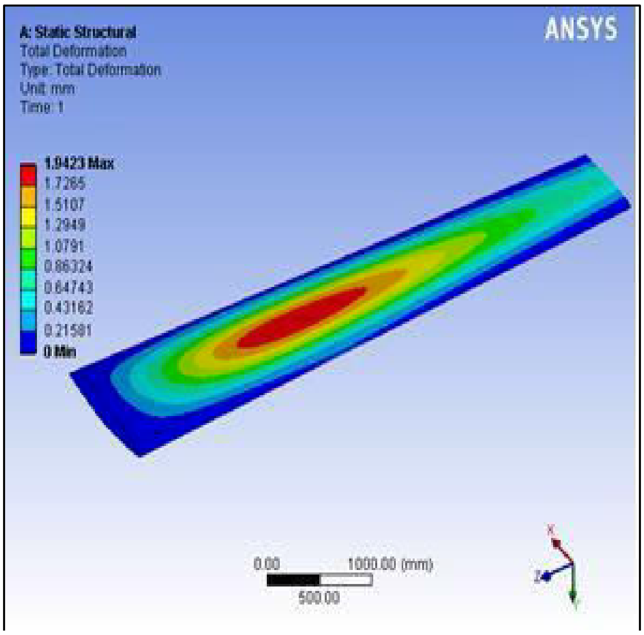


Fig3.8Deformation

Fromfig3.13whentheloadsappliedonwingofAluminum7075-T651®49material,themaximumdeformationvalueis1.9423mm

STRESS:

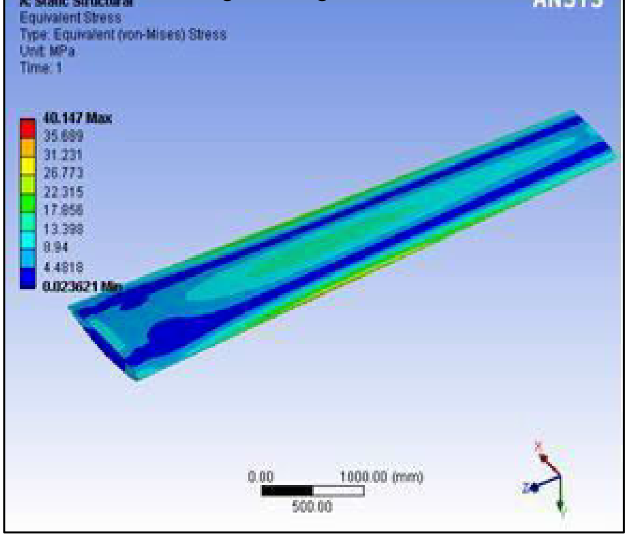


Fig3.9Stress

Fromfig3.14whentheloadsappliedonwingofAluminum7075-T651®49 material,themaximumstressvalueis40.147Mpa

GRAPHITE/EPOXYCOMPOSITEMATERIAL DEFORMATION:

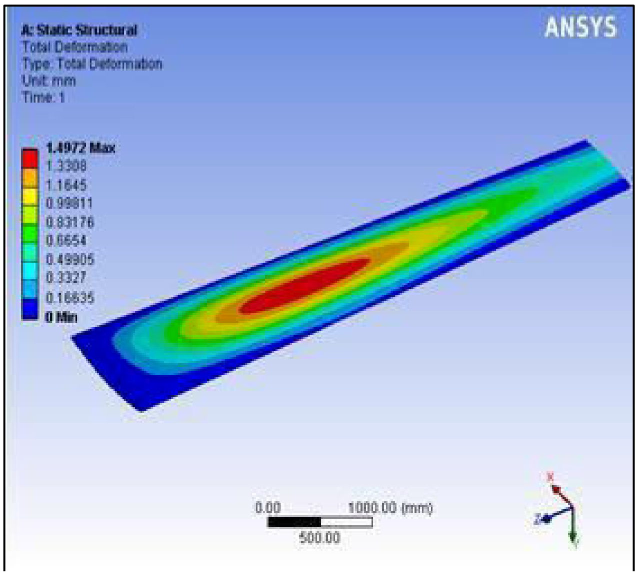


Fig3.10Deformation

Fromfig3.15whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueis1.4972mm

STRESS:

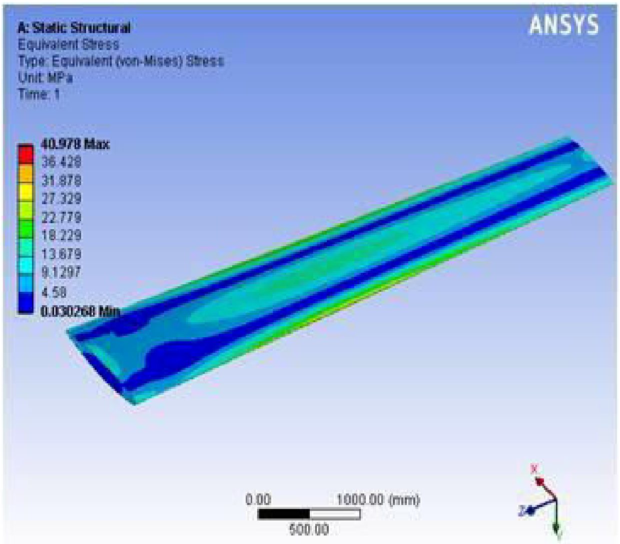


Fig3.11Stress

Fromfig3.16whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumstressvalueis40.978Mpa

3.3.2 STATICANALYSISOFMODIFIEDMODELS

avePro-EModelas.igesformat

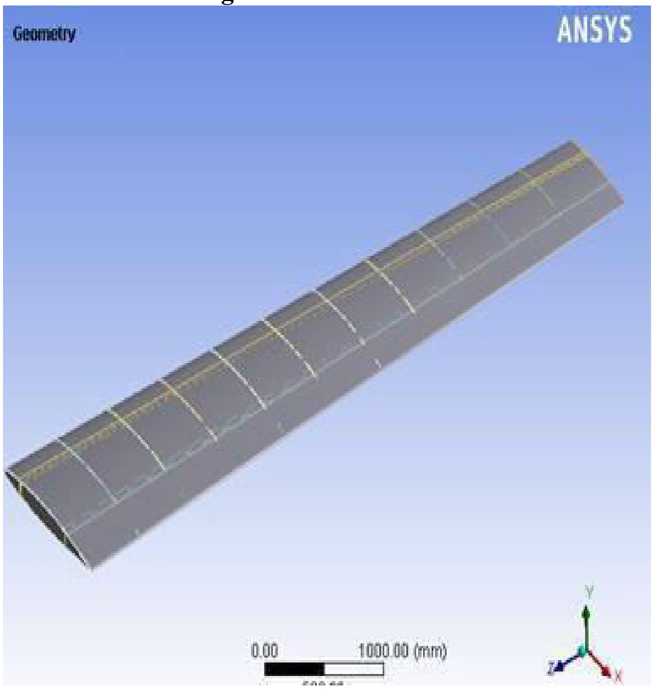


Fig3.12Importedmodel

MeshedModel:

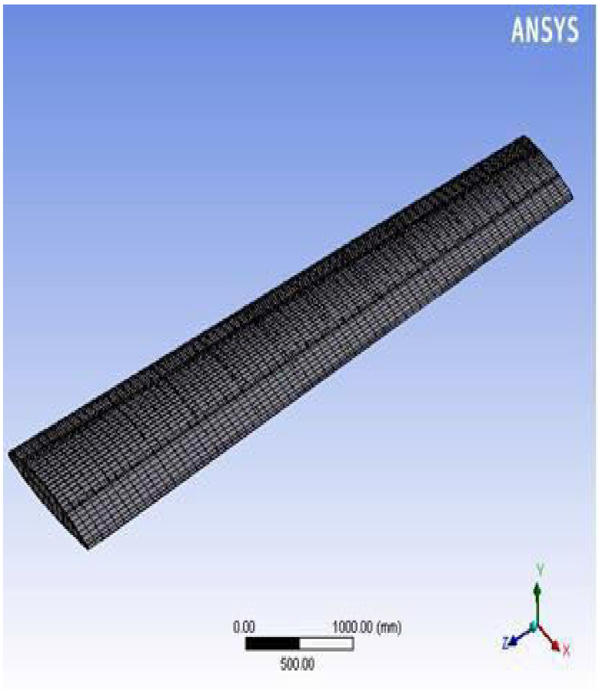


Fig3.13MeshedmodelD

EFORMATION:

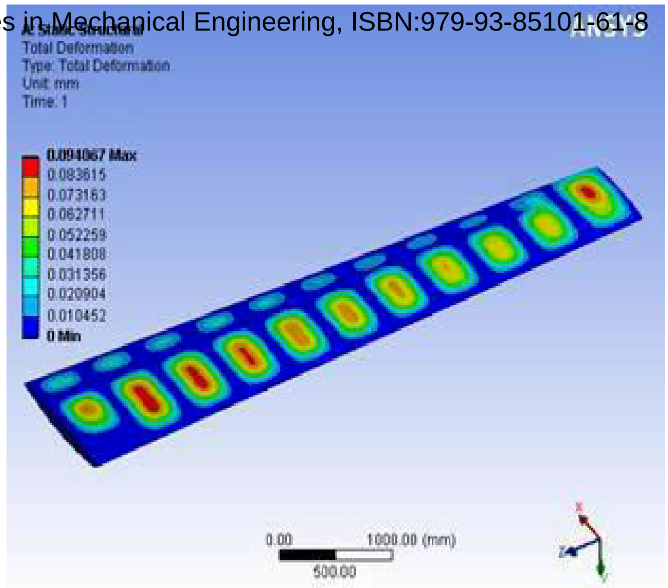


Fig3.14Deformation

From fig3.19whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformationvalueis0.094067mm

STRESS:

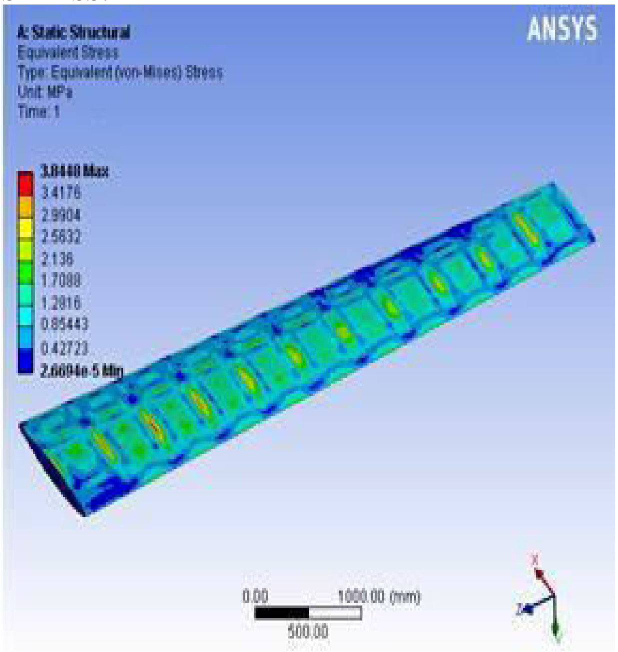


Fig3.15Stress

Fromfig3.20 whentheloadsappliedonwingofS-glassmaterial,themaximumstressvalueis3.8448Mpa

ALUMINUM7075-T651DEFORMATION:

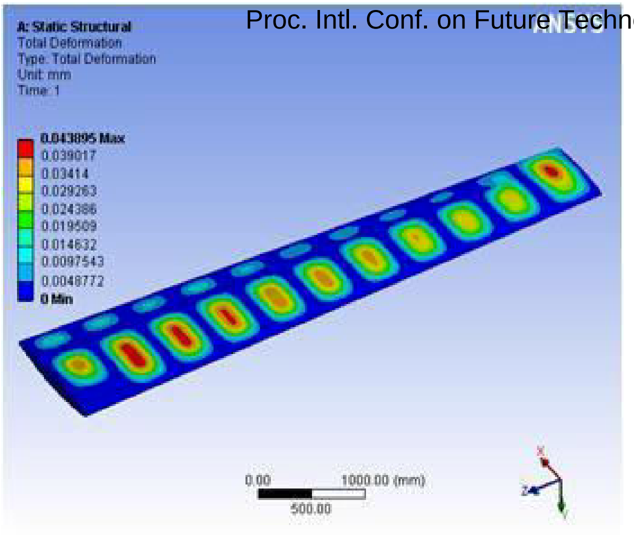


Fig3.16Deformation

Fromfig3.21whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueis0.043895 mm

STRESS:

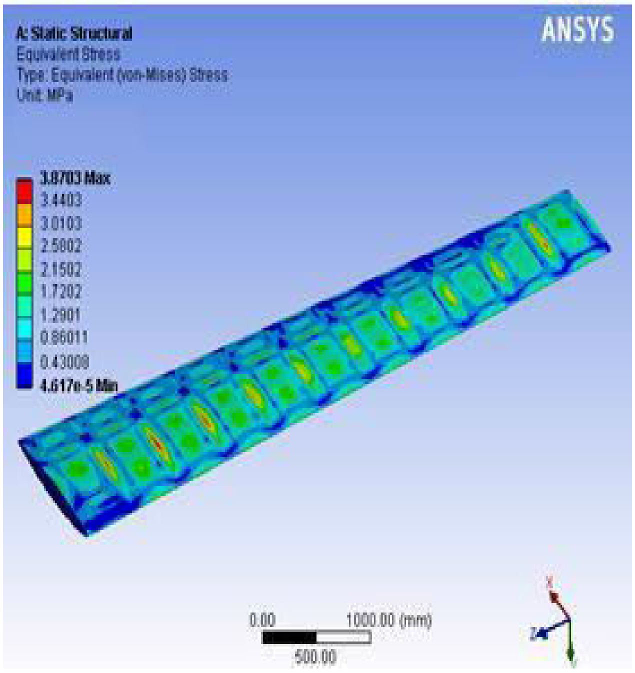


Fig3.17Stress

Fromfig3.22whentheloadsappliedonwingofAluminum7075-T651material,themaximumstressvalueis3.8703Mpa

GRAPHITE/EPOXYCOMPOSITEMATERIAL

DEFORMATION:

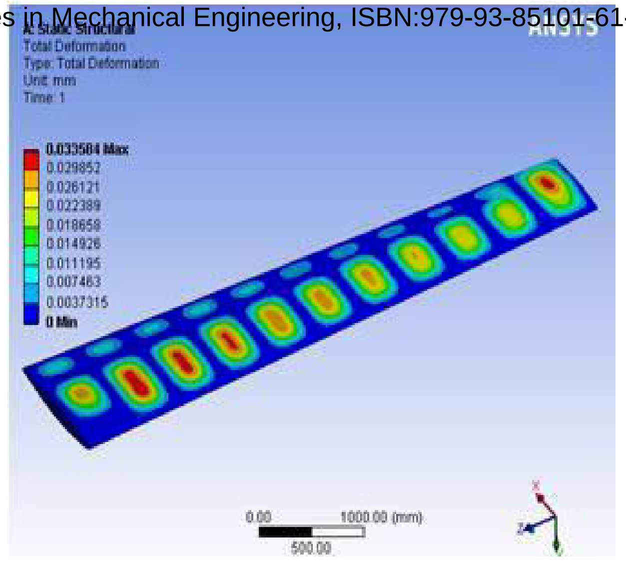


Fig3.18Deformation

Fromfig3.23whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueis0.033504mm

STRESS:

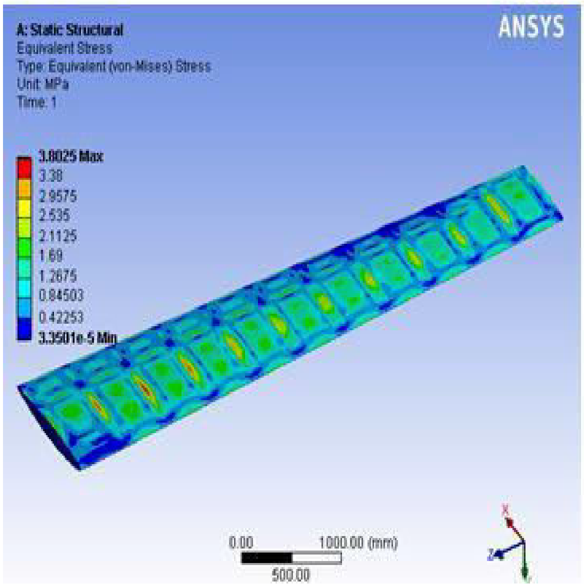


Fig3.19Stress

Fromfig3.24whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumstressvalueis3.8025Mpa

3.3.3 MODALANALYSISOFORIGINALMODELS-GLASS

Mode1:

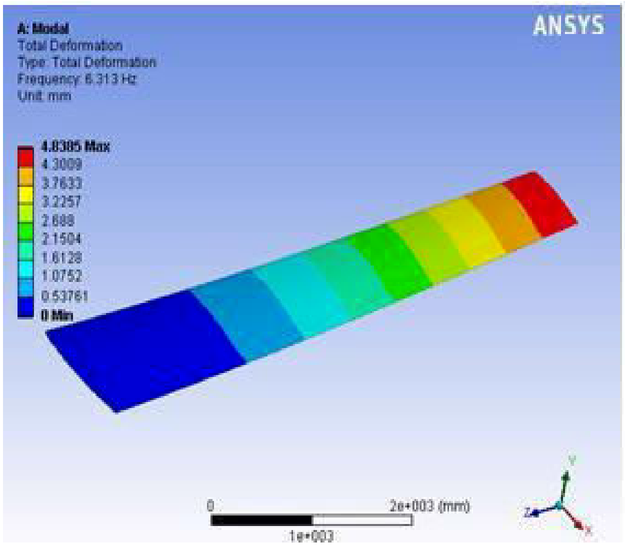


Fig3.20Modal1

From fig3.25whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformationvalueforfirstmodeis4.8385mmandfrequencyis6.313Hz

Mode2:

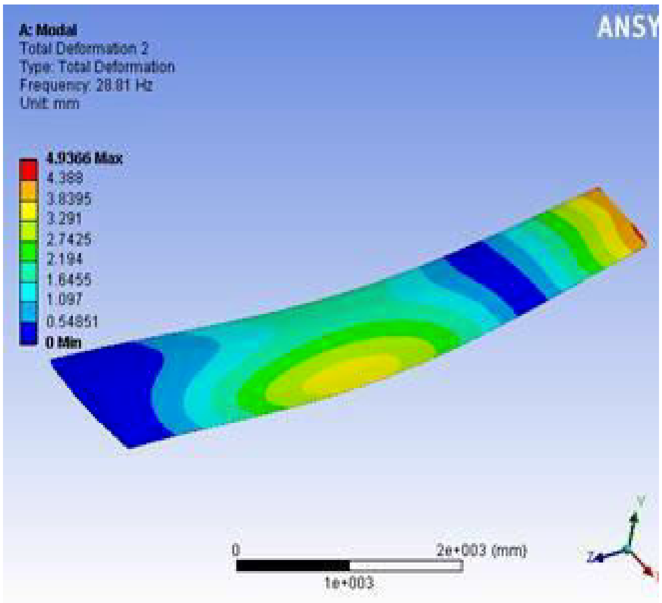


Fig3.21Modal2

From fig3.26whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformationvalueforsecondmodeis4.9366mmandfrequencyis29.81Hz

ALUMINUM7075-T651

Mode1:

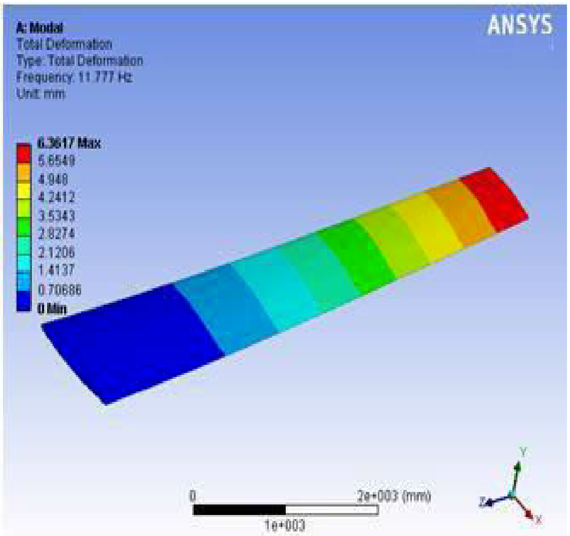


Fig3.22Modal1

Fromfig3.27whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforfirstmodeis6.3617mmandfrequencyis11.777Hz

Mode2:

