

Modal Analysis of an Adhesive Joint

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ABSTRACT: Adhesive bonding is widely used for sheet metal joining. Single lap joints are considered as a good category joint for sheet metals. Here, investigation on single lap adhesive joint is to be done for the vertical loaded high finished aluminium frames. Adherend used is aluminium 99.5% with the same specimen size while adhesive used is Loctite E-30CL. Overlap length is kept constant. Adhesive layer thickness has to be varied in the defined range of 0.05 mm to 0.6 mm. Total six model specimens are drawn. Modal analysis is done by using Ansys to see the nature of changes in the Natural frequencies of single lap adhesive joint. Natural frequencies and Maximum displacement at various modes have been studied. Characteristic are plotted.

KEYWORDS: Adhesive joint, single lap, Ansys, Natural frequency, Maximum displacement.

I. INTRODUCTION

In the 1940s, adhesive bonding became importance in structural bonding in aircraft industry. The subject of adhesives became even more interesting to scientists when the application of synthetic resins as adhesives for wood, rubber, glass and metals were discovered. Adhesive bonding as an alternative method of joining materials together has many advantages over the more conventional joining methods such as fusion and spot welding, bolting and riveting. Adhesive bonding is gaining more and more interest due to the increasing demand for joining similar or dissimilar structural components, mostly within the framework of designing light weight structures.

Adhesive Bonding [1]: Adhesive bonding is a material joining process in which an adhesive, placed between the adherend surfaces, solidifies to produce an adhesive bond (Figure1). When we bond components together the adhesive first thoroughly wets the surface and fills the gap between, then it solidifies. When solidification is completed the bond can withstand the stresses of use. Adhesives come in several forms thin liquids, thick pastes, films, powders, pre-applied on tapes, or solids that must be melted. Adhesive can be designed with a wide range of strengths, all the way from weak temporary adhesives for holding papers in place to high strength structural systems that bond cars and airplanes.

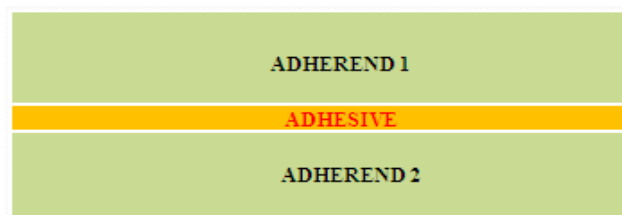


Figure 1: Adhesive Bond^[1].

Epoxy Adhesive [1]: Epoxy adhesives consist of an epoxy resin plus a hardener. Upon cure, epoxies typically form tough, rigid thermo-set polymers with high adhesion to a wide variety of substrates and superior environmental resistance. When using a one-part heat-cure system, the resin and a latent hardener are supplied already mixed and

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 4, Issue 6, June 2015

typically need to be stored refrigerated or frozen. By heating the system, the latent hardener is activated causing cure to initiate. The epoxy will normally start to cure rapidly at temperatures of 100 to 125°C (212 to 257°F) and cure times of 30 to 60 minutes are typical. Heat curing also generally improves bond strengths, thermal resistance and chemical resistance. When using a two-part system, the resin and hardener are packaged separately and are mixed just prior to use. This allows more active hardeners to be used so that the two-part epoxies will rapidly cure at ambient conditions.

Adhesives [2]: Adhesive is defined as a material that is capable of joining bodies together by surface adhesion and internal strength without the structures of the bodies undergoing any changes. The process of this adhesion is called bonding and the bodies are called adherents.

Advantages [3]-

- The adhesives materials allow joint substrates with different geometries, sizes and composition. With the adhesive we can joint glass, plastics, metals, ceramics ...
- The use of adhesives eliminates the corrosion associated with dissimilar metals joining with different galvanic potential, such as the joining of steel with aluminium.
- Great flexibility in the product design as well as an improvement in its aesthetics.
- Reduction of the product weight.
- Increasing the resistance to impact and fatigue resistance using elastic adhesive, increasing reliability and product life cycle.
- Homogeneous distribution of tensions throughout the union allowing the elimination of stress concentrations that can lead to the fracture of the union.
- Reduction of noise and vibration.
- Reduction in the number of components such as screws, nuts, washers, rivets, etc ... necessary for the union, reducing the manufacturing cost of the union.