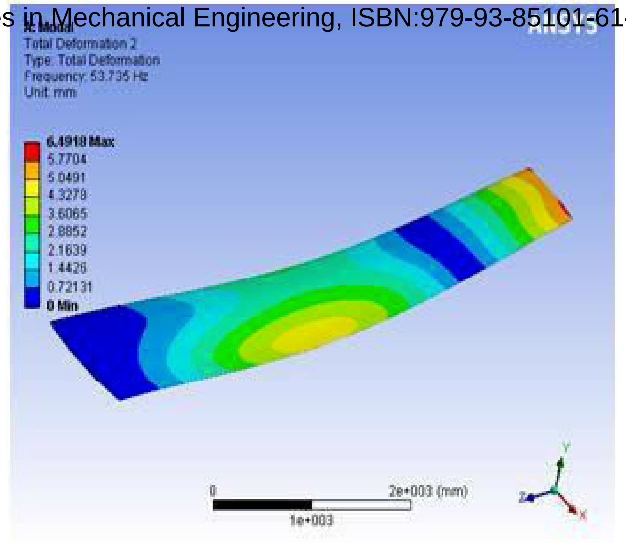


Fig3.23Modal2

Fromfig3.28whentheloadsappliedonwingofAluminum7075-T651®49material,themaximumdeformationvalueforsecondmodeis6.4918mmandfrequencyis53.735Hz

GRAPHITE/EPOXYCOMPOSITEMATERIAL

Mode1:

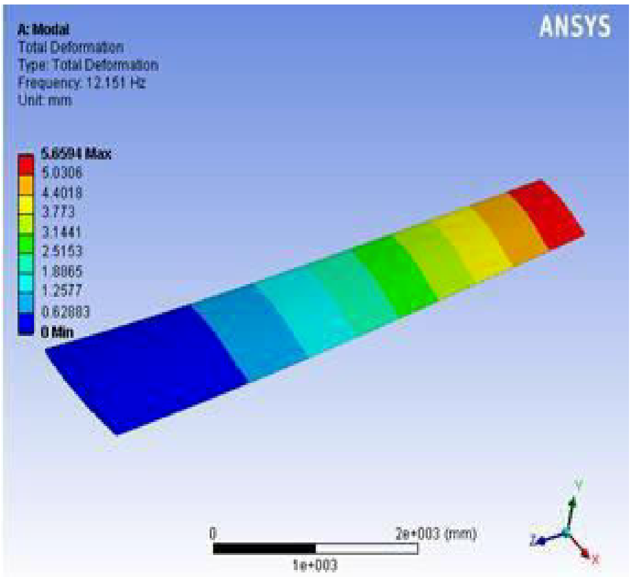


Fig3.24Modal1

Fromfig3.29whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforfirstmodeis45.6564mmandfrequencyis12.151Hz

Mode2:

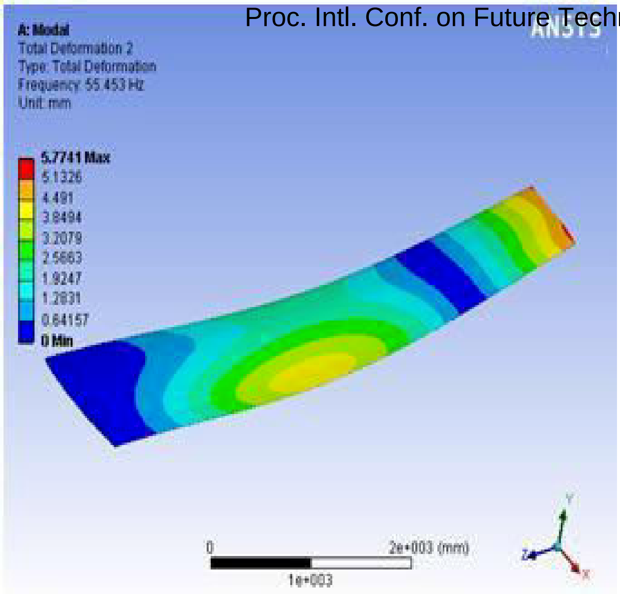


Fig3.25Modal2

Fromfig3.30whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforsecondmodeis5.7741mmandfrequencyis55.453Hz

3.3.4 MODALANALYSISOFMODIFIEDMODELS-GLASS

Mode1:

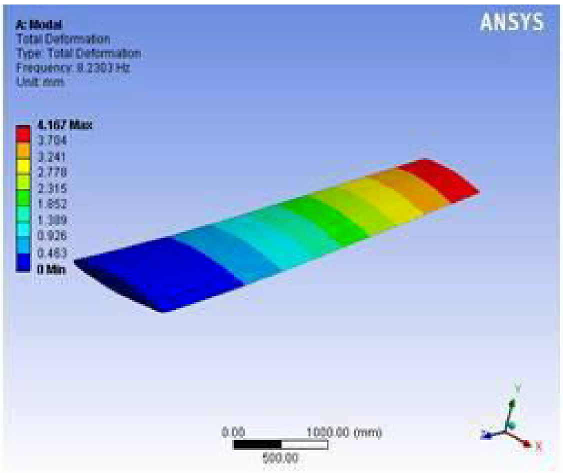


Fig3.26Modal1

From fig3.31whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformationvalueforfirstmodeis4.167mmandfrequencyis8.2303Hz

Mode2:

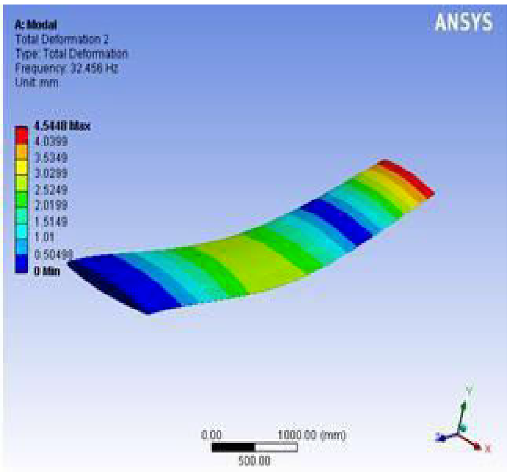


Fig3.27Modal2

From fig3.32whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformation valueforsecondmodeis4.5448mmandfrequencyis32.458Hz

ALUMINUM7075-T651

Mode1:

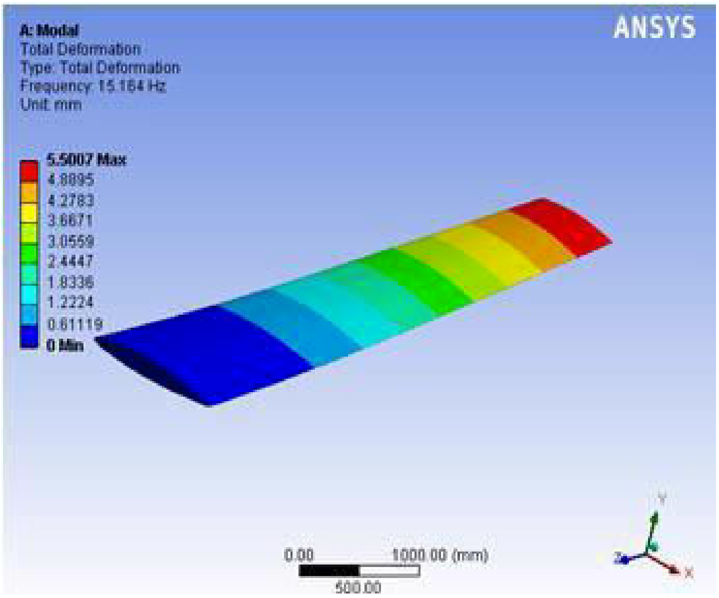


Fig3.28Modal1

Fromfig3.33whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforfirstmodeis5.5007mmandfrequencyis151.164Hz

Mode2:

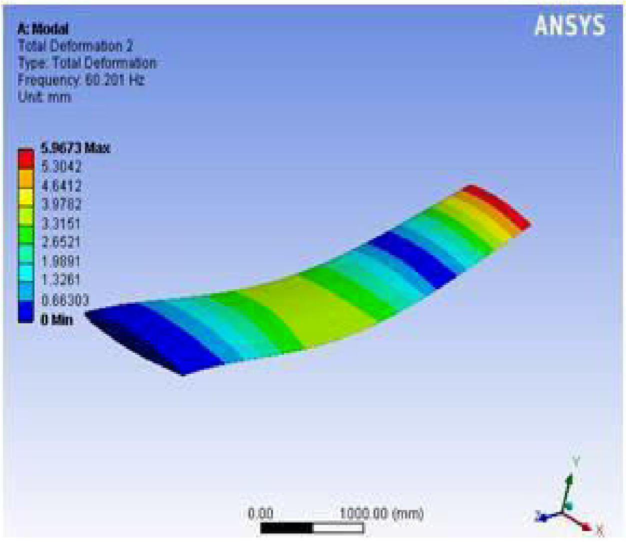


Fig3.29Modal2

Fromfig3.34whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforsecondmodeis5.9673mmandfrequencyis60.201Hz

GRAPHITE/EPOXYCOMPOSITEMATERIAL

Mode1:

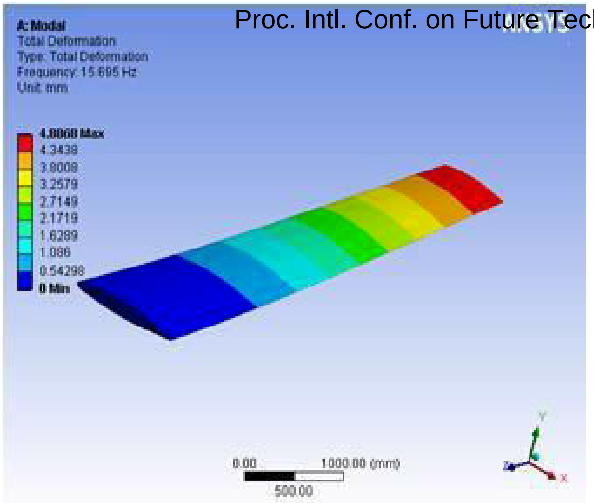


Fig3.30Modal1

Fromfig3.35whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforfirstmodeis4.8868mmandfrequencyis15.695Hz

Mode2:

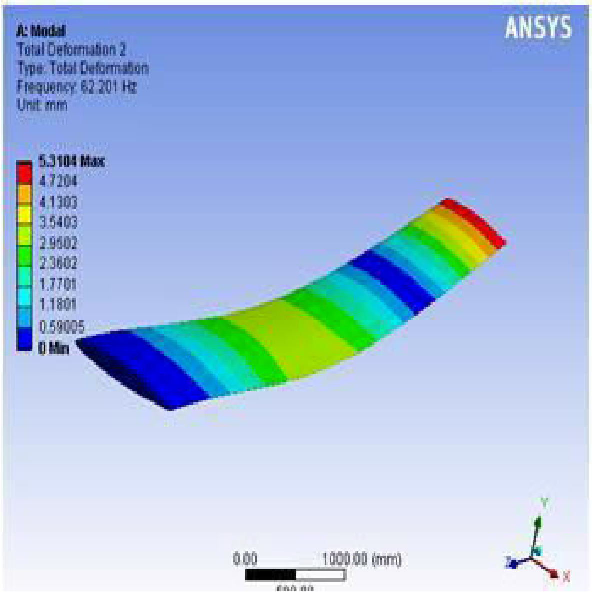


Fig3.31Modal2

Fromfig3.36whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforsecondmodeis5.3104mmandfrequencyis62.201Hz

3.3.5 BUCKLINGANALYSISOFORIGINAL MODEL

S-GLASS

DEFORMATON1:

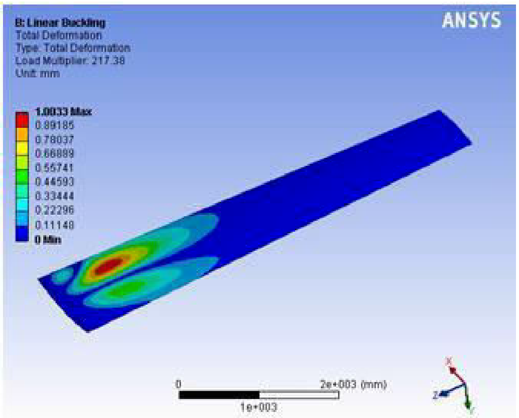


Fig3.32Deformation1

Fromfig3.37whentheloadsappliedonwingofS-glassmaterial,themaximumdeformationvalueforfirstmodeis1.0033mmandloadmultiplieris217.38**DEFORMATON2:**

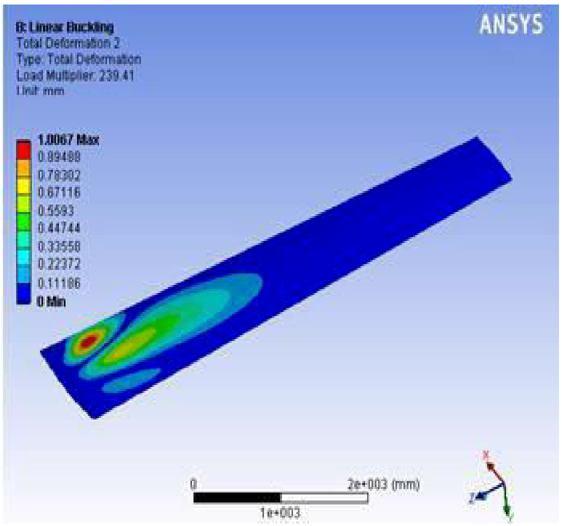


Fig3.33Deformation2

From fig3.38whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformation valueforsecondmodeis1.0067mmandloadmultiplieris239.41

ALUMINUM7075-T651DEFORMATON1:

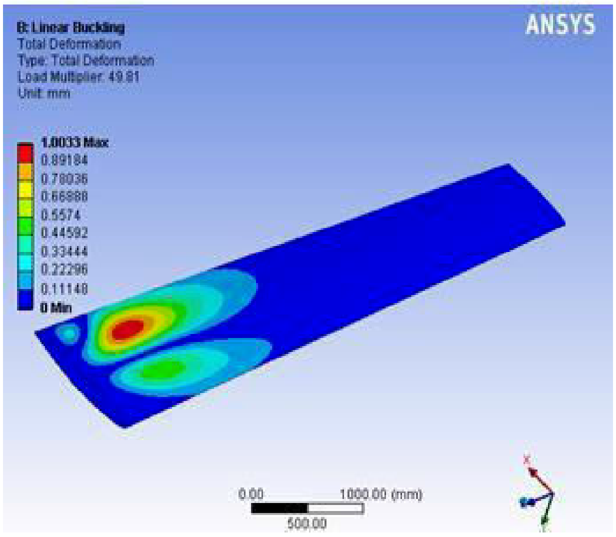


Fig3.34Deformation1

Fromfig3.39whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforfirstmodeis1.0033mmandloadmultiplieris49.81

DEFORMATON2:

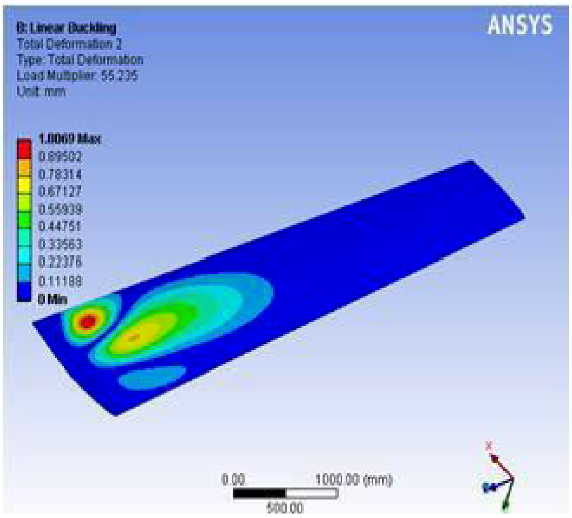


Fig3.35Deformation2

Fromfig3.40whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforsecondmodeis1.0069mmandloadmultiplieris55.235

GRAPHITE/EPOXYCOMPOSITEMATERIALDEFORMATON1:

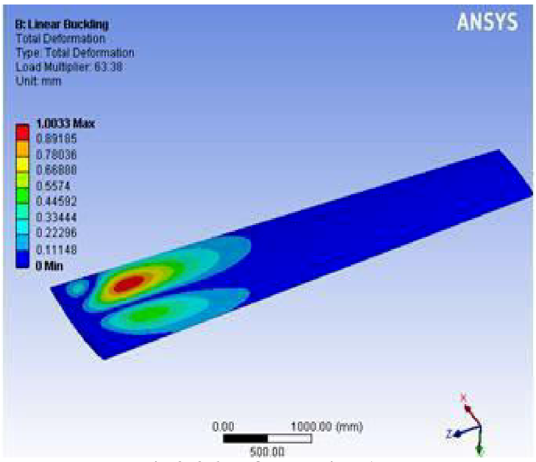


Fig3.36Deformation1

Fromfig3.41whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforfirstmodeis1.0033mmandload multiplieris63.38

DEFORMATON2:

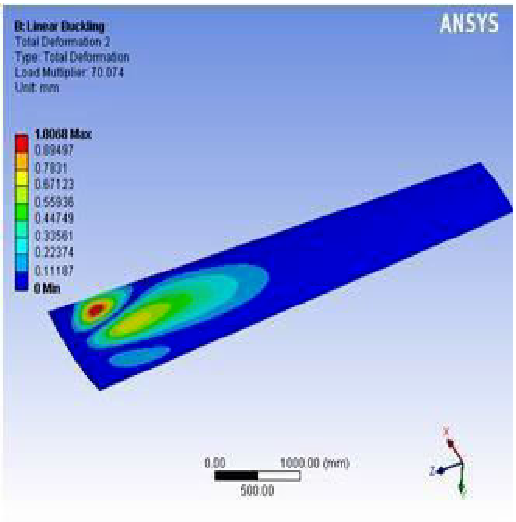


Fig3.37Deformation2

Fromfig3.42whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforsecondmodeis1.0068mmandload multiplieris70.074

3.3.6 BUCKLINGANALYSISOFMODIFIED MODEL

S-GLASS

DEFORMATON1:

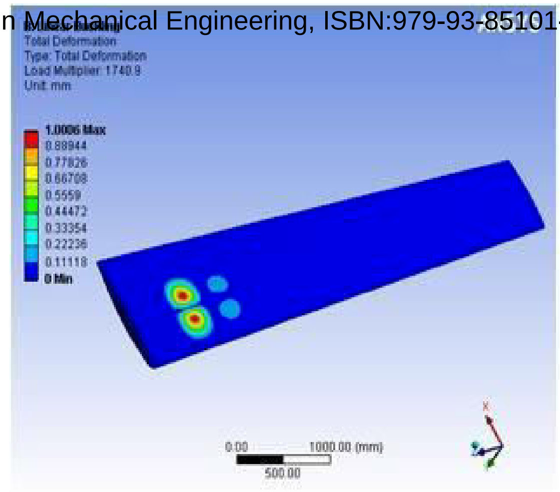


Fig3.38Deformation1

From fig3.43whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformationvalueforfirstmodeis1.0006mmandloadmultiplieris1740.9**DEFORMATON2:**

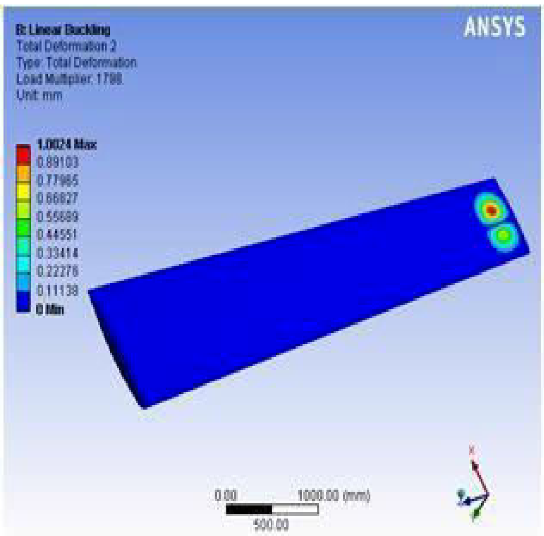


Fig3.39Deformation2

From fig3.44whentheloadsappliedonwing ofS-glassmaterial,themaximumdeformation valueforsecondmodeis1.0024mmandloadmultiplieris1798

ALUMINUM7075-T651DEFORMATON1:

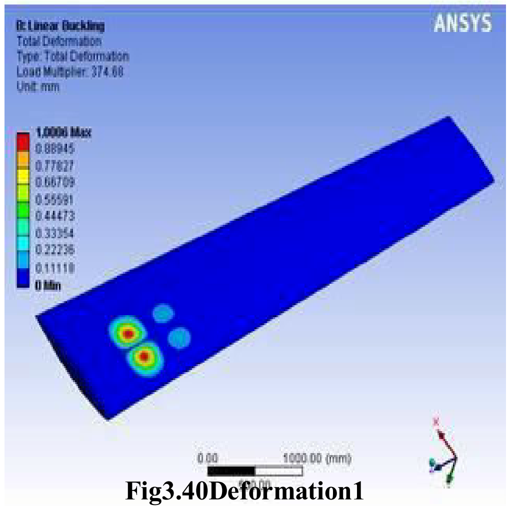


Fig3.40Deformation1

Fromfig3.45whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforfirstmodeis1.0006mmandloadmultiplieris374.68

DEFORMATON2:

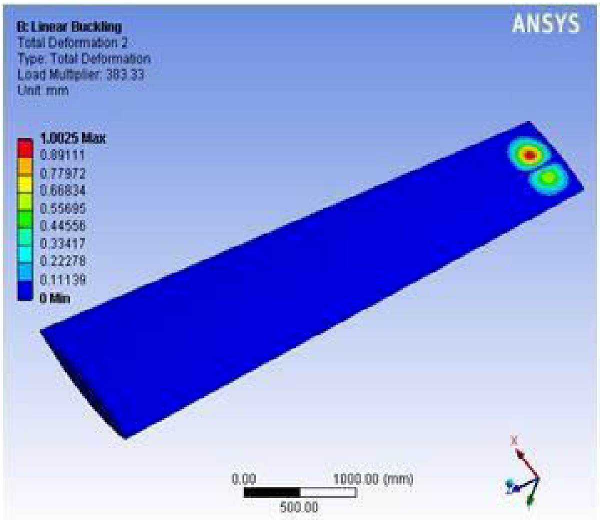


Fig3.41Deformation2

Fromfig3.46whentheloadsappliedonwingofAluminum7075-T651material,themaximumdeformationvalueforsecondmodeis1.0025mmandloadmultiplieris383.33

GRAPHITE/EPOXYCOMPOSITEMATERIAL

DEFORMATON1:

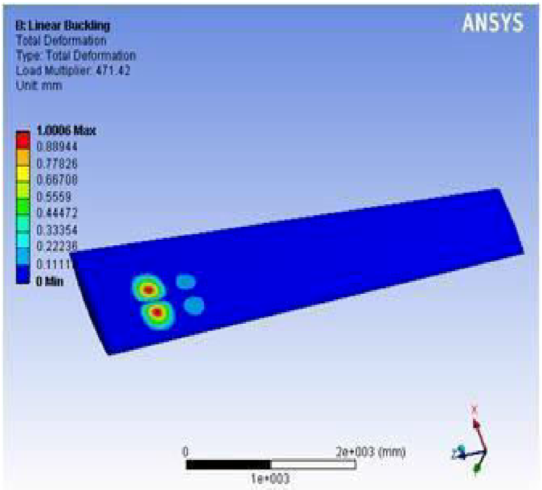


Fig3.42Deformation1

Fromfig3.47whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforfirstmodeis1.0006mmandload multiplieris471.42

DEFORMATON2:

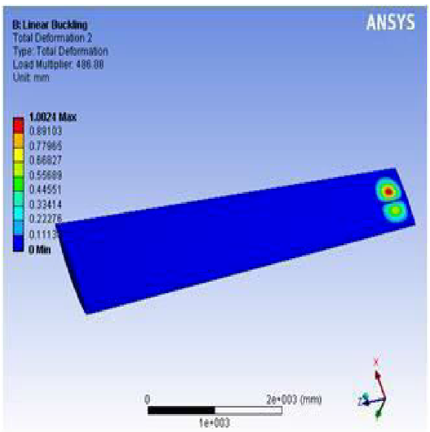
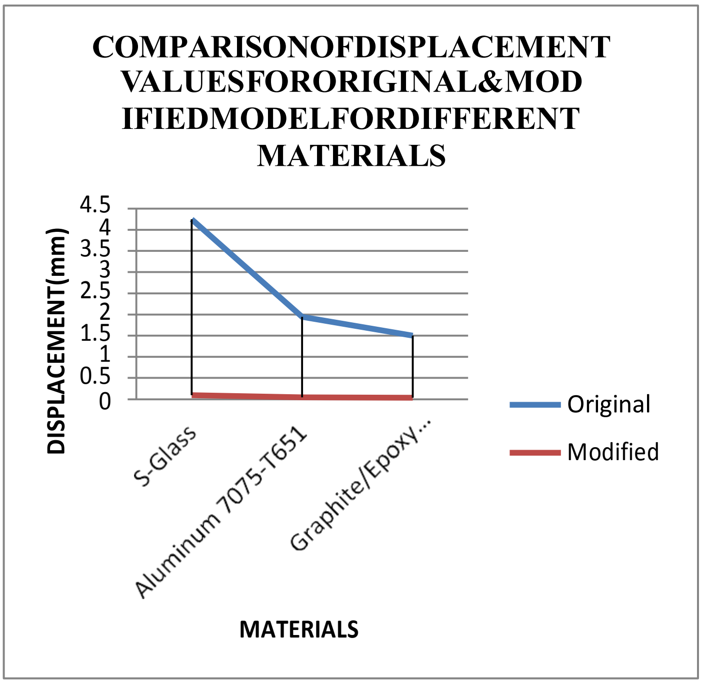


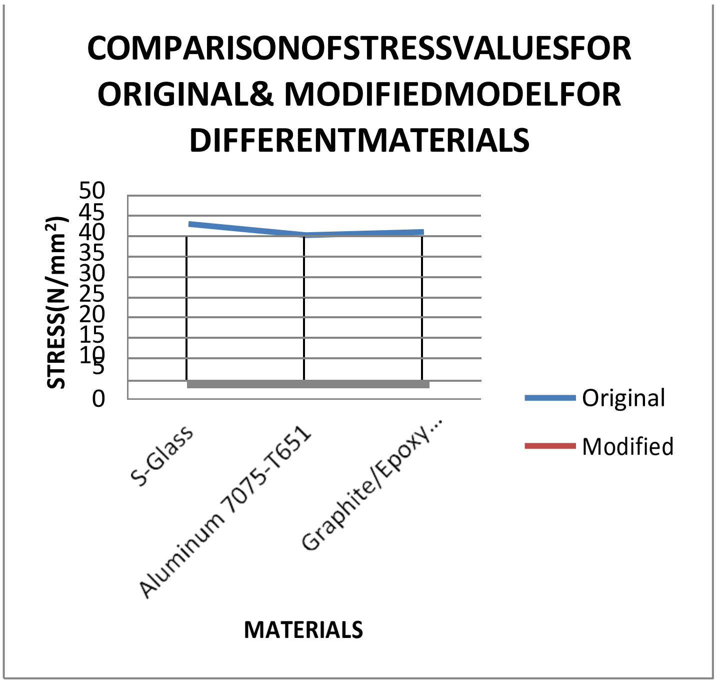
Fig3.43Deformation2

Fromfig3.48whentheloadsappliedonwingofGraphite/EpoxycompositeMaterialmaterial,themaximumdeformationvalueforsecondmodeis1.0024mmandload multiplieris486.88

RESULTS&DISCUSSIONS4.2STATICANALYSIS-GRAPHS



Graph1:ComparisonofdisplacementvaluesforOriginalmodal&Modifiedmodalfordifferentmaterials



Graph2:ComparisonofstrainvaluesforOriginalmodal&Modifiedmodalfordifferentmaterials

4.3 MODALANALYSISTABLE

		ORIGINAL MODEL			MODIFIED MODEL		
		S-glass	Aluminum 7075-T651	Graphite/Epoxycomposite Material	S-glass	Aluminum 7075-T651	Graphite/Epoxycomposite Material
MODE 1	Def (mm)	4.8385	6.3617	5.6594	4.167	5.5007	4.8868
	Freq (Hz)	6.313	11.777	12.151	8.2303	15.164	15.695
MODE 2	Def (mm)	4.936	6.4918	5.7741	4.5448	5.9673	5.3104
	Freq (Hz)	28.81	53.735	55.453	32.456	60.201	62.601

Table2:Comparisonbetweenoriginalandmodifiedmodelfordifferentmaterialsatdifferentmodes

4.4 BUCKLINGANALYSISTABLE

		ORIGINAL MODEL			MODIFIED MODEL		
		S-glass	Aluminum7075-T651	Graphite/EpoxycompositeMaterial	S-glass	Aluminum7075-T651	Graphite/EpoxycompositeMaterial
MODE 1	Def(mm)	1.0033	1.0033	1.0033	1.0006	1.0006	1.0006
	Load Multi plier	217.38	49.81	63.38	1740.9	374.68	471.42
MODE 2	Def (mm)	1.0067	1.0069	1.0068	1.0024	1.0025	1.00024
	Load Multi plier	239.41	55.235	70.074	1798	383.33	486.88

Table3:Comparisonbetweenoriginalandmodifiedmodels

CONCLUSION

- Inthisthesis,anaircraftwingisdesignedandmodeledin3DmodelingsoftwarePro/Engineer.Thewingismodifiedbyaddingribsandspars.Thematerialsusedforaircraftwingsaremostlymetallicalloys.Inthisthesis,thematerialsarereplacedbycompositematerialsSGlass,Aluminum7075-T651andGraphite/EpoxycompositeMaterial.Theadvantageofusingcompositematerialsistheirhighstrengthtoweightratio.
- Staticanalysisisdoneonthewingbyapplyingairpressureforthreematerials.Byobservingtheanalysisresults,thedeformationandstressesarelessforwingwithribsandsparsthan comparedwith thatoforiginal wing.Whencomparedtheresultsbetweenmaterials,thestressesarelessforGraphite/Epoxycomposite Material.
- Modalanalysisisdoneontheaircraftwingtodeterminethefrequencies.Byobservingtheresults,thefrequenciesaremoreformodifiedmodelbutdeformationsareless.Sothevibrationsaremoreformodifiedmodel.ThefrequenciesarelessforSGlass.

REFERENCESS

1. TheInternationalJournalofEngineeringAndScience(IJES)"FiniteElementAnalysisofAircraft WingUsingCompositeStructureDr.R.Rajappan,V.Pugazhenthi"
2. InternationalJournalofApplicationorInnovationinEngineering&Management(IJAIEM)"StatisticandDynamicAnalysisofTypicalWingStructureofAircraftusingNastran.Mr.PritishChitte, Mr.P.K.Jadhav,Mr.S.S.Bansode"
3. IOSRJournalofMechanicalandCivilEngineering(IOSR-JMCE)"FiniteElementAnalysisofCarbonFibreReinforcedAircraftWingKirankumarReddy,Sunil Manganshetty"

Design and Analysis of Conveyor Idler Frame

Dr.D K N Rao, Sivasankara Gowda, Dr.VV.Prathibha Bharathi[3]

1:DepartmentofMechanicalEngineering,MRCE,JNTU Hyderabad.

2 &3:Professor,DepartmentofMechanicalEngineering,MRCE,JNTU Hyderabad

Abstract--Troughingidlersframesareusedforconveyingbulkmaterials,andaredesignedandmanufacturedwithdifferentTroughingangels.DesignofidlersandidlersframesaredoneasperCEMAstandards.Staticanddynamicanalysesarecarriedouttoevaluatethestructuralstabilityintermsofstrengthandfrequency.Thestressesobtainedfromstaticanalysisarebelowtheallowablelimitandthefundamentalfrequencyobtainedfromthedynamicanalysisissafewhencomparedtooperatingfrequencyoftheconveyorbelt.

1.INTRODUCTION

Conveyorsaredurableandreliablecomponentsusedinautomateddistributionandwarehousing.Incombinationwithcomputercontrolledpallethandlingequipmentthisallowsformoreefficientretail,wholesale,andmanufacturingdistribution.Itisconsideredalaborsavingsystemthatallowslargevolumestomoverapidlythroughaprocess,allowingcompaniestoshiporreceivehighervolumeswithsmallerstoragespaceandwithlesslaborexpense.

Beltconveyorsarethemostcommonlyusedpoweredconveyorsbecausetheyarethemostversatileandtheleastexpensive.Productsconveyeddirectlyonthebeltsobothregularandirregularshapedobjects,largeorsmall,lightandheavy,canbetransportedsuccessfully.Theseconveyorsshoulduseonly the highestquality premium belting products,whichreducesbeltstretchandresultsinlessmaintenancefortensionadjustments.Beltconveyorscanbeusedtotransportproductinastraightlineorthroughchangesinelevationordirection.Incertainapplicationstheycanalsobeused forstaticaccumulationorcartons.

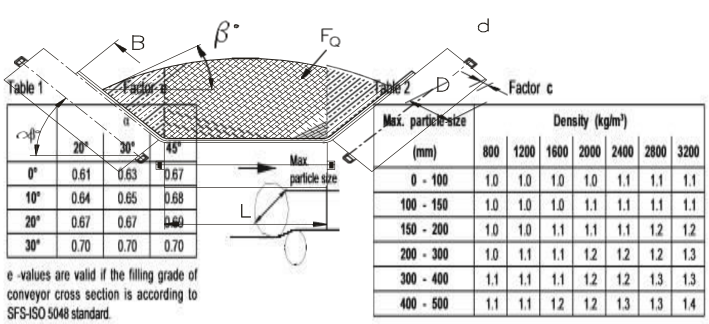


Table 1 Factor e

β \ α	20°	30°	45°
0°	0.61	0.63	0.67
10°	0.64	0.65	0.68
20°	0.67	0.67	0.69
30°	0.70	0.70	0.70

e -values are valid if the filling grade of conveyor cross section is according to SFS-ISO 5048 standard.

Table 2 Factor c

Max. particle size (mm)	Density (kg/m³) 800	1200	1600	2000	2400	2800	3200
0 - 100	1.0	1.0	1.0	1.0	1.1	1.1	1.1
100 - 150	1.0	1.0	1.0	1.1	1.1	1.1	1.1
150 - 200	1.0	1.0	1.1	1.1	1.1	1.2	1.2
200 - 300	1.0	1.1	1.1	1.2	1.2	1.2	1.3
300 - 400	1.1	1.1	1.1	1.2	1.2	1.3	1.3
400 - 500	1.1	1.1	1.2	1.2	1.3	1.3	1.4

2.CALCULATIONS

SELECTIONANDLOADRATINGOFTHEIDLERSFORBELTCONVEYORS

Selectionofthebulkhandlingidlersisbasedontheidlerload,generallyonthecenteridlerofa3-rollset.

Q=conveyorcapacity(t/h)v= beltspeed(m/s)

G=beltweight(kg/m)

FT=totalloadofoneidlerset(N)FQ= totalloadofcenteridler(N)B=beltwidth(mm)

L=lengthofidlershell(mm)D=idlerdiameter(mm)

d=shaftdiameter(mm)a =idler spacing(m)

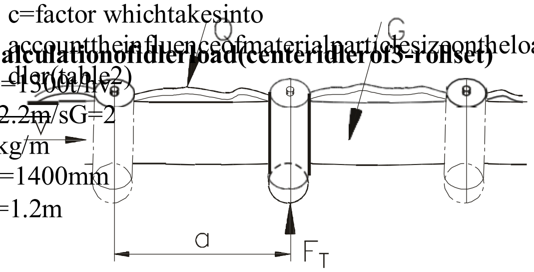
a=troughingangle

þ=rollingangleofthe materialinmotion

e=factorwhichtakesintoaccounttheinfluenceofthetroughingangleontheloadofcentreidler(table1)

c=factor whichtakesinto accounttheinfluenceofmaterialparticlesizeontheloadofcentreidler(table2)

Calculationofidlerload(centeridlerof3-rollset)



Q=1500t/hv =2.2m/sG=20kg/m

B=1400mm

a=1.2m

$\alpha=45^0$

$\beta=30^0$(Coal)

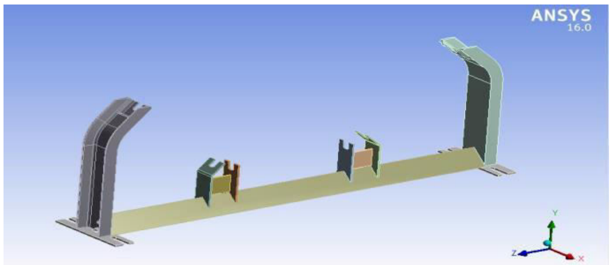
Loadforoneidlerset

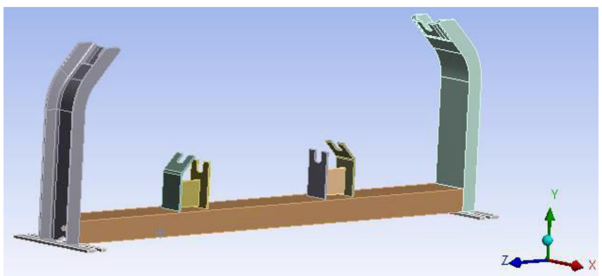
Loadofcenteridler

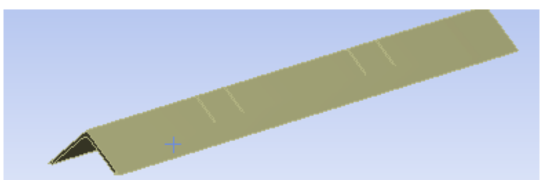
e=0.7(Table1)
e=1.2(Table2)

T×T.′ x′ ′ TT=T˛ν

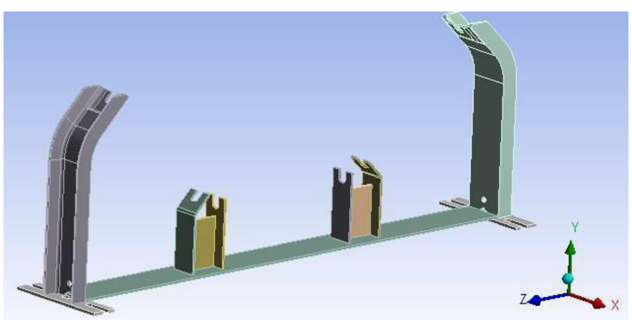
GeometryofIdlerframe
Inthepresentanalysisfourgeometriesareanalysedandresultsarecomparedtoselectbestoptimizeddesign.Thedifferentgeometriesareshowninthebelowfigures.

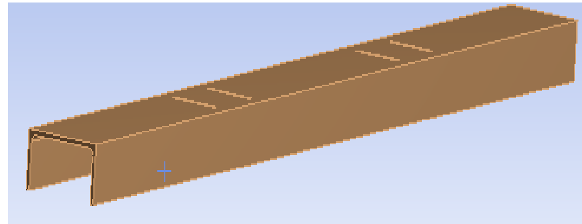




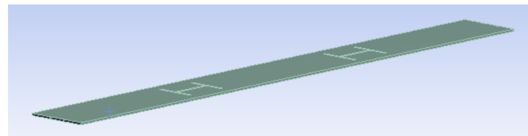


Geometry1&Baseframedesign

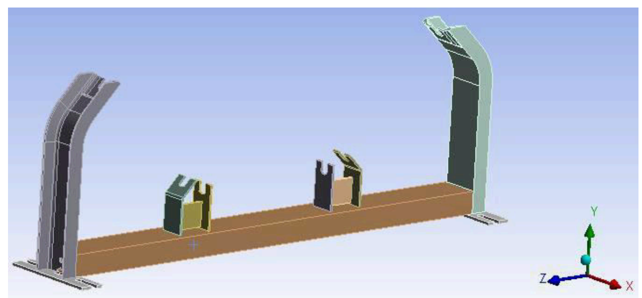


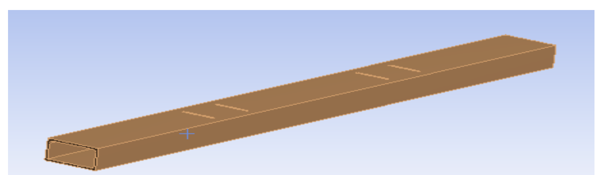


Geometry2&Baseframedesign



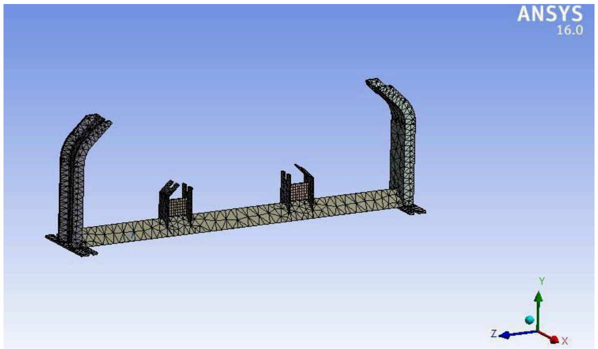
Geometry3&Baseframedesign



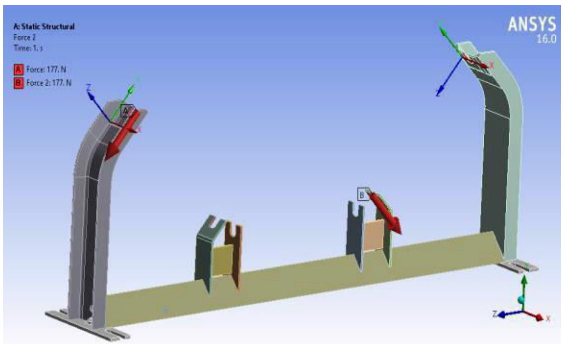


Geometry4&Baseframedesign

Meshing.OneofthemostrelevantstepsintheFiniteElementAnalysisisthemeshing.Thespeedandtheaccuracyoftheresultshaveadirectconnectioninhowthispartisdone.Thehigherthenumbersofnodesarethehighertheaccuracyoftheresults,howeverthespeedofthesimulationdecreases.Figure5showshowthemeshlooksinANSYSMechanical.