Disadvantages [3]-

- Time to cure - The final strength of the adhesive bond is not obtained immediately, unlike the case with a rivet or a screw, you must wait a time to solidify or cure the adhesive..
- Resistance to temperature - Adhesives are polymer-based materials, for this reason the adhesives and glues have an average resistance to temperature.
- Ageing - The long-term strength of adhesive bonding is affected by various physical and chemical actions which are in the environment, actions such as ultraviolet light, chemical attacks on the environment, presence of moisture.
- Surface Preparation - As in the process of painting, surface preparation required prior to adhesive application process in order to achieve good adhesion between the adhesive and the substrate.
- Removal or disassembly – As in welding or rivet process, the process of disassembly of adhesive joints can destroy or distort the substrates joint together, being an expensive process to do, this does not happen when using technique such as bolting.

II. PROBLEM DEFINITION

Adhesive joints of aluminium as adherend sheet material have been considered in this work. Basic single lap adhesive joint is represented in figure 1.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 4, Issue 6, June 2015

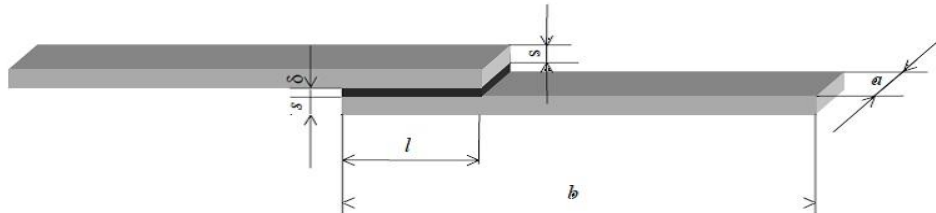


Figure2: Single lap adhesive joint^[6]

Thin plates from aluminium with dimensions[6]: $a \times b \times s = 30 \times 130 \times 1.95$ mm are to be bonded with two component epoxy adhesive Loctite E-30CL. Here “l” is overlap length which is optimized at 40mm for maximum joint capacity. Generally, increasing of the overlap length leads to the increasing of the joint strength due to increased area of bonding. It should be pointed also that an optimal design of the bonded joint depends not only on the overlap length, but also on the applied adherend and adhesive material. Adhesive layer thickness is to be varied in between 0.05mm to 0.6 mm. Loctite® Hysol® Product E-30CL[5] is a low-viscosity, industrial grade epoxy adhesive. Once mixed, the two-part epoxy cures at room temperature with minimal shrinkage and forms an ultra clear adhesive bond line with excellent impact resistance.

III. MATERIALS AND METHOD

Overview of Ansys:

The ANSYS[7] computer program is a large scale multipurpose finite element program, which may be used for solving several classes of engineering analyses. As ANSYS has been developed, other special capabilities, such as sub structuring, sub modelling, random vibration, free convection fluid analysis, acoustics, magnetic, piezoelectric, couple field analysis and design optimization have been added to the program.

Analysis of any problem in ANSYS has to go through three main steps. They are,

- Preprocessor
- Solution
- Postprocessor

The input of the ANSYS is prepared using Pre-processor. The general Pre-processor contains powerful solid modelling and mesh generation capabilities, and is also used to define all the other analysis data such as geometric properties like real constants, material properties, constraints, loads, stiffness damping etc.,

The ANSYS software has many finite element analysis capabilities ranging from simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis Any problem in ANSYS has to go through the three main steps

- Build the model
- Apply loads and obtain solution
- Review the results

Steps in Ansys:

- 1) Preferences – Structural
- 2) Element Type – Solid – Brick 8 node 185
- 3) Material Properties:

Table 1: Material Properties

Properties	Adhesive ^[4] (A199.5)	Adherent ^[5] (E-30CL)
Young's Modulus, E_0	1400Mpa	70000Mpa
Poisson's ratio, ν	0.35	0.3
Density, ρ	2740kg/m ³	1100kg/m ³