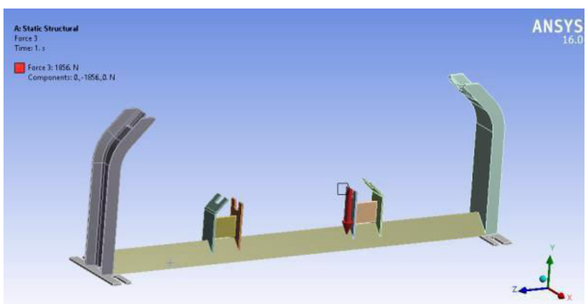


Meshofthestructure



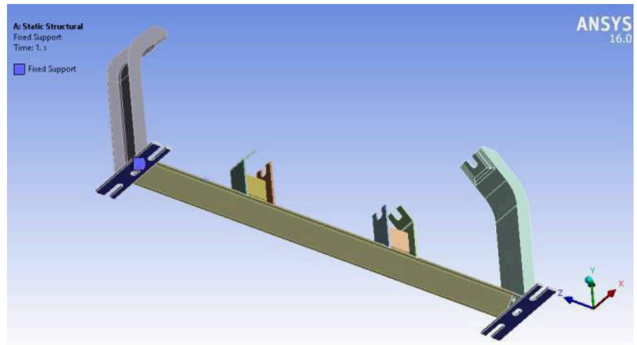
Sideidlerloadonthestructure

Centreidlerloadonthestructure



Centreidlerloadonthestructure

Boundaryconditiononthestructure

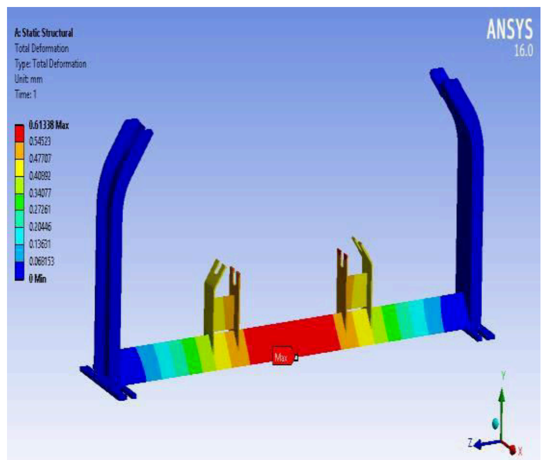


Boundaryconditiononthestructure

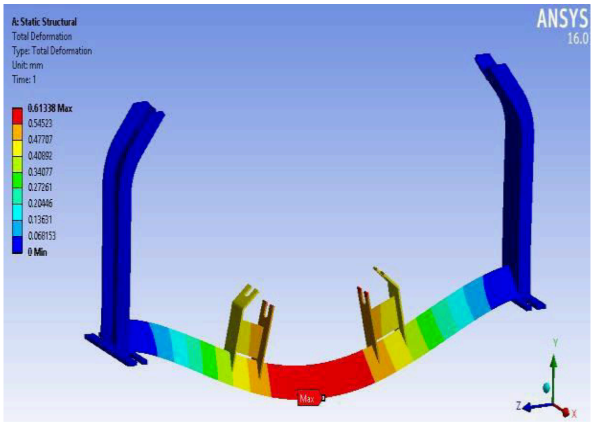
3. RESULTSANDDISCUSSIONS:

Geometry1:Results

TotalDeformation(mm)

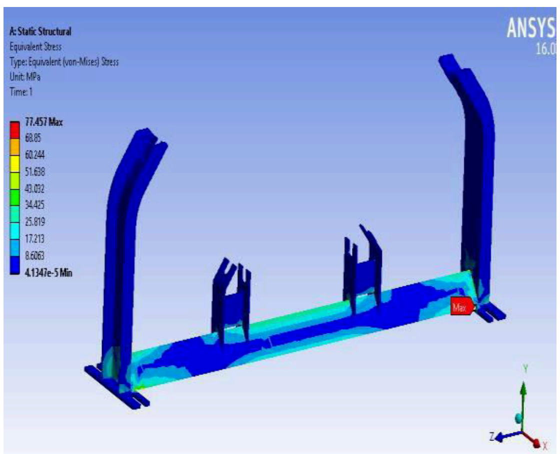


Totaldeformation-Truescale

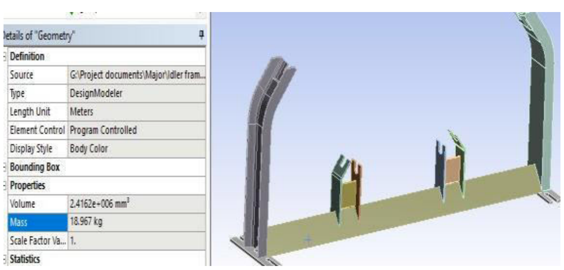


Totaldeformation-Deformedscale

vonMisesstress(MPa)



vonMisesstressinthestructure



weightoftheGeometry1

Geometry2:ResultsTota

lDeformation(mm)

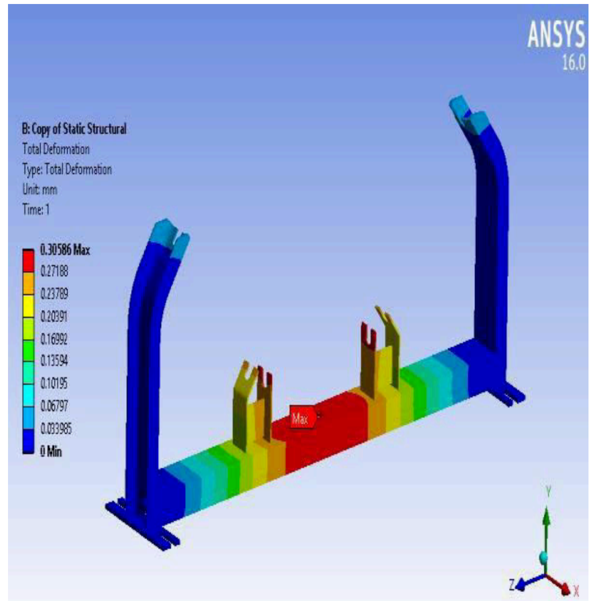


Figure:Totaldeformation-Truescale

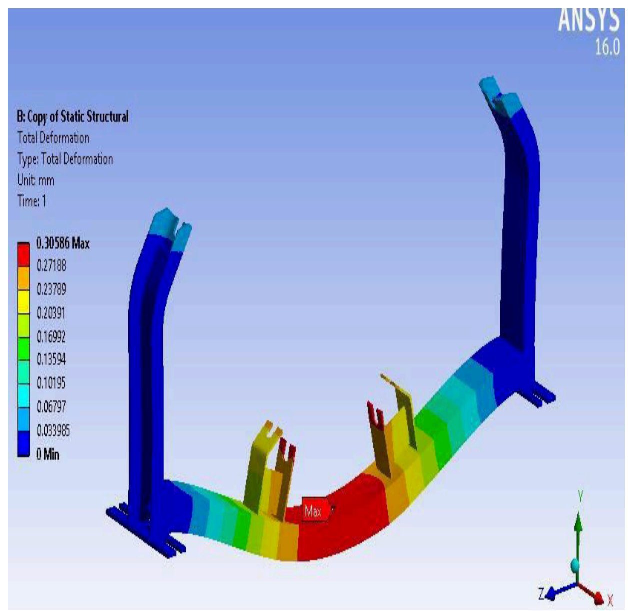


Figure:Totaldeformation-Deformedscale

vonMisesstress(MPa)

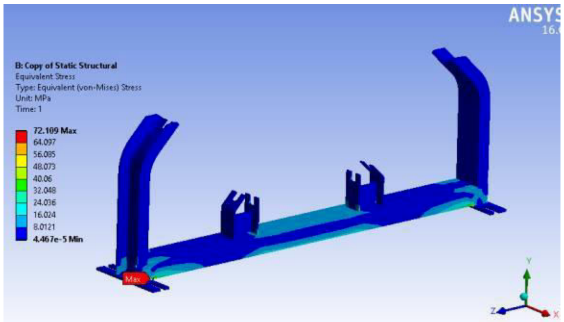


Figure:vonMisesstressinthestructure

Thetotaldeformationobservedinthestructureis0.30mm.Maximum vonMisesstressobservedinthestructureis72MPa

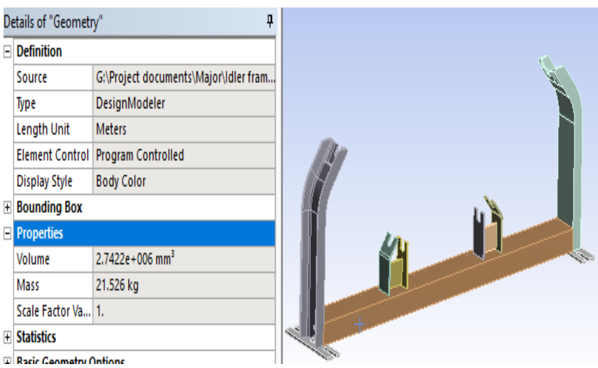


Figure:weightoftheGeometry2

Geometry3:ResultsTotal

Deformation(mm)

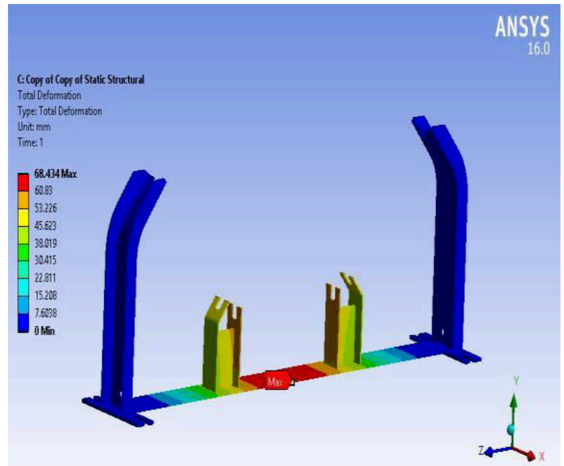


Figure:Totaldeformation-Truescale

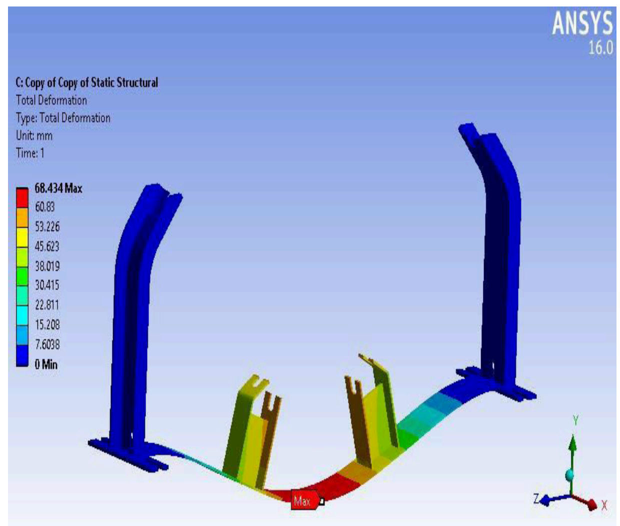


Figure:Totaldeformation-Deformedscale

vonMisesstress(MPa)

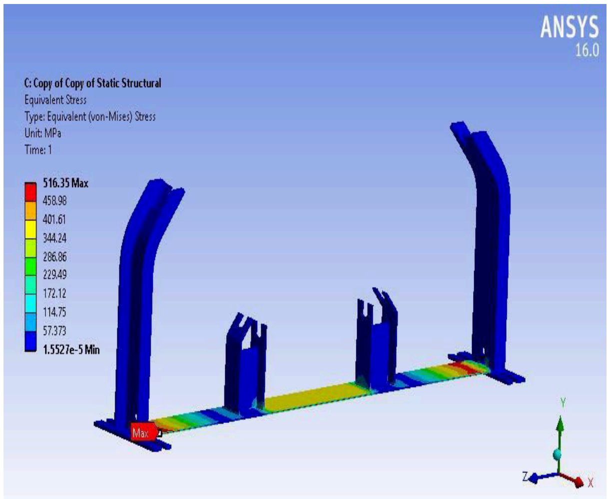
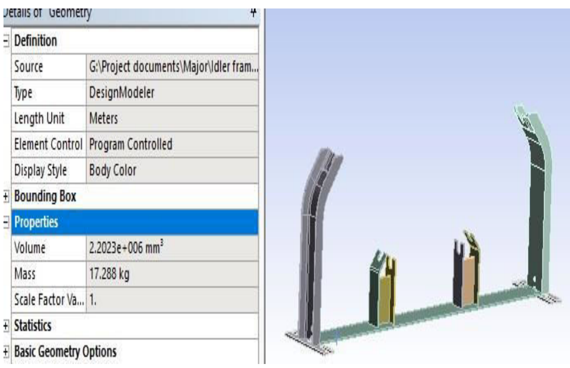


Figure:vonMisesstressinthestructure

ThetotaldeformationobservedinthestructureIs68.4mm.Maximum vonMisesstressobservedinthestructureis516MPa.



Details of "Geometry"	
Definition	
Source	G:\Project documents\Major\Idler fram...
Type	DesignModeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Properties	
Volume	2.2023e+006 mm³
Mass	17.288 kg
Scale Factor Va...	1.
Statistics	
Basic Geometry Options	

Figure:weightoftheGeometry3

Geometry4:ResultsTotal

Deformation(mm)

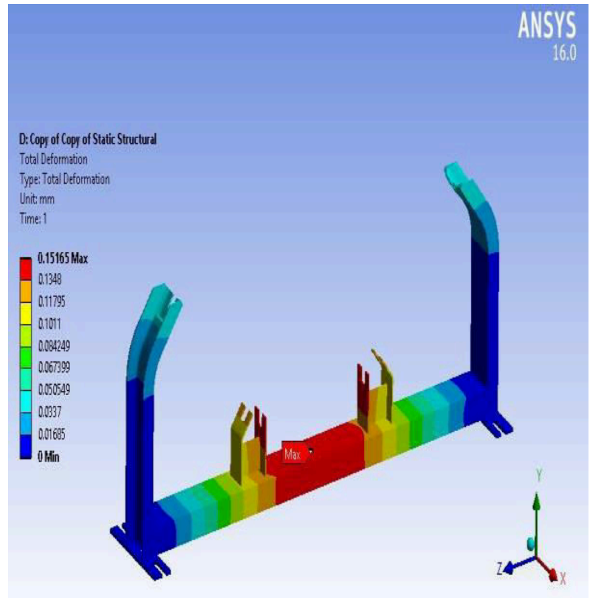


Figure:Totaldeformation-Truescale

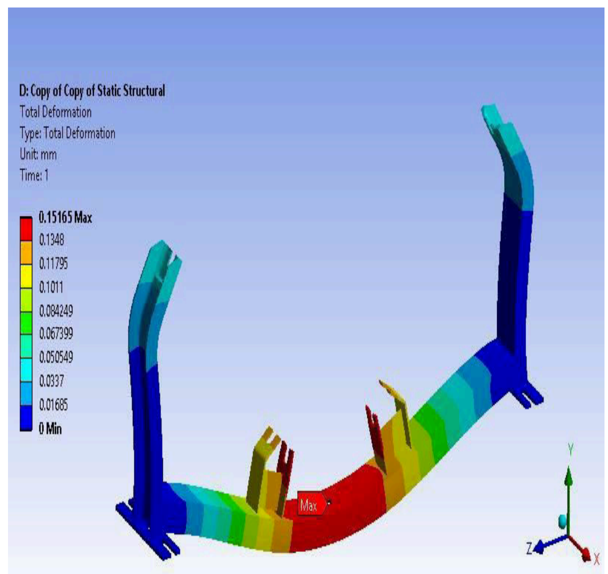


Figure:Totaldeformation-Deformedscale

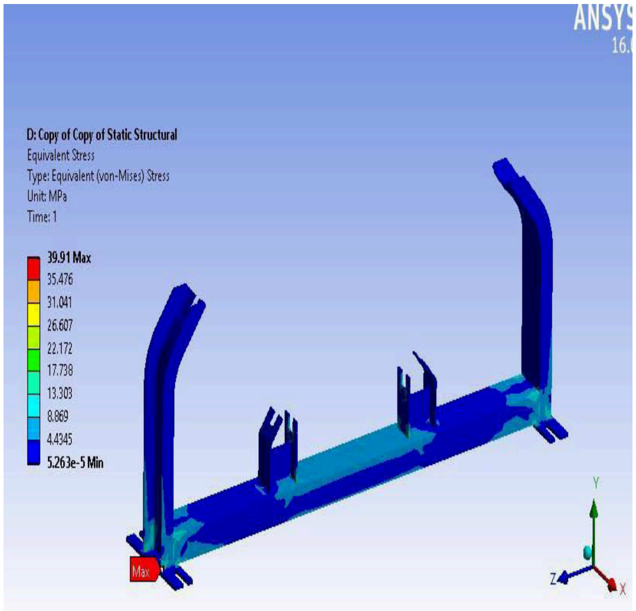


Figure:vonMisesstressinthestructure

Thetotaldeformationobservedinthestructureis0.15mm.Maximum vonMisesstressobservedinthestructureis39.9MPa.

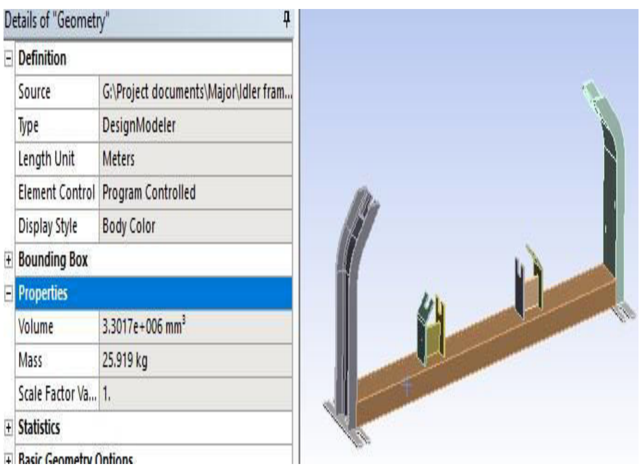


Figure:weightoftheGeometry4Re

sultsSummary

Theanalysisaredoneonthefourdifferentgeometriesbyapplyingidler forcesonthestructure.Theresultsaresummarizedinthebelowtable.F romtheresultsitisobservedthatstressesandbehaviour resultsareasexpectedandbelowthelimits.Thegeometry1Vshapecha nnelresultsarebetterinweightandstress&deformationresultsascom parewithothergeometriesofCchannel,Plate&Tubechannelframede signs.

	Geometry 1 VShape	Geometry 2 C Channel	Geometry 3 PlateCh annel	Geometry 4 TubeCh annel
TotalDeform ation(mm)	0.61	0.305	68.43	0.15
von Mises stress(MPa)	77.45	72.1	516	39.9
Weight(kg)	18.967	21.526	17.288	25.919

CONCLUSION

stressesandbehaviourresultsareasexpectedandbelowthelimits.T hegeometry1Vshapechannelresultsarebetterinweightandstress &deformationresultsascomparewithothergeometriesofCchanne l,Plate&Tubechannelframedesigns.

REFERENCES

Abdullah,S,Fahruddin,A,Syarif,J,Omar,MZ&Zulkifli,R2009,'Fati gueCrackGrowthModellingofFibre MetalLaminate(FML)Composite',EuropeanJournalof ScientificResearch,vol.35,no.1,pp.43-53,

EBSCOhost,a9h,item:44090172.ACE2011,AustralianConveyorE ngineering(ACE),viewed9May,.Aktivind2013,AktivIndustrialSol utions- aleadingsupplierofIndustrialComponents,viewed16March,.

Andersons,J&Paramonov,Y2011,'Applicabilityofempiricalmodel sforevaluationofstressratioeffectonthedurabilityoffiber- reinforcedcreeprupture- susceptiblecomposites',JournalofMaterialsScience,vol.46,no.6,pp .1705-13,

EBSCOhost,a9h,item:57283032.Askeland,DR,&Phule,PP,2008, ThescienceandengineeringofMaterials,5thedn,Cengagelearning,S tamford,USA.ASMHandbooksonline,2003,Volume21,

Dynamic Analysis of Spindle in CNC Horizontal Boring Machine

J.Chandrasekhar, B.Rajendra Prasad, B.c.Raghukumar reddy,Dr.D.K.NageswaraRao
DeptofMechanicalEngineeringMallaReddyCollegeofEngg,HYD
•

***Abstract*--Thestructureofmachinetoolforms thevitallinkbetweenthecuttingtoolandtheworkpiece.Themachinetoolaccuracymostlydependsuponthestructuraldesignof the variouscomponentsofthemachinetool. Tomaintainthe accuracyunder theinfluenceofcuttingforcesandthemovingweightofmachinetoolelements,thestructure,particularlyspindlemust poseshighdynamicstiffness.Thespindleshouldberigidenoughtowithstandthevariousforcesactingonit.Therefore, theextenttowhichthebehaviorofthevariouselementsofa machinetoolcontributedtoitsoverallperformanceisbyno means fullyunderstood.**

To sumupmachinetoolmustmeettheeverincreasingdemandofmoderni ndustryforfasterspeeds,greateraccuracy,smootherfinishandhighproductionrateatminimumcost.Thevariousinfluencingparametersontheperformanceofmachinetool spindle(CNC horizontal Boringmachine) are

- Differentspindlespeeds
- Typeofworkpiecematerial
- Variousdepthofcuts
- Typeof cuttingtoolsusedetc.,

Theobjectiveofthepresentprojectworkistodesignthemachinetoolspindle(CNCHorizontalBoringmachine)fordynamicstiffnessbyconsideringtheaboveinfluencingparameters.

Forthis purposeFiniteElementMethodis being implementedtoanalyzethespindlebehaviorinCNCHorizontalBoringmachine.FEM packagelike ANSYS15isused in thisproject.

1. INTRODUCTION

Thestructureofmachinetoolformsthevitallinkbetweenthecuttingtoolandthe Workpiece.Themachinetoolaccuracymostlydependsuponthestructuraldesignofvariouscomponentsof themachine tool.Tomaintaintheaccuracyundertheinfluenceofcuttingforcesandthemovingweightofthemachinetoolelements,thestructure,particularlyspindlemustpossesshighstaticanddynamicstiffness.ForthisconditiontheSpindleshouldberigidenoughtowithstandthevariousforcesacting onit.Machinetool mustmeettheever increasing demandof modernindustryfor faster Speeds,greater accuracy,smootherfinishandproductionrateatminimumcost.Suchconsiderationsareinfluencedbymachinetoolsspindleswithitssupport bearings.TheMachinetoolbuilder,spindlemakerandbearingmanufacturerareallofgreatimportanceinachievingthesegoals.Themachinetoolspindleisexpertlydesignedtomeetaboverequirement.

- Operating speed
- Typeof lubrication
- Estimatingtheworking loads
- Torque
- Spindlematerial.

1.1 A REVIEWOFEARLIER ANALYSIS ON

SPINDLEExperiment models andanalysis:

Generallythescaledownmodelsofthedesiredspindleswerebeingmadeandtestedtoobtainstaticanddynamiccharacteristics.Thesemodelswerealsosometimesbeingtested under working conditions.Staticloadsareapplied

atdesiredpointsanddirectionsbydeadweightfortests.For dynamicanalysisexcitationsareappliedby usingexciters,suchaselectrodynamicexciter,electromechanicalexciteretc.thedisplacementpickupandelectronicindicatorswerebeingusedtomeasurethedisplacementsanddeflectionsrespectively.Forthistypeofanalysisateststructureshouldexist,becauseitisan experimental method.

1.2 SALIENT FEATURESOFCNC HORIZONTALMACHINGCENTRE

TheMachine usedfor analysisof its spindleis showninfig anditsdetailsare givenbelow.

MachineSpecification

X-Axisstroke:

1300mmY-Axisstroke:

1000mmZ-Axisstroke:

1000 mm

Pallettablesurface:760X760 MM

Maximumpermissibleloadon table (fixtureandworkpiece): 1800 kg

Number of tools:

40Selection:

Random

Tool identification: Codedtool pocket

Full diameter cutter with adjacentpocketsempty:

160mmMaximumtool weight: 15 kg

Maximumtool length: 400 mm

Total weightof the machine:17000kg

Overall dimensions(lengthXwidthXheight): 4300 X 5910X 4025mm

Spindle:

Spindlebore:ISO45Int.

taper.FrontBearing:

boredia.85mmDrive:

DCElectricmotor

Methodof tool clamping: clawtype clamping adaptor fittedonendof tool holder and drawn into spindle bydiscsprings. Unclamped byhydraulicpiston.

Spindlespeed Range: 20-3600 rpmin 1min increment.Tapping

range: 20-1000rpmincrement.

Spindle drive:30HP(22kw),continuousdutyDCelectricmotorwith

ConstantHPof137rpm.

1.3 DESCRIPTION OFMACHINE:

Inthistypeofmachinetoolthespindleholdsthecuttingtool toperformitsoperations.Thismachinecanperformdrilling,holemilling,reaming,tapping,boringmillingetc.operationsand has4-differentaxes.

X-axis:Itistheaxisonwhichthefixtureandcomponentsareplaced.Thisaxisgives thelength of operationson component.

Y-axis:Spindleheadstockisplacedonthecolumnandmovesupanddowntogivey-axismovement.Thisaxisgivestheheightofoperationoncomponent.Spindleheadmountedontheaxis.

2. LITERATURE SURVEY

2.1**SPINDLE:**

ThespindleusedforthismachineisshowninFig:ThespindleheadistheY–axisslidememberofthemachine.ThisonepiececastIronhousingisdrivenbytheY–axisleadscrewthroughitsrecirculatingBallnut.Itcarriesahorizontalspindlecapableof3580separateprogrammablespeedscoveringarange20to3600rpm.Thestandardspeedrangeisvariablefrom20to3600rpmin1rpmsteps,3.1Hpperrpmto187rpmandwithaconstant20Hpfrom187rpmto3600rpm.Spindlespeedsbelow50rpmarenotrecommendedforheavydutymetalremovalduetoreducedavailableHp.Theselowerspeedshoweverareusefulfortramming,checkingtool or spindlerunoutetc.,

Speedrange	Spindlespeed/Motorspeed	Motorspeed/spindlespeed
Lowrange	Z_1/Z_2x Z_3/Z_6xZ_4/Z_7 17/43x21/59x37/57 =0.09134	10.948
Mediumrange	Z_1/Z_2x Z_2/Z_4xZ_4/Z_7 17/43x43/37x37/57 =0.29824	3.353
Highspeedrange	Z_1/Z_2x Z_2/Z_4x$Z_5/Z_8$17/43x43/ 37x61/33	1.1774

Therearethreespindlegearrangeswhichareautomaticallyshiftedbyahydrauliccylinder.Thecylinderspeedswithineachgearrangeareproducedbyvaryingthespindlemotorspeedin1rpmincrements.Therangechangegearclusterismovedbyaforkconnectedtoathreepositionhydraulicpistonandinterlockedbyproximityswitches.Therangechange

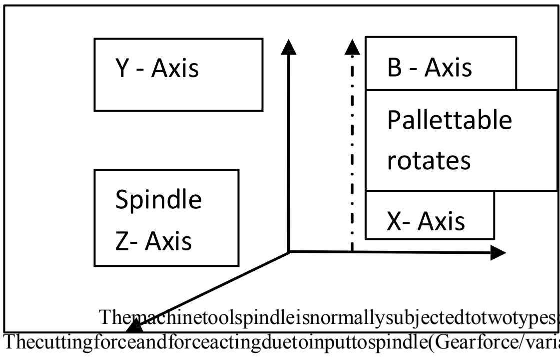
Ratiosare:-Range1–(Low)10.7to1,Range2–(Medium)3.3to1and Range3 –1

2.2 OBSERVATIONSON SPINDLE:

Z-axis:Thewholecolumnalongwithheadmovestowardsandawayfromtableto givez-axismovement.Hereworkandfixtureareloadedontable.Indrillingcolumnisgivenmotionalongz-axiswhere as in milling x-axistoperformoperation.

B-Axis:ArotarytableishousedontheX-axissaddle.Aprecisionpallettableofworkingsurface760mmsquarecornersroundedoftoØ1000mm.ArotarytablefacilitatesthefullrangeofB–axisisprogrammedforfeedratewithinrangeof0–9.999m/minresultingintablespeedof0–4rev/mininеitherCWorCCWdirectionandpositionedtoresolutionof 0.001degrees.DriveisprovidedbyDCmotorviawormandwormgear train with ratio of 1:360.

4–AXISOF A CNC HORIZONTALMACHINING CENTER



Themachinetoolspindleisnormallysubjectedtotwotypesofloadsviz. Thecuttingforceandforceactingduetoinputtospindle(Gearforce/variationofresultingbelttension).Theresultantdeflectionatcuttingpoint isdueto

1. Deflectionofspindledueto drivingforce.
2. Reflectedbearingdeflectiondue todriving.
3. Deflectionof spindledueto cutting force.
4. Reflectedbearingdeflectiondue tocutting force.

BEARINGS:

Abearingisamachineelementwhichsupportsanothermovingmachineelement(Knownasjournal).Itpermitsarelativemotionbetweenthecontactsurfaces,acertainamountofpoweriswastedinovercomingfrictionalresistanceandiftherubbingsurfacesareindirectcontact,therewillberapidwear.Inordertoreducefrictionalresistance,wearandheatgeneratedalayer oflubricant can beused.

2.3CLASSIFICATION OFBEARINGS:

1. Dependinguponthedirectionofloadstobesupported.Thebearingsunder thisgroup areclassifiedas:

(a) Radial bearingsand(b)Thrust bearings.

Inradialbearings,theloadactsperpendiculartothedirectionofmotionofthemoving element.

Inthrust bearings,theload actsalong theaxisof rotation.

2. Dependinguponthenatureofcontact.Thebearingsunderthisgroupareclassified as:

(a)Sliding contact bearings,(b) Rollingcontact bearings

Inslidingcontactbearings,theslidingtakesplacealongthesurfacesofcontactbetweenthemovingelementandthefixedelement.Theslidingcontact bearingsarealso knownas plain bearings.

2.4 TYPESOFBEARINGS:

Radialbearings

1) Deepgroove ball bearings.
2) Self aligning ball bearings.
3) Angular contact ball bearings.
4) Needleroller bearing.

5) Spherical plain bearing.
6) Cylindrical roller bearing.
7) Spherical roller bearings.
8) Taper roller

bearings.Thrust bearings

1) Thrust ball bearings.
2) Cylindrical roller thrust bearings.
3) Spherical roller thrust bearings.
4) Needleroller thrust bearings.
5) Angular contact thrust ball bearings.

2.5 SELECTION OF BEARINGTYPE:

Eachtypeofbearinghascharacteristicpropertieswhichmakeitparticularsuitablef orcertainapplications.Howeveritisnotpossibletolaydowngenerallyapplicabler ulesfor theselectionof bearingtypeas several factorsmustbe consideredand assessedrelativeto each other.

2.6 SELECTION CRITERIA:

1) Available space.
2) Loads.
3) Misalignment.
4) Speed.
5) Precision.
6) Silentrunning.
7) Stiffness.
8) Axial displacements.
9) Mountingand dismounting.

Availablespace:-
Deepgrooveballbearingsarenormallyselectedforsmalldiametershafts,wh ereasdeepgrooveballbearingscylindricalrollerbearingsandsphericalroller bearingscanbeconsideredfor shaftsof largediameter.

Loads-
Thisisthefactorwhichusuallydeterminesthesizeofbearingstobeused.Gen erallyrollerbearingscancarryheavierloadsthanballbearingshavingthesam eexternaldimensions.Thusballbearingsaremostlyusedto carrylightandlargediameter shafts,

2.7ANGULAR CONTACT BEARINGS: -

Thesearethemostadaptableandimportantbearingforusein machinetoolspindles.Theseareparticularlyforaccommodationofbothradialand axialloads.Angularcontactbearingcantakeaxialloadsinonedirectiononly.There sultantforceactinginaxialdirectionwhichisproducedinbearingwhenitissubjecte dtoradialforcemustbebalancedbyacounterforce.Thereforethebearingisadjuste dagainstsecondbearing.Abacktobackarrangementcombinationoftwoangularc ontactbearinghavingacommonloadcenterisabletoaccommodateheavyradialan daxialloadsactinginbothdirections.lowcontactangle.25^0ishighcontactangle usedin angular contactbearings.

2.8PRE LOAD:-

Axial(orradial)deflectionofabearingistheaxial(orradial)displacementof onering inrelationtoone another

δ1 deflectionfor abearing withoutpre loadδ2

deflection havingan initial preload P.

MODELLINGOFCATALYTIC

CONVERTOR3.1MODELINGSOFTWARE:

CatiaV5R20 isaninteractiveComputer-AidedDesignandComputerAidedManufacturingsystem.TheCADfunctionsaut omatethenormalengineering,designanddraftingcapabilitiesfoundintoday'sma nufacturingcompanies.TheCAMfunctionsprovideNCprogrammingformodern machinetoolsusingtheCatiaV5R20designmodeltodescribethefinishedpart.Cat iaV5R20functionsaredividedinto"applications"of commoncapabilities.Theseapplicationsaresupportedbyaprerequisite application called"CatiaV5R20Gateway".

3.1.1BASICPROCEDUREFORCREATINGA3-DMODELINCATIAV5R20:

Creationofa3-DmodelinCatiaV5R20canbeperformedusingthreeworkbenchesi.e.,sketcher,m odelingandassembly.

Sketcher:

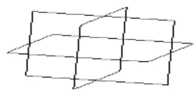
Sketcherisusedtocreatetwo-dimensionalrepresentationsofprofilesassociatedwithinthepart.Wecancreatear oughoutlineofcurves,andthenspecifyconditionscalledconstraintstodefinethesh apesmorepreciselyand captureour designintent.Eachcurveis referredtoas a sketchobject.

3.2 SKETCHPLANE

Thesketchplaneis theplanethatthesketchis locatedon.Thesketchplanemenu hasthe following options:

Face/Plane:Withthisoption,wecanusetheattachmentface/planeicontoselecta planarfaceorexistingdatumplane.Ifweselectadatump lane,wecanusethereversedirectionbuttontoreversethedirectionofthenormal to theplane.

XC-YC,YC-ZC,andZC-XC**:**Withtheseoptions,wecancreateasketchononeoftheWCSplanes.Ifweusethism ethod,adatumplaneandtwodatumaxesarecreatedas below.



3.3 MODELING

FEATURE CREATION

"Feature"isanall-encompassingtermthatreferstoallsolids,bodiesandprimitivesusedinCatiaV5R2 0FormFeaturesareusedtosupplydetailtothemodelintheformofstandardfeaturet ypes.Theseincludehole,slot,groove,pocket,ribandpad.Wecanalsocreateourow ncustomfeaturesusing theUserDefinedoption.All of thesefeaturesareassociative

3.4.CREATION OFSOLIDBODIES

Wecancreatesolidbodiesby sweepingsketchandnon-sketchgeometry tocreateassociativefeaturesorCreatingprimitivesforthebasicbuildingblocks,th en adding morespecificfeatures(for example,holes andslots).

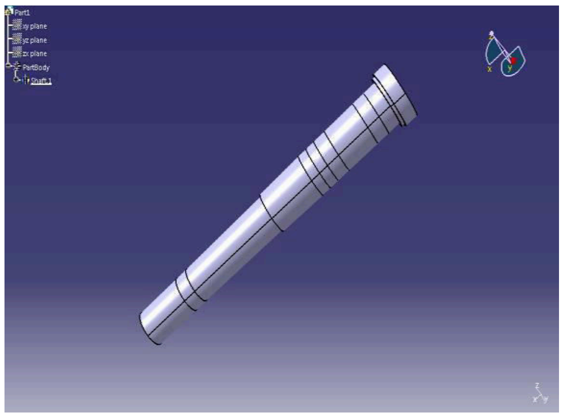


Fig.3.1.Geometricmodelof SpindleinBoringMachine

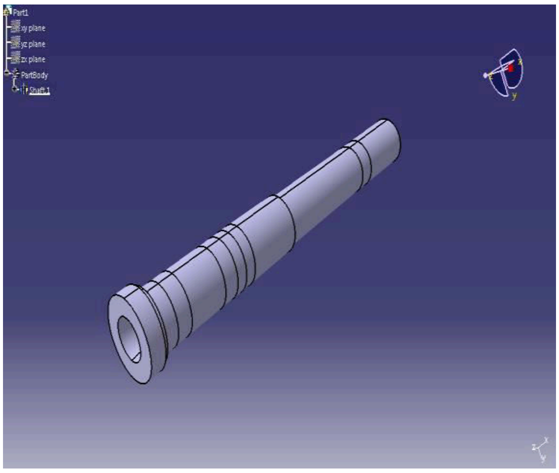


Fig.3.2. Geometricmodelof Spindlein BoringMachine

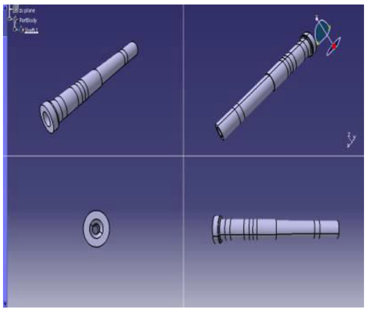


Fig.3.1.Geometricmodelwith differentviewsof SpindleinBoringMachine

FINITE ELEMENT METHODS

Thefiniteelementmethodisnumericalanalysistechniqueforobtainingapproximatesolutionstoawidevarietyofengineeringproblems.Becauseofitsdiversityandflexibilityasananalysistool,itisreceivingmuchattentioninengineeringschools andindustries.Inmoreandmoreengineeringsituationstoday,wefindthatitisnecessarytoobtainapproximatesolutionstoproblemsrather than exact closedformsolution.

Itisnotpossibletoobtainanalyticalmathematicalsolutionsformanyengineeringproblems.Ananalyticalsolutionsisamathematicalexpression thatgivesthevaluesofthedesiredunknownquantityatanylocationinthebody,asconsequenceit is validfor infinite number of location in thebody.

- **MATRIXALGEBRA.**
- **SOLIDMECHANICS.**
- **VARIATIONMETHODS.**
- **COMPUTERSKILLS.**

4.1 TERMSCOMMONLYUSEDINFINITEELEMENTMETHOD:

- **DESCRITIZATION:**Theprocessofselectingonlyacertainnumberofdiscretepointsinthebodycanbetermedas Descritization.
- **CONTINUUM:**Thecontinuumisthephysicalbody,structureorsolidbeing analyzed.
- **NODE:**Thefiniteelements,whichareinterconnectedatjoints,arecallednodesor nodalpoints.
- **ELEMENT:**Smallgeometricalregularfiguresarecalledelements.
- **DISPLACEMODELS:**Thenodaldisplacements,rotationsandstrainsnecessarytospecifycompletelydeformationoffiniteelement.
- **DEGREEOFFREEDOM:**Thenodaldisplacements,rotationsandstrainsnecessarytospecifycompletelydeformationoffiniteelement.

4.2 GENERALDESCRIPTIONOFFEM:

Inthefiniteelementmethod,theactualcontinuumofbodyofmatterlikesolid,liquid orgasisrepresentedasanassemblageofsubdivisionscalledFiniteelements.These elementsareconsideredtobeinterconnectedatspecifiedpointsknownasnodesornodalpoints.Thesenodesusuallylieontheelementboundarieswhereanadjacentelementisconsideredtobeconnected

4.3 ADVANTAGESOFFEM:

TheFEMisbasedontheconceptofdiscretization.Neverthelessaseitheravariationalorresidualapproach,thetechniquerecognizesthemultidimensionalcontinuityofthebodynotonlydoestheidealizationsportraythebody ascontinuousbutitalsorequiresnoseparateinterpolationprocesstoextendtheapproximatesolutiontoeverypointwithinthecontinuum.Despitethefactthatthesolutionisobtainedatafinitenumberofdiscretenodepoints

4.4 LIMITATION:

Onelimitationoffiniteelementmethodisthatafewcomplexphenomenonsarenot accommodatedadequatelybythemethodasitscurrentstateofdevelopment.Some examplesofsuchphenomenonformtherealmofsolidmechanicsarecrackingandfracturebehavior,contactproblems,bondfailuresofcompositematerials,andnon-linearmaterialbehavior withworksoftening.