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

- 4) Modelling:
 Create – Volumes – Block – By Dimensions
- 5) Meshing:
 Mesh Tool – Free mesh
- 6) Loads:
 Define Loads – Apply – Structural – Displacement – On Areas
- 7) Solution:
 Analysis Type – New Analysis – Modal
 Analysis Options – Block Lanczos
 No. of modes to extract – 5
 NMODE No. of modes to expand – 5
- 8) Solve – Current LS

IV. RESULTS AND DISCUSSION

TABLE 2: NATURAL FREQUENCY VS THICKNESS

Thickness (mm) \ Mode	0.05	0.1	0.15	0.20	0.30	0.60
1	0.3448	0.3445	0.3443	0.3441	0.3438	0.3429
2	2.2517	2.2539	2.2555	2.2563	2.2564	2.2518
3	2.3863	2.3782	2.3732	2.3691	2.3631	2.3530
4	5.7923	5.7805	5.7731	5.7646	5.7575	5.7389
5	5.9449	5.9417	5.9394	5.9377	5.9338	5.9234

Above table shows the frequencies ranging from 0.3448 Hz to 5.9234 Hz obtained for various thickness of adherent at different modes.

Table 3: Maximum Displacement Vs Thickness

Thickness (mm) \ Mode	0.05	0.1	0.15	0.2	0.3	0.6
1	10.0382	10.0353	10.0309	10.0267	10.0172	9.9862
2	9.9519	9.9369	9.9216	9.9092	9.8888	9.8428
3	11.7646	11.7484	11.7308	11.7225	11.7206	11.7291
4	13.0226	12.8674	12.7369	12.7091	12.616	12.4608
5	12.3654	12.2115	12.1076	12.1012	12.0308	11.9603

Above table shows the displacements ranging from 10.0382mm to 11.9603mm obtained for various thickness of adherent at different modes.

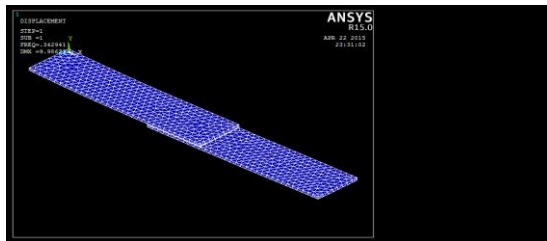
The Ansys results for 5 modes and Natural frequencies and Displacement graphs have been plotted below:

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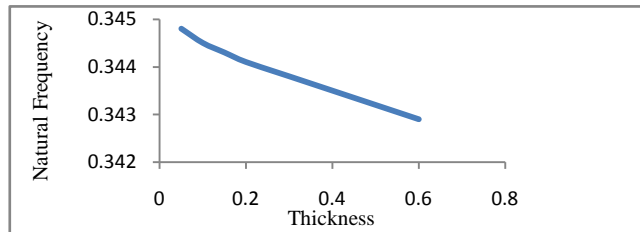
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Vol. 4, Issue 6, June 2015

MODE 1:

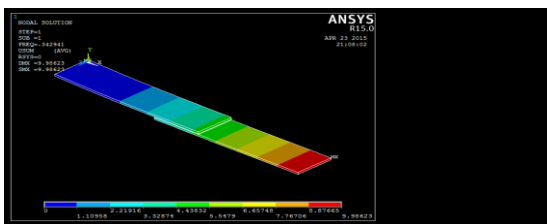


(a) Natural Frequency

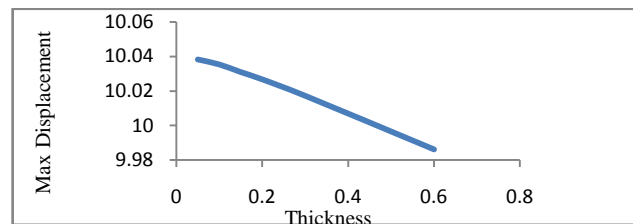


(b) Natural Frequency Vs Thickness

The above figure shows the frequency for first mode and the graph of frequency Vs thickness is linear curve and falling downwards as the thickness increases and ranging from 0.3448 to 0.3429 Hz.