4.5 BASIC APPROACHTO FEA SOFTWARE:

Basicapproachforanyfiniteelementanalysis(FEA)canbedividedinto threeparts

- **Pre–processors**
- **Solver**
- **Post–Processor**

4.5.1 PRE–PROCESSOR:

Pre–processormainlycontainsbuildingofmodel,meshing,assigningmaterialpropertiesetc.

4.5.1.1 UILDINGOFMODEL:

Geometryisusuallydifficultto**describe**,asithastobeasclosetoasreal.Sinceithastotakerealworldloadsandboundaryconditions,itisequal toprototypesimulated incomputer.

4.5.1.2 CREATIONOFFINITEELEMENTMODELFORMESHING:

Afterassigningmaterialpropertiesandstructuralpropertiestothemodel,meshingisdone.Meshingistheprocessofdividingthemodelintofinitenumber of finite sizedelements.

4.5.2 SOLVER: Solversaregeometrictaskoriented.Thesearedevelopedforspecificapplications.Solversaredesignedbasedoncontinuumapproachwhereinconstructionofmass,momentumandenergyequationofstate,thermodynamicequationsasandwhenrequiredforeachoftheelementsandthesolutionisobtainedbyinterpretingthesesolutions.Thesolution to theseequationsessentially dependsontwo methods

1. Implicit
2. Explicit

Choiceof the methodisbased on thenatureof problems.

4.5.3.POST–PROCESSOR:

Heretheresultsoftheanalysisarereadandinterpreted.Theycanbepresentedintheformofatable,acontourplot,deformedshapeofthecomponenttothemodeshapesandnaturalfrequenciesiffrequenciesareinvolved.Otherresultsareavailableforfluids,thermalandelectricalanalysistypes.

FEASOFTWARE– ANSYS

5.1 INTRODUCTION TOANSYS:

ANSYSStands forAnalysisSystemProduct.

Dr.JohnSwansonfoundedANSYS.Incin1970withavisiontocommercializetheconceptofcomputersimulatedengineering,establishinghimselfasoneofthepioneersofFiniteElementAnalysis(FEA).ANSYSinc.supportstheongoingdevelopmentofinnovativetechnologyanddeliversflexible,enterprisewideengineeringsystemsthatenablecompaniestosolvethefullrangeofanalysisproblem,maximizingtheirexistinginvestmentsin softwareandhardware.ANSYSInc.

5.2 EVOLUTION OFANSYS:

ANSYShasevolved intomultipurposedesignanalysissoftwareprogram,recognizedaroundtheworldforitsmanycapabilities.Todaytheprogram is extremelypowerful and easyto use.

5.3 OVERVIEWOFTHEPROGRAM

TheANSYSprogramisflexible,robustdesignanalysisandoptimizationpackage.Thesoftwareoperatesonmajorcomputersandoperatingsystems,fromPCstoworkstationsandtosupercomputers.ANSYSfeaturesfilecompatibilitythroughoutthefamilyofproductsandacrossallplatforms.ANSYSdesigndataaccessenablesusertoimportcomputeraideddesignmodelsintoANSYS,eliminatingrepeatedwork.Thisensuresenterprisewide,flexibleengineeringsolutionforallANSYSuser.

UserInterface:

AlthoughtheANSYSprogramhasextensiveandcomplexcapabilities,itsorganizationanduser-friendlygraphicaluserinterfacemakesiteasytolearnand use.

There arefour graphical methodsto instruct the ANSYSprogram:

1. Menus.
2. Dialog Boxes
3. Tool bar.
4. Directinputof commands.

Menus:

Menusaregroupingsofrelatedfunctionsoroperatingtheanalysisprogramlocated in individual windows.Theseinclude:

Dialogboxes:

Windowspresenttheuserswithchoicesforcompletingoperationsorspecifying settings.Theseboxesprompttheusertoinputdataormakedecisionsfor aparticular function.

Tool bar:

ThetoolbarrepresentsaveryefficientmeansforexecutingcommandsfortheANSYSprogrambecauseofitswiderangeofconfigurability.Regardlessofhowtheyarespecified,commandsareultimatelyusedtosupplyall thedataand control all programfunctions.

Output

window:Graphicswindo

w:

Representstheareaforgraphicdisplayssuchasmodelorgraphicallyrepresentedresultsof ananalysis.Theuser canadjustthesizeof thegraphicswindow,reducing or enlarging ittofittopersonal preferences.

Input window:

ProvidesaninputareafortypingANSYScommandsanddisplaysprogrampromptmessages.

Mainmenu:

ComprisetheprimaryANSYSfunctions,whichareorganizedinpop-upsidemenus,basedon theprogression of theprogram.

Utilitymenu:

ItcontainsANSYSutilityfunctionsthataremappedhereforaccessatanytimeduringanANSYSsession.Thesefunctionsareexecutedthroughsmooth,cascading pulldownmenusthatleaddirectly toanactionordialogbox.

Database:

TheANSYSprogramusesasingle,centralizeddatabaseforallmodeldataandsolutionresults.Modeldata(includingsolidmodelandfiniteelementmodel geometry,materialsetc) arewritten

5.4 REDUCINGTHEDESIGNAND MANUFACTURINGCOSTSUSINGANSYS(FEA):

TheANSYSprogramallowsengineerstoconstructcomputermodelsortransferCADmodelsofstructures,products,components,orsystems,applyloadsorother designperformanceconditionsandstudyphysicalresponsessuchasstresslevels,temperaturedistributionortheimpactoflector magneticfields.

Programavailability:

TheANSYSprogramoperatesonPentiumbasedPCsrunningonWndows95or WindowsNTandworkstationsandsupercomputersprimarilyrunningonUNIXoperatingsystem.ANSYSInc.continuallyworkswith newhardwareplatformsand operating systems.

Analysistypesavailable:

1. **STRUCTURALSTATICANALYSIS.**
2. **STRUCTURALDYNAMICANALYSIS.**
3. **STRUCTURALBUCKLINGANALYSIS.**
   - **LINEARBUCKLING**
   - **NONLINEARBUCKLING**

4. **STRUCTURALNONLINEARITIES**
5. **STATICANDDYNAMICKINEMATICSANALYSIS.**
6. **THERMALANALYSIS.**
7. **ELECTROMAGNETICFIELDANALYSIS.**
8. **ELECTRICFIELDANALYSIS**
9. **FLUIDFLOWANALYSIS**
    - **COMPUTATIONALFLUIDDYNAMICS**
    - **PIPEFLOW**
10. **COUPLED-FIELDANALYSIS**
11. **PIEZOELECTRICANALYSIS.5.5TYP**

ESOFSTRUCTURAL ANALYSIS:

Structuralanalysisisthemostcommonapplicationofthefiniteelement method.Thetermstructural(orstructure)impliescivilengineeringstructuressuch asbridgesandbuildings,butalsonaval,aeronauticalandmechanical structuressuchasship

5.5.1STRUCTURALSTATIC ANALYSIS:

Astaticanalysiscalculatestheeffectsofsteadyloadingconditiononastructure, whileignoringinertiaanddampingeffectssuchasthosecausedbytimevarying loads.Astaticanalysiscan,however includesteadyinertialoads(suchasgravityandrotationalvelocity),andtimevaryin gloadsthatcanbeapproximatedas staticequivalentloads(suchas thestaticequivalentwindandseismicloadscommonlydefined in manybuildingcodes.)

5.6 PROCEDURE FOR ANSYSANALYSIS:

Staticanalysisisusedtodeterminethedisplacements,stresses,strainsandforce sinstructuresorcomponentsduetoloadsthatdonotinducesignificantinertiaandda mpingeffects.Steadyloadinginresponseconditionsareassumed.Thekinds of loading thatcanbeappliedinastaticanalysisincludeexternallyappliedforcesandpressures ,steadystateinertialforcessuchasgravityorrotationalvelocityimposed(non-zero)displacements,temperatures(for thermal strain).

Theprocedurefor staticanalysisconsistsof thesemainsteps:

1. **Building themodel.**
2. **Obtainingthesolution.**
3. **Reviewingtheresults.**

5.6.1 BUILDTHEMODEL:

InthisstepwespecifythejobnameandanalysistitleusePREP7todefinetheelem enttypes,elementrealconstants,materialpropertiesandmodelgeometryelementt ypesbothlinearandnon-linearstructuralelementsareallowed.TheANSYSelementlibrarycontainsover8 0differentelementtypes.Auniquenumberandprefixidentifyeachelementtype.

E.g.BEAM94,PLANE71,SOLID96andPIPE16MATERIA

LPROPERTIES:

Young'smodulus(EX)mustbedefinedforastaticanalysis.Ifweplantoapplyin ertialoads(suchasgravity)wedefinemasspropertiessuchasdensity(DENS).Simi larlyifweplantoapplythermalloads(temperatures)wedefinecoefficient of thermal expansion(ALPX)

5.6.2 OBTAINTHESOLUTION:

Inthisstepwedefinethe analysistypeandoptions,applyloadsandinitiatethefiniteelementsolution.This involvesthreephases:

- **Pre– processorphase**
- **Solutionphase**
- **Post-processorphase**

THE FOLLOWING TABLE SHOWS THE BRIEF DESCRIPTION OF STEPSFOLLOWEDINEACHPHASE:

PREPROCESSOR PHASE	SOLUTIONPHASE	POST-PROCESSOR PHASE
GEOMETRY DEFINITIONS	ELEMENTMATRIX FORMULATION	POSTSOLUTI ONOPERATI ONS
MESH GENERATION	OVERALLMATRIXT RIANGULARIZATION	POSTDATA PRINTOUTS (FORREPOR TS)
MATERIAL	(WAVEFRONT)	POSTDATA
DEFINITIONS		SCANNING POSTDATA DISPLAYS
CONSTRAINT DEFINITIONS	DISPLACEMENT. STRESS,ETC	
LOADDE FINITION	CALCULATION	
MODEL DISPLAYS		

Table5.1

5.6.2.1 PRE –PROCESSOR:

Preprocessorhasbeendevelopedsothatthesameprogramisavailableonmicro,mi ni,super-miniandmainframecomputersystem.Thisslowseasytransfer of modelsonesystem to other.

Preprocessorisan interactivemodelbuildertopreparetheFE(finiteelement)modelandinputdata.Th esolutionphaseutilizestheinputdatadevelopedbythepreprocessor,andpreparest hesolutionaccordingtotheproblemdefinition.Itcreatesinputfilestothetemperatu reetc.,onthescreenin theformof contours.

GEOMETRICALDEFINITIONS:

Therearefourdifferentgeometricentitiesinpreprocessornamelykeypoints,lin es,areasandvolumes.Theseentitiescanbeusedtoobtainthegeometricrepresentati onof thestructure.Alltheentitiesareindependentofother and haveuniqueidentificationlabels.

MODEL GENERATIONS:

Twodifferentmethodsareusedtogeneratea model:

- **Directgeneration.**
- **Solidmodeling**

Withsolidmodelingwecandescribewecandescribethegeometricboundarieso fthemodel,establishcontrolsoverthesizeanddesiredshapeoftheelementsandthe ninstructANSYSprogramtogenerateallthenodesandelementsautomatically.By contrast,withthedirectgenerationmethod,wedeterminethelocationof everynodeandsize,shapeand connectivityofeveryelementpriortodefiningtheseentitiesintheANSYSmodel.A lthough,someautomaticdatagenerationispossible(byusingcommandssuchas FILL,NGEN,EGEN etc) thedirectgenerationmethodessentiallya handsonnumericalmethodthatrequiresustokeeptrackofallthenodenumbers as we developthefiniteelementmesh.Thisdetailedbookkeepingcanbecomedifficultforlargemodels,givingscopeformodelingerrors.Solidmodelingisusuallymorepowerfulandversatilethandirectgenerationandis commonlypreferredmethod of generatingamodel.

MESHGENERATION:

Inthefiniteelementanalysisthebasicconceptistoanalyzethestructure,whichis anassemblageofdiscretepiecescalledelements,whichareconnected,togetherata finitenumberofpointscalledNodes.Loadingboundaryconditionsarethen appliedto theseelementsand nodes.

BOUNDARYCONDITIONSANDLOADING:

Aftercompletionofthefiniteelementmodelit has to constrainandloadhastobe appliedto themodel.Usercandefineconstraintsandloadsinvariousways.Allconstraintsand loadsareassignedset1D.Thishelpstheuser to keeptrack of load cases.

MODELDISPLAY:

Duringtheconstructionandverificationstagesofthe modelitmaybenecessarytoviewitfromdifferentangles.Itis usefultorotatethemodelwithrespecttotheglobalsystemandviewit fromdifferentangles.Preprocessoroffersthis capability.By windowingfeaturepreprocessorallowstheuserto enlargeaspecificareaofthemodelforclarityanddetails.Preprocessoralsoprovidesfeatureslikesmoothness,scaling,regions,activeset, etcforefficientmodelviewingandediting.

MATERIALDEFINITIONS:

Allelementsaredefinedbynodes,whichhaveonlytheirlocationdefined.Inthe caseofplateandshellelementsthereis noindicationofthickness.Thisthicknesscanbegivenaselementproperty.Propertytablesforaparticularpropertyset1-Dhavetobeinput.Differenttypesof elementshavedifferentpropertiesfor e.g.

Beams : Crosssectional area,momentof inertiaetc

Shells : Thickness

Springs : Stiffness

Solids : None

Theuseralsoneedsto definematerialpropertiesoftheelements.Forlinearstaticanalysis,modulesofelasticityand Poisson'srationeedtobeprovided.Forheattransfer,coefficientofthermalexpansion,densitiesetcarerequired.Theycan be givento theelementsbythematerialpropertysetto1-D.

5.6.2.2 SOLUTION:

Thesolutionphasedealswiththesolutionoftheproblemaccordingtotheproblemdefinitions.All the tediousworkofformulatingandassemblingofmatricesaredonebythecomputerandfinallydisplacementsarestressvaluesaregivenasoutput.Someofthecapabilities oftheANSYSarelinearstaticanalysis,non-linearstaticanalysis,transientdynamicanalysis,etc.

5.6.2.3 POST–PROCESSOR:

Itisapowerfuluser-friendlypost-processingprogramusinginteractivecolourgraphics.Ithasextensiveplottingfeaturesfordisplayingtheresultsobtainedfromthefiniteelementanalysis.Onepicture ofthe analysisresults(i.e.theresultsinavisualform)canoftenrevealinsecondswhatwould takeanengineerhourtoassesfromanumericaloutput,sayintabularform.Theengineermay alsoseetheimportantaspectsof theresultsthat could beeasilymissedin astack ofnumericaldata.

Employingstateof artimageenhancementtechniques,facilitiesviewing of:

- Contoursof stresses,displacements,temperatures,etc.
- Deformgeometricplots
- Animated deformedshapes

RESULTSAND DISCUSSIONS

Fig.6.1.Deformationof Spindle in Boring MachineofHSSAlloyFig.6.2.DeformationofSpindle in Boring Machineof carbide Alloy

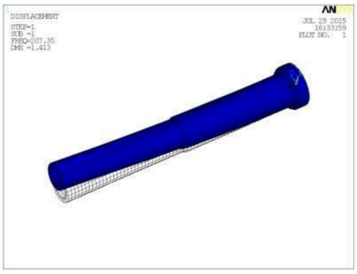


Fig.6.3.1stModeShapeof SpindleinBoringMachineofHSSAlloy

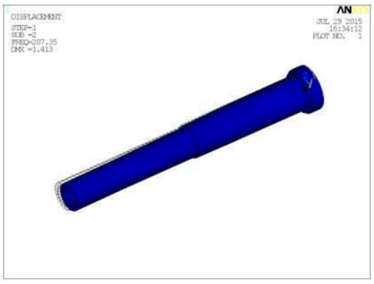


Fig.6.4.2ndModeShapeof Spindle inBoringMachineofHSSAlloy

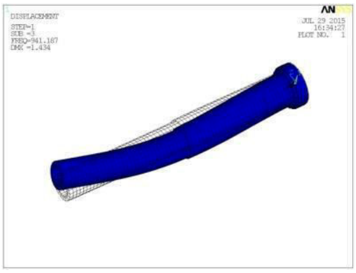


Fig.6.5.3rdModeShapeof Spindle inBoringMachineofHSSAlloy

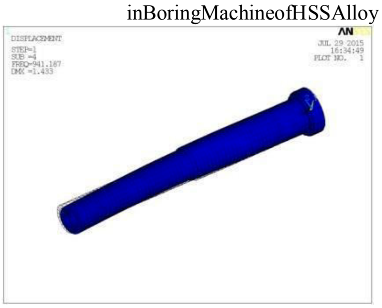


Fig.6.6.4th ModeShapeof Spindle inBoringMachineof HSSAlloy

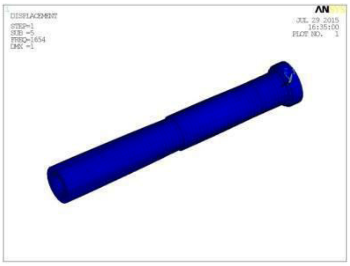


Fig.6.7. 5stMode Shape of SpindleinBoringMachineofHSSAlloy

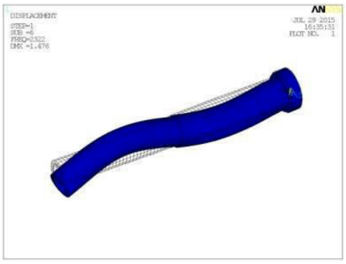


Fig.6.8.6stModeShapeof SpindleinBoringMachineofHSSAlloy

Fig.6.9.1stModeShapeof SpindleinBoringMachineof carbide Alloy

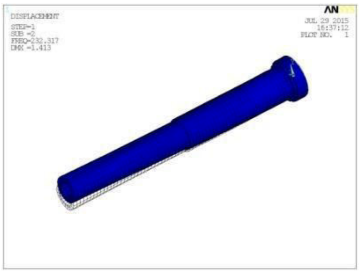


Fig.6.10.2ndModeShapeof SpindleinBoringMachineof carbide Alloy

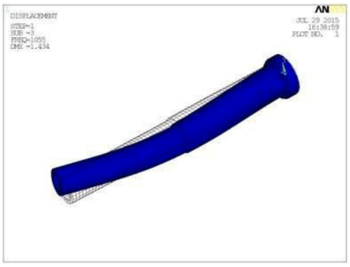


Fig.6.11.3rdModeShapeof SpindleinBoringMachineof carbide Alloy

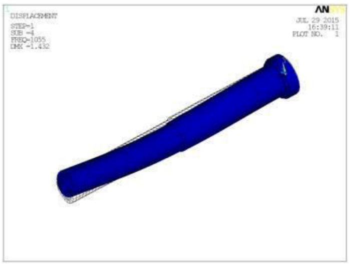


Fig.6.12.4rdModeShapeof SpindleinBoring Machineof carbide Alloy

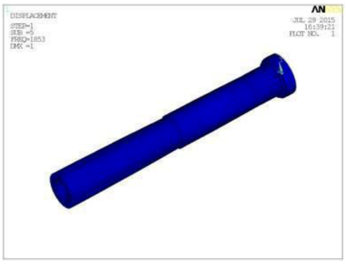


Fig.6.13.5stModeShapeof SpindleinBoringMachineof carbide Alloy

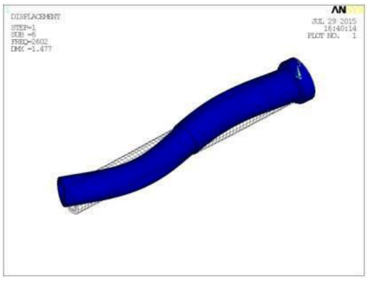


Fig.6.14.6stModeShapeof SpindleinBoringMachineof carbide Allo

CONCLUSION

1. Generally,thematerialthatisusedintheconstructionofaSpindleinBoringMachineis HSSAlloy.Butnowthebigger companieshavealreadystartedusingcarbideAlloyfortheirSpindles.Sowetriedto comparethetwomaterialsi.e.HSSAlloyandcarbideAlloyandthroughANSYSfoundouttheresultsthatwhichmaterialcanwithstandtheloadsappliedandhavelessdeformation.

2. HSSAlloygetsdeformedeasilywithsomeamountofloadswhereascarbideAlloydoesn'tgetdeformedeasilywithlessloads.AthightemperaturesHSSAlloystrengthdecreasesunlikethat carbideAlloy is heatresistantandwhenthetemperatureismorethenHSSAlloygetsverymuchaffected.

3. FromStaticAndModalAnalysisofHSSAlloyandcarbideAlloymaterials,Ihavefoundthatthecarbide Alloymaterialshavelesss DeformationandmoreFrequency values,whencomparetoHSSAlloy.So,Finally,IhaveconcludedThatthecarbideAlloyisbetterthantheHSSAlloy.

References

1.AeberliU,WannerWJ.Ontheinfluenceofdiscontinuitiesattheapplicationoftunneling machines.In:Proceedingsofthe3rdinternational congressIAEG;1978.p.7–14.

2.AlberM.Predictionofpenetration,utilizationforhardrockTBMs.In:ProceedingoftheISRMinternational conferenceofEurock'96.Rotterdam: A.A.Balkema; 1996. p.721–5.

3.BartonN.TBMtunnelinginjointedandfaultedrock.Rotterdam:A.A.Balkema; 2000.

4.BartonN,LienR,LundeJ.Engineeringclassificationofrockmassesforthedesignof tunnel support.Rock Mechanics1974;6(4):189–236.

5.BieniawskiZT.Engineeringrockmassclassification.NewYork:JohnWilley &Sons;1989.

6.BrownET.Rockcharacterizationtestingandmonitoring:ISRMsuggestedmethods.OxfordandNew York: PergamonPress;1981.

7.BrulandA.Hardrocktunnelboring.PhDThesis.Trondheim:NorwegianUniversityof Scienceand Technology;1998.

8.CheemaS.Developmentofarockmassboreabilityindexfortheperformanceoftunnelboringmachines.PhDThesis.Golden,USA:Colorado School of Mines; 1999.

9.FarmerIW,GlossopNH.Mechanicsofdisccutterpenetration.TunnelsandTunnelling 1980;12(6):22–5.

10. FarrokhE,RostamiJ,Laughton C.Analysisof unit supporting timeandsupportinstallationtimeforopenTBMs.RockMechanicsandRockEngineering 2011;44(4):431–45.

Model analysis of spindle rod

Sivasankara Gowda ,M. Ajaykumar[2], D Vijaykumar[3], Jsudha Pallavi[4].
1,2&3- Student ofmechanicalDepartment,MRCE,Secunderabad,India.
4- Assistantprofessor ofmechanicalDepartment,MRCE,Secunderabad,India.
Email[4]:-sudhapallavi24@gmail.com

ABSTRACT- Inmachinetools,aspindlearearotatingaxisofthemachine,whichoftenhasashaftatitsheart.Theshaftitselfiscalledaspindle,butalso,inshop-floorpractice,theword often isused metonicallytorefertotheentirerotaryunit,includingnotonlytheshaftitself,butitsbearingsandanythingattachedtoit(chuck,etc.).inthis paperspindlemodeliscrestedbyusingCADsoftwareandmodelanalysisiscarriedoutandresultsare enlisted.

Key words- spindlerod,modelanalysis,

I. INTRODUCTION

Amachinetoolmayhaveseveralspindles,suchastheheadstock andtailstock spindles onabenchlathe.Themainspindleisusuallythebiggestone. Referencesto"thespindle"withoutfurtherqualificationimply themainspindle.Somemachinetoolsthatspecializeinhigh-volumemassproductionhaveagroupof4,6,orevenmoremainspindles.Thesearecalled**multispindle**machines.Forexample, gangdrillsandmanyscrewmachinesaremultispindlemachines.Althoughabenchlathe hasmorethanonespindle(countingthetailstock),itisnotcalledamultispindlemachine;ithasonemainspindle.

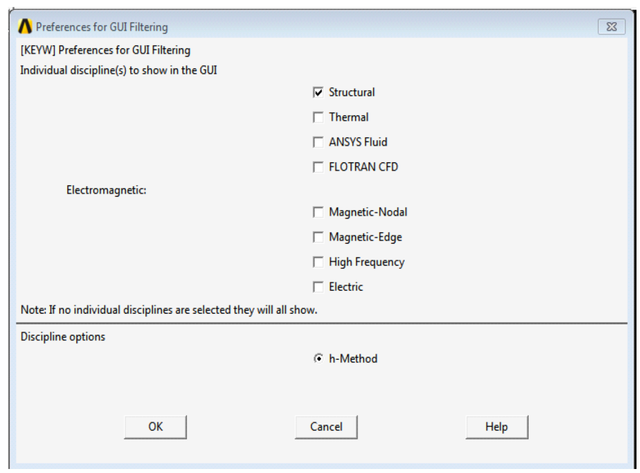
SpindleBearings:Type,Quantity,Mounting,andLubricationMethod

Oneofthemostcriticalcomponentsofanyhighspeedspindledesignisthebearingsystem.Ourdesignrequirementsstatethatthespindlemustprovidehighrotationalspeed,transfertorqueandpowertothecuttingtool,andbecapableofreasonableloadingandlife.Thebearingtypeusedmustbeconsistentwiththesedemands,or thespindlewillnotperform.Highprecisionbearingsareavailabletodayfromavarietyofmanufacturersworldwide.Thetypeofbearingsavailableforhighspeedspindlesincludesroller,taperedrollerandangularcontact ball bearings. Theselectioncriteriaofwhichtypetousewilldependuponthespindlespecifications,aseach willhave animpactor impactuponthebearingselection,asthefollowingtableexplains.

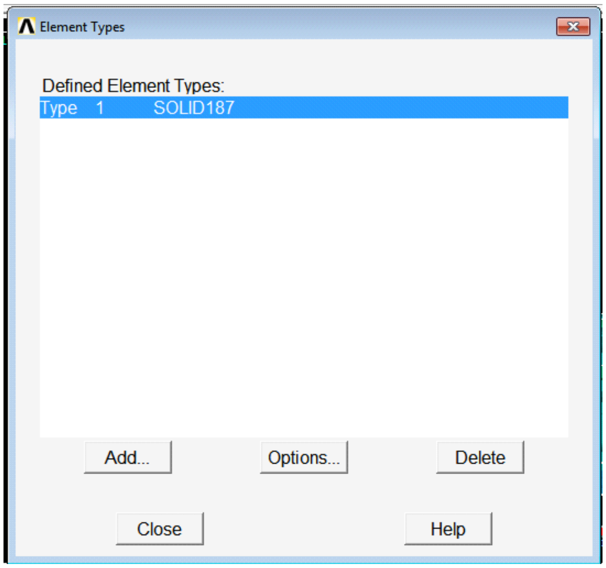
Requirement	**Best Bearing Type**	**DesignImpact**
High Speed HighStiffness AxialLoading RadialLoading HighAccuracy	SmallAngularContact Large Roller High Contact Angle Low Contact	SmallShaft,LowPower Low Speed, Large Shaft LowerSpeed HigherSpeedExpensive,LowSpeed

Asyoucansee,therearemanyfactorsthatdeterminethefinaldecision.Aspindlethatisdesiredtohavethe highestspeedwillnothavethemaximumstiffnesspossible,and ,thespindlewiththehigheststiffnesscannotrunathighspeeds withoutsacrificingbearinglife.So,asdesigners,compromises mustbemadeinordertoarriveatafinaldesignthatwillofferthecompromise.

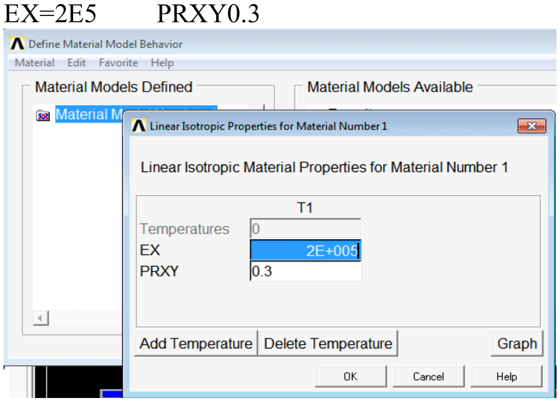
II. ANALYSIS PREFERENCES–STRUCTURAL



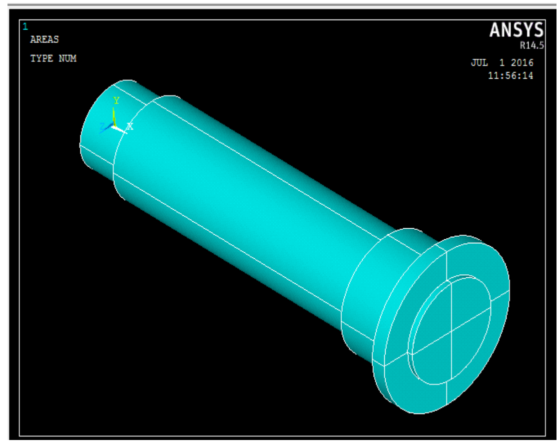
ELEMENTTYPE–ADD–SOLID187



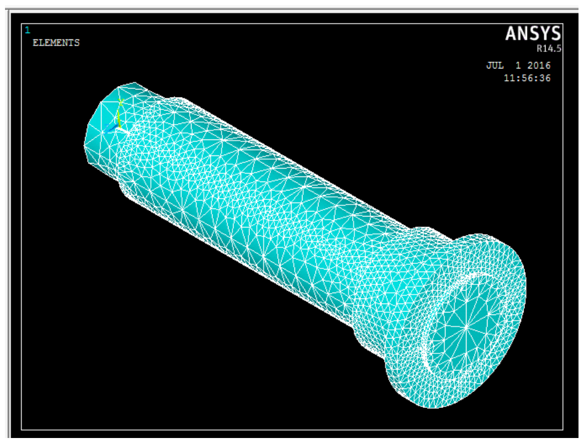
MATERIALPROPERTIES–STRUCTURALLINEAR
ELASTICISOTROPI
C
EX=2E5 PRXY0.3



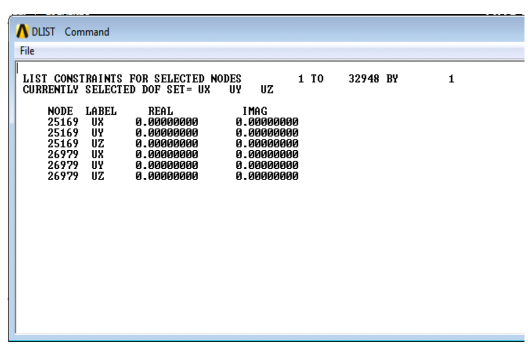
MODELING–CREATE–KEYPOINTSLINES
CREATE–
AREASARBITRARY
BYLINES
SELECTALLLINES
OPERATEEXTRUD
EBYAXISOK



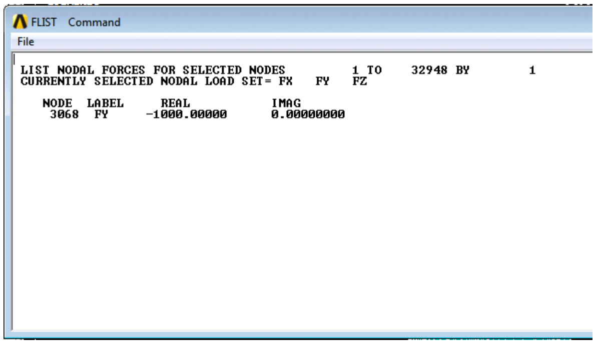
MESHING–VOLUMESFREE
SELECTVOLUMEO
K



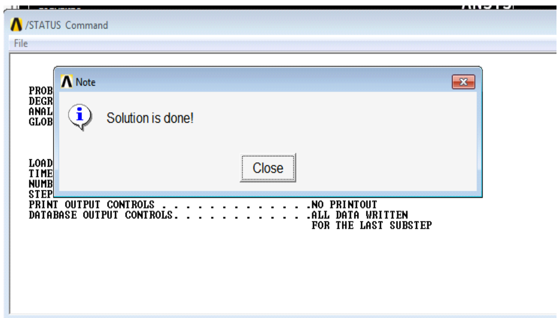
LOADS–
DEFINELOADSAPPLY
STRUCTURALDISP
LACEMENTONARE
ASSELECTTHEARE
AALLDOF



FORCE–
ONNODESSELECTTHENO
DE

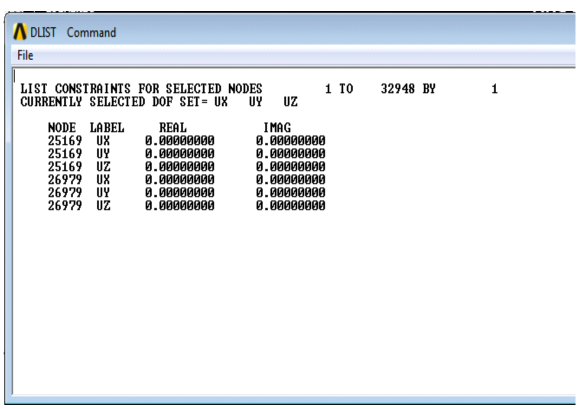


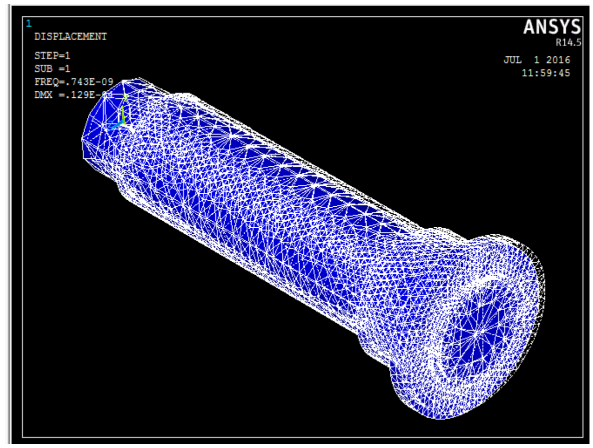
SOLUTION -
SOLVECURRENTLS
OK



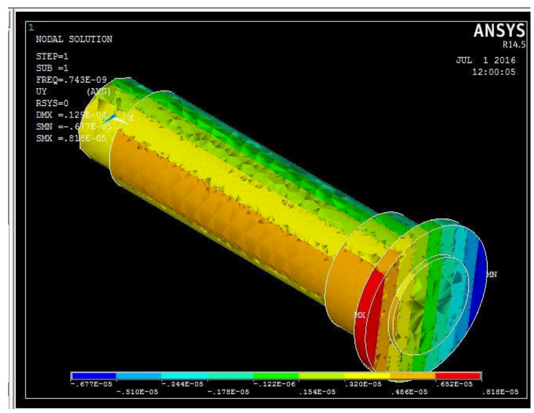
III. RESULTS

POSTPROCEDURE–
READRESULTSRESULTSSUMMERY

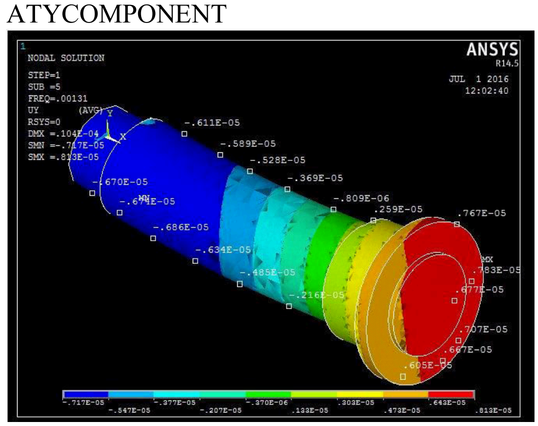




PLOTRESULTS-
CONTOUREDPLOTDEFORMATION
ATYCOMPONENT

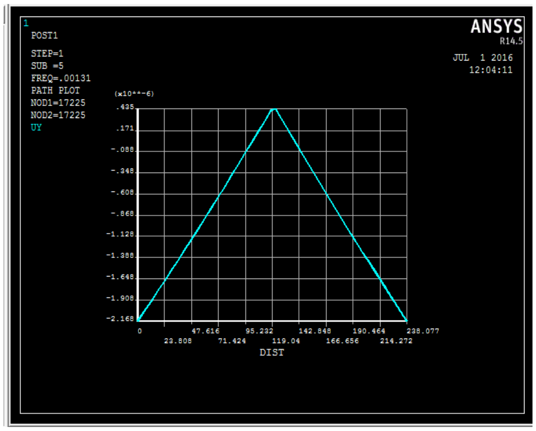


PLOTRESULTS-
CONTOUREDPLOTVONMISESSTRESS
ATYCOMPONENT

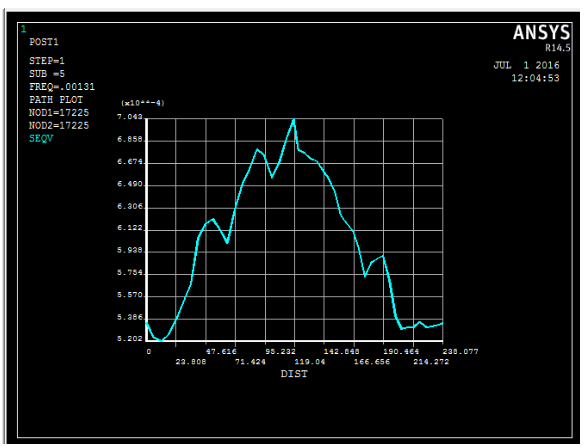


PLOT–NODES
POSTPROCEDURE–
PATHOPERATIONSDEFINEPATH
SELECTNODES–
OKMAPONTOPATHSELE
CTDOFATY-OK

PLOTPATHITEMO
NGRAPHSELECTU
Y



PLOT–NODES
POSTPROCEDURE–
PATHOPERATIONSDEFINEPATH
SELECTNODES–
OKMAPONTOPATHSELE
CTDOFATY-
OKPLOTPATHITEM
ONGRAPHSELECTVONMISESSTRESS-
OKPLOTPATHITEM
ONGRAPHSELECT
SEQY



IV. CONCLUSION

In modernmachine toolapplicationsthe performanceofamachine toolisjudgedbyitsabilityto producework-piecesaccuratelyandefficiently.Thestiffnessofthemachine toolspindlehasaprofound impact on the overallmachineperformance.Theworkpresentedhereprovides atoolformachinetoolspindledesignerstodevelopspindlesthat aresufficientlystifftomeettheirneeds. Theanalysispresentedhereismodalanalysisofspindlerod.Themodalanalysiscalculatesthelateraldeflectionwithfrequencyoftimeofthespindle-bearing system. Theobjectiveofthispresentworkistoestimatethedeflection,stressesinducedatfrequenciesandthevonmisesinthemachinetoolspindle.Theemphasisinthisprojectisontheapplicationofcomputeraidedanalysisusingfiniteelement.Appropriateboundaryconditionsareapplied,materialpropertiesaregivenandloadsareappliedasperitsdesign,theresultantdeformationandstressesandthefrequencyofmodeshapesobtainedarereportedand discussed.

REFERENCE

[1]Tischuk,L.,Solomonov,K.,2013.Marketanalysisofsoftwareproductsdesignedtosimulatetechnologicalprocesses.BulletinoftheKaragandaStateIndustrial University2,50–55.

[2]Lisunets,N.,Solomonov,K.,Tsepin,M.,2009.Bulkformingofaluminumbillet.Mechanical Engineering,Moscow.

[3]Solomonov,K.,2011.Simulationofmorphogenesisofforgings:researches,hypotheses,developments.LAMBERTAcademicPublishing,Saarbrücken.

[4]Nadai,A.,1954.Plasticityandfractureofsolids.StateTechnicalPublishing, Moscow.

[5]Ilyushin, A.,1948.Plasticity.StateTechnical Publishing, Moscow.

[6]Solomonov,K.,Kostarev,I.,Abashkin,V.,2008.Simulationofprocessesbulkformingandforgingofflatblanks.PublishingHouseoftheMoscow Instituteof Steel andAlloys,Moscow.

[7].JamieCorcoran,ErikHahn,BarrettMarion,JonathonPangbomandJeffrey Spencer(2000),"Computer-AssistedDesignofPre-FormandFinisher Diesfor ColdForging of Aluminum".

[8]CatarinaCastro,LuisaSousa,C.A.C.AntonioandJ.M.ACesardeSa(2001), "Anefficient Algorithmtoestimateoptimal preformdieshape

NITRO SHOCK ABSORBERS

C.Shashikanth, Venu, B. Rajendra Prasad, Sivasankara Gowda
MechanicalDepartment, MRCE,Secunderabad

Abstract- *Inthepresentscenarioofautomobileindustrymanufacturersaretryingtoproducecomfortableandsafevehicleswhichtheconsumersarelookingfor.As hockabsorberisadampingelementofthevehiclesuspension,anditsperformancedirectlyaffectsthecomfortability,dynamicloadofthewheelanddynamicstrokeofthesuspension.Theconventionaltypeofshockabsorbershasgotthemaindrawbackthatitcausesfoamingofthefluidathighspeedsofoperation.Thisresultsinadecreaseofthedampingforcesandalossofspringcontrol.Thegasfilled(nitrogen)shockabsorbersaredesignedtoreducefoamingoftheoilandprovideasmoothridefora longperiod.*

Keywords*-nitro,shockabsorbers,suspension,spring,dynamic load*

I. INTRODUCTION

Forasmoothandcomfortableridethedisturbingforcesshouldbeeliminatedorreducedconsiderablybyusingsomedevices.Shockabsorbersaresuchdeviceswhichisolatethevibrationsbyabsorbingsome disturbingenergythemselves.Ofthemanytypes telescopicshocksarewidelyusedwhichhasgotthedrawbackthattheflowof oilinthecylindercancausefoamofoilandairtoform.Theselimittheoptimum throughoutoftheflowinthevalves.Gasshocksrepresentanadvanceovertraditionalshocks.Nitrogenfilledgasshockabsorbersaretheresultsofyearsofextensiveresearchanddevelopmentwithtopflightshockdesignengineers.Theyaredesignedforbothloweredandstockvehiclestoprovideshockabsorbersthatwouldoutperformanythingonthemarkettoday.Nitroshockabsorbers arehighquality,nitrogenfilledshocksdesignedandgaschargedspecifically foreachvehicleapplication.Theadditionofnitrogenunderpressurelimitsthefoamingeffectandincreasesefficiency.

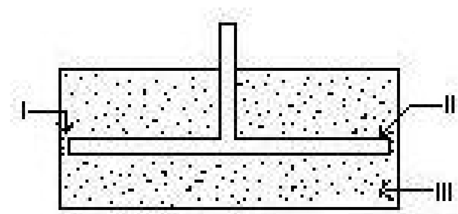
A. Need for shockabsorbers:

Springs alone cannot providea satisfactorily smooth ride.Thereforeanadditionaldevicecalleda“shockabsorber”isusedwitheachspring.Considertheactionofacoilspring.Thespringisunderaninitialloadprovidedbytheweightofthevehicle.Thisgivesthespringanoriginalamountofcompression.Whenthewheelpassesoverabump,thespringbecomesfurthercompressedafterthebumpis passedthe springattemptsto returntoitsoriginalposition.Howeveritoverridesitsoriginalpositionandexpandstoomuch.Thisbehaviorcausesthevehicleframetobethrownupward. Havingexpandedtoomuch,thespring attemptstocompress thatitwillreturn toitsoriginalposition;but incompressingit againoverrides.In doing this thewheelmayberaisedclearof the roadandthe frameconsequentlydrops.Theresultisanoscillatingmotionofthespringthat causesthewheeltoreboundorbounceupanddownseveraltimes, aftera bump is encountered.If,inthemeantime,anotherbumpisencountered,asecondseriesofreboundingwillbestarted.Onabumpyroad,andparticularlyinrounding acurve,theoscillationsmightbesoseriousasto causethedriverto losecontrolofthevehicle.

Ashockabsorberisbasicallyahydraulicdampingmechanismforcontrolling springvibrations.Itcontrolsspringmovementsinbothdirections:whenthespringiscompressedandwhenitisextended,the amountof resistanceneededineachdirectionis determinedbythetypeofvehicle,thetypeofsuspension,thelocationoftheshockabsorberinthesuspensionsystemandthepositioninwhichitismounted. Shock absorbers areacriticalproductthatdeterminesanautomobile’scharacternotonlybyimprovingridequalitybutalsobyfunctioningtocontroltheattitudeandstability ofthe automobilebody.

B. Principleofoperation:

Thedampingmechanismofa shock absorber is viscousdamping.Viscosityisthepropertyofafluidbyvirtueofwhichitoffersresistancetothemotionofonelayerovertheadjacenton.Themaincomponents ofa viscousdamperarecylinder, pistonandviscousfluid.Thereisaclearancebetweenthecylinderwallsandthe piston.Moretheclearancemorewillbethevelocityofthepistonintheviscousfluidanditwillofferlessvalueofviscousdampingcoefficient.Thebasicsystem isshownbelow.Thedampingforceisoppositetothedirectionofvelocity.



I-CLEARNCE,II-PISTON,III-VISCOUSFLUID

Fig.1.1componentsofviscousdamper

Thedampingresistancedependsonthepressuredifferenceonthebothsidesofthepistonintheviscousmedium.Thefigureshownbelowshowsthe exampleof freevibrationswithviscousdamping.

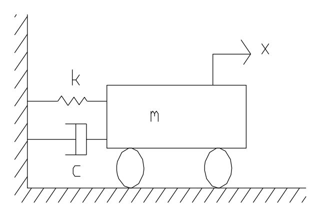


Fig.1.2Freevibrationswithviscousdamping

Theequationof motionforthesystem canbewrittenasm$(dx/dt)^2$ + c(dx/dt)+kx=0

C. Energydissipationinviscousdamping:

Foravibratorybodysomeamountofenergyisdissipatedbecauseof damping.Thisenergydissipationcanbepercycle.RateofchangeofworkWi scalledenergy.Foraviscouslydampedsystemthe forceFis expressedas F=cdx/dt,
WorkdoneW=Fx= (cdx/dt)x
Therate ofchangeof workper cycle
i.e.Energydissipated

$$\Delta E = \int_0^{2\Pi/\omega} (Fx)dt = \int_0^{2\Pi/\omega} c(dx/dt*dx/dt)dt = \int_0^{2\Pi/\omega} c(dx/dt)^2 dt$$

Let usassumethe simpleharmonicmotion ofthetypex=Asinωt

$$(dx/dt)^2=\omega^2A^2\cos^2\omega t$$

Theequationfor

$$\Delta E = \int_0^{2\Pi/\omega} c\,\omega^2A^2((1+\cos 2\omega t)/2)dt = \Pi c\,\omega A^2$$

Thisshowsthattheenergydissipationpercycleisproportionaltothe squareofthe amplitudeofmotion. Thetotalenergyofavibratingsystemcanbeeithermaximumofitspotentialo r kineticenergy.The maximumkineticenergy ofthesystemcanbewrittenas

$$E = (KE)max = 1/2mx^2max$$
$$=1/2m\omega^2A^2$$

II. SHOCKABSORBERACTION

Shockabsorbersdevelopcontrolorresistancebyforcingfluidthroughr estrictedpassages.Across-sectionalviewofatypicalshockabsorberisshownbelow.Itsmaincompone ntsandworkingisalsogivenbelow.

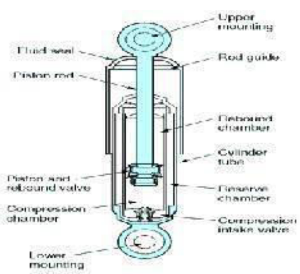


Fig.2.1Theinsidepartsof ashockabsorber

Theuppermounting isattachedtoapistonrod.Thepistonrodisattachedtoapistonandreboundval veassembly.Areboundchamberislocatedabovethepistonandacompressio nchamberbelowthepiston.Thesechambersarefullofhydraulicfluid.Acom pressionintakevalveispositionedinthebottom ofthecylinderandconnectedhydraulicallytoareservechamberalsofullofh ydraulicfluid.Thelowermountingisattachedtothecylindertubeinwhichthe pistonoperates.

During compression,the movementof the shock absorbercausesthepistontomovedownwardwithrespecttothecylindertub e,transferringfluidfromthecompressionchambertothereboundchamber. Thisisaccomplishedbyfluidmovingthroughtheouterpiston holeandunseatingthepistonintakevalve.

Duringrebound,thepressureinthecompressionchamberfallsbelow thatofthereservechamber.Asaresult,thecompressionvalvewillunseatand allowfluidtoflowfrom thereservechamberintothecompressionchamber.Atthe sametime,fluidin thereboundchamberwillbetransferredintothecompressionchamberthrou ghthe innerpistonholesandthe reboundvalve.

A.Whygasfilledshockabsorbers?

Therapidmovementofthefluidbetweenthechambersduringtherebou ndandcompressionstrokescancausefoamingofthefluid.Foamingisthemi xingoffreeairandtheshockfluid.Whenfoamingoccurs,theshockdevelops alagbecausethepistonismovingthroughanairpocketthatoffersupresistanc e.Thefoamingresultsina decreaseofthe dampingforcesanda lossofspringcontrol.

During themovementof the piston rod,the fluididforcedthroughthevaluingofthepiston.Whenthepistonrodismovingq uickly,theshockabsorbersoilcannotgetthroughthevaluingfastenough,whi chcausespressureincreasesinfrontofthepistonandpressuredecreasesbehin dthepiston.Theresultisfoamingandalossofshockabsorbercontrol.Theneed foragasfilledshockabsorberariseshere.

III. GASFILLEDSHOCKABSORBERS

Thegasfiledshockabsorbersisdesignedtoreducethefoamingoftheoil. Itusesapistonandoilchambersimilartoothershockabsorbers.Thedifferenc eisthatinsteadofadouble tubewithareservechamber,adividingpistonseparatestheoilchamberfromt hegaschamber.Theoilchambercontainsspecialhydraulicoilandthegascha mbercontainsnitrogenat25timesatmosphericpressure.Theschematicdiag ramshowingthe insidepartsofagasfilled shockabsorberis shown below.

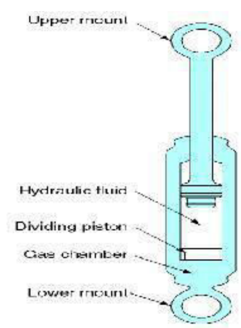


Fig.3.1Theinsidepartsof agas-filledshockabsorber.

Whenthepistonrodismovedintotheshockabsorber,oilisdisplacedasin doubletubeprinciple.Thisoildisplacementcausesthedividingpistontopress inthegaschamber,thusreducingitinsize.Withthereturnofthepistonrodtheg aspressurereturnsthedividingpiston toitsstartingposition.

Wheneverthe oil columnis held ata staticpressureofapproximately25timesatmosphericpressure,thepressured ecreasesbehind,theworkingpistoncannotbehighenoughforthegastoexitfro mthe oil column.Consequently,the gasfilledshockabsorberoperateswithout foaming.

IV. TYPESOFGASFILLEDSHOCKABSORBERS

1. Twin–tubewithlowpressuregas.
2. Single-tubewithhigh pressuregas.

A. Lowpressuretwin-tubeshocks:

Twin-tubegastechnologydesignretainstheclassicaltwin-tubewhileaddingatthetopofthereserve tubenitrogenunderrelatively lowpressure2.5-5barsinsteadof25-30barsusedinhighpressureshockabsorbers.Thispressureissufficienttorad icallyimprovethe efficiencyofthe shockabsorbers.

B. High pressuresingle-tubeshocks:

Gasshockabsorbersoperateinthesameprincipleofmovementof thepistoninanoilfilledtubebuttheycontainatoneendasmallquantityofnitr ogenunderhighpressure(25bars).Thegasispreventedfrommixingwiththe oilbyafloatingpiston.Whenthepistonrodpassesintothebodyanddisplaces oil,theoilcompressesthenitrogenevenfurther.Thevolumeofgaschangespl aying theroleasanequalizationtube.Thepermanentpressureexertedontheoilbyt hegasguaranteesaninstantaneousresponseandthequieterpistonvalveoper ation.Atthesametimethisconstantpressureeliminatescavitationsandfoam ingwhichcouldmomentarilydegradethe effectivenessoftheshockabsorber.

a) TWIN– TUBESHOCK ABSORBERS:Themaincomponentsare:

- Outertube,alsocalledreservoirtube
- Innertube, alsocalledcylinder
- Piston connected toa pistonrod
- Bottomvalve,alsocalledfootvalve
- Upperandlower attachment

Howdoesitwork?B ump Stroke:

Whenthepistonrodispushedinoilflowswithoutresistancefrombelow thepistonthroughtheorificesandthenon-returnvalvetotheenlargedvolumeabovethepiston.Simultaneously,aquant ityofoilisdisplacedbythevolumeoftherodenteringthecylinder.Thisvolum eofoilisforcedtoflowthroughthebottomvalveintothereservoirtube(filled withair(1bar)ornitrogengas(4-8bar)).Theresistance,encounteredbytheoil passingthroughthefootvalve,generatesthe bump damping.

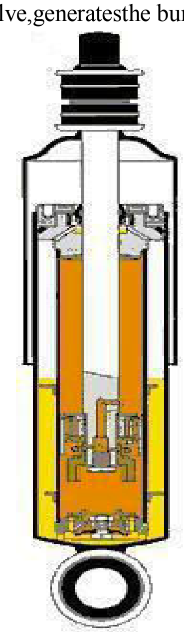


Fig.4.1bumpstrokeoftwintubeshockabsorber

ReboundStroke:

Whenthepistonrodispulledout,theoilabovethepistonispressuri zedandforcedtoflowthroughthepiston.Theresistance,encounteredbytheo ilonpassingthroughthepiston,generatestherebound damping.Simultaneously,some oil flowsback,withoutresistance,fromthereservoirtubethroughthefootvalvet othelowerpartofthecylindertocompensatefor thevolumeofthepistonrode merging fromthe cylinder.

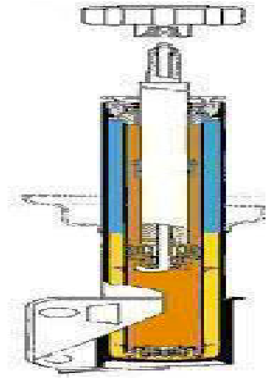


Fig.4.2reboundstrokeoftwintubeshockabsorber

b) MONO-TUBESHOCKABSORBERS:Themaincompo nentsare:

- Pressurecylinder,also called housing
- Piston rodconnected toapistonrod
- Floatingpiston, also calledseparatingpiston
- Piston rodguide
- UpperandlowerattachmentH

owdoesitwork?
Bump Stroke:

Unlikethebi-tubedamper,themono-tubehasnoreservoirtube.Still,apossibilityisneededtostoretheoilthatisdispl acedbytherodwhenenteringthecylinder.Thisisachievedbymakingtheoilca pacityofthecylinderadaptable.Thereforethecylinderisnotcompletelyfilled withoil; the lowerpart contains (nitrogen)gasunder20-30bar.Gasandoilareseparatedbythefloatingpiston.Whenthepistonrodispu shedin,thefloatingpistonisalsoforceddownthe displacement ofthe pistonrod,thusslightlyincreasingpressureinbothgasandoilsection.Also,the oilbelowthepistonisforcedtoflowthroughthepiston.Theresistanceencount eredinthismannergeneratesthe bump damping.

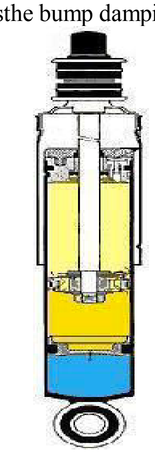


Fig.4.3bumpstrokeofmonotubeshockabsorberReboundSt roke:

Whenthepistonrodispulledout,theoilbetweenpistonandguidei sforcedtoflowthroughthepiston.Theresistanceencounteredinthismanner generatestherebounddamping.Atthesametime,partofthepistonrodwille mergefromthecylinderandthefree(floating)pistonwillmoveupwards.

V. ADVANTAGESOFNITROSHOCKS

Instantaneousresponse:

- Becausethehighpressureeliminatesaeration(foaming),action is alwaysis immediate.

- Thelowmassofgasandthesingletubefurtherimprovesresponsetime.

Better fade resistance:

- Sincethereisnooutertube,coolingismuchbetterwhichgivesadrasticreductioninfade.Thusmoreconsistenthandlingand control.

Betterdurability:

- Single-tubeconstructionalsoallowsfora largerinternalworkingarea,reducing stressand fatigueforbetterdurability.
- DeCarbon'smonodiesvaluingsystemfeaturesa singlemovingpartthatdrasticallyreducesinertiaandfriction,toimprovedurabilityandperformance.
- Bettercoolingofthemonotubedesignresultsin loweroperatingtemperaturesand thuslonger life.

Noneed for re-adjustment:

- Theviscosity ofhydraulicfluidchangesastemperaturechanges.Thismaybecauseofclimate,season(summer/winter)orheavyduty(motorway cruising).Thehighpressuregascompensatesimmediatelyandautomaticallyforchangesinviscosity.

TIPSBEFOREMOUNTING:

Astiffsuspensiondoes notnecessarilymeangoodhandling.Oftenthecontrary.Ifstillastiffsuspensionisneededitshouldcomefromthesprings.Thefunctionoftheshockabsorberistodampenoscillationsofthespringbyconvertingenergytoheat.Donotuseshockabsorberstoobtainastiffsuspension.Shockabsorbersandspringseachhavetheir ownfunction.Respectthosefunctions.

Donotusenewshockstocompensateforoldandtiredsprings.Theshockswillsoonfailwhenthespringsarebad.Wornshocksdonotonlyreducesafetyandhandling,theyalsoincreasetheriskofhavinga broken springas thespringis allowedto oscillate.

When tobuyshocks?

Shock absorberslasta long time,but they tend to degradeslowlythroughouttheir life.So when is it timetoreplacethem?

Insomecases,asealwillrupture.Ashockcoveredinoilisagoodindicationthatithasfailed.Theage-oldtestofbouncingonafenderisreallyonlyaroughguideastowhetherthevehicleneedsnew shocks.Usually the slow degradationin shock absorbersperformancewon'tbe noticed until it affectshandling fairlydramatically.Dependingonhow roughtheroadsare,modernshockscanlast80-100,000miles,butrememberthatashockwith60,000milesonitwon't performaswellas anewone.

Which onesareright?

Choosingwhichshockstobuylargelydependsuponwhatkindofvehicleandthekindofdriving.Aswithmostautomotivecomponents,itisimportant thespecificvehicle,sincemismatchedshockscandrasticallyaffecthandling andcouldevenbedangerous.Thebestadvicewillprobablycomefromamechanicwhoisfamiliarwiththe vehicle.

VI. CONCLUSION

Inthecurrentscenarioofautomobileindustrytheneedforvehicleswhichprovidessmoothandcomfortrideisgrowing.Nitroshock absorbers aredesignedtobe ultimatein performanceand comfort.Ina countrylikeours whoseroadsarenotup to worldstandardstheneedforautomotivecomponentslikenitroshocksarenecessary.Itgoeswithoutsayingthatiftherightchoiceismadetheimprovementsinvehiclesrideandhandlingcanbeshocking.

REFERENCES

[1]"InForAShock",S.B.LBeohar;MechanicalSystemsandSignalProcessing.
[2] Automotive Encyclopedia;Tobolt,Johnson.
[3] AutoMechanicalFundamentals,Stockel.
[4] http://belltech.net/
[5] http://monroeshocks.com

ISBN: 978-93-85101-61-8

Proceedings of the

International Conference on Future Technologies in Mechanical Engineering

23rd, 24th Jan 2015

Malla Reddy College of Engineering, Hyderabad-500100

About MRGI

Malla Reddy group of institutions is one of the biggest conglomerates of hi-tech professional educational institutions in the state of Telangana, established in 2001 sprawling over 200 acres of land. The group is dedicated to impart quality professional education like pharmacy, Engineering & Technology, MCA, MBA courses. Our sole objective is to turn out high caliber professionals from those students who join us.

About MRCE

Malla Reddy College of Engineering (Formerly CM Engineering College) has been established under the aegis of the Malla Reddy Group of institutions in the year 2005, a majestic empire, founded by chairman Sri. Ch. Malla Reddy Garu. He has been in the field of education for the last 22 years with the intention of spearheading quality education among children from the school level itself. Malla Reddy College of Engineering has been laid upon a very strong foundation and has ever since been excelling in every aspect. The bricks of this able institute are certainly the adept management, the experienced faculty, the selfless non-teaching staff and of course the students.

About Conference

ICTIMES started long back with its banner to promote the vision of future technologies that change the trends of life on this planet earth. Under this banner, the Department of Mechanical Engineering at MRCE organizes the ICFTME-International Conference on Future Technologies in Mechanical Engineering to provide a scholarly platform to ignite the spirit of research and bring out the latent potential in teaching fraternity and student community. ICFTME accommodates major areas like, Thermal Engineering, Design Engineering, Materials Science and Manufacturing Technology, CAD/CAM/CIM, I.C. Engines and Fluid Mechanics.

ICFTME Focuses to identify the innovations in Energy development and Conservation, innovations in new materials and their applications, creative design concepts and advanced methods of analysis of complex systems and components and research in alternate fuels for sustainability.