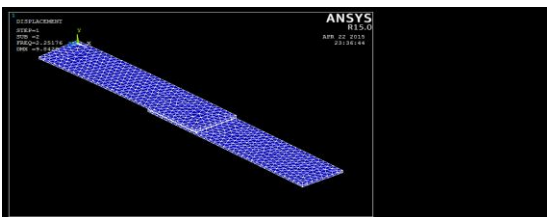
(c) Maximum Displacement



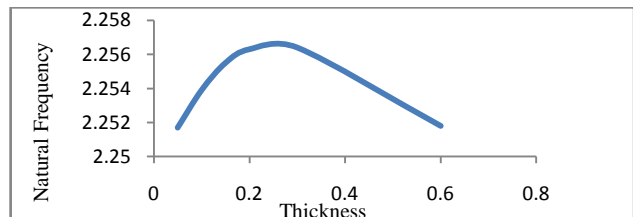
(d) Maximum Displacement Vs Thickness

The above figure shows max displacement for first mode and the graph of displacement Vs thickness is linear curve and falling downwards as thickness increases and ranging from 10.0382 to 9.9862 mm.

MODE 2:

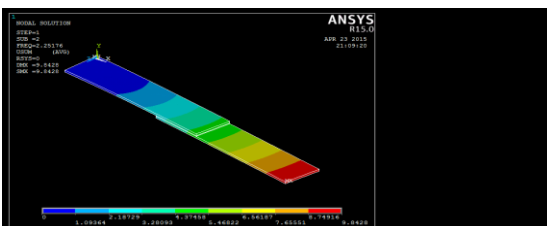


(a) Natural Frequency

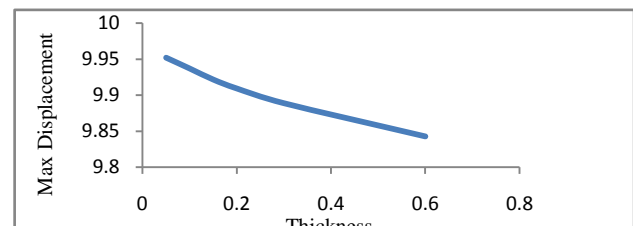


(b) Natural Frequency Vs Thickness

The above figure shows the frequency for second mode and the graph of frequency Vs thickness is non-linear curve and increasing initially till 2.256Hz and decreasing as the thickness increases and ranging from 2.2517 to 2.2518Hz.



(c) Maximum Displacement



(d) Maximum Displacement Vs Thickness

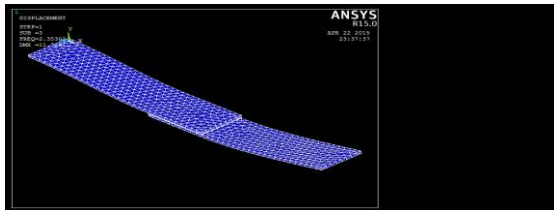
The above figure shows max displacement for second mode and the graph of displacement Vs thickness is linear curve and falling downwards as thickness increases and ranging from 9.9519 to 9.8428mm.

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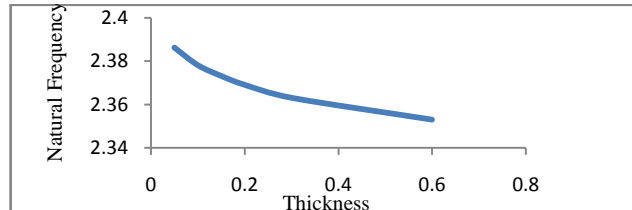
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Vol. 4, Issue 6, June 2015

MODE 3:

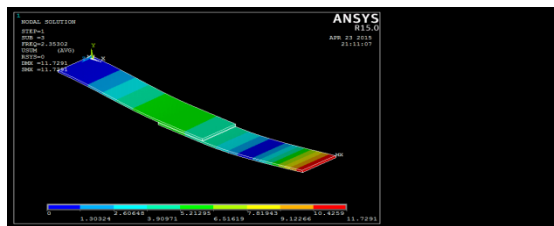


(a) Natural Frequency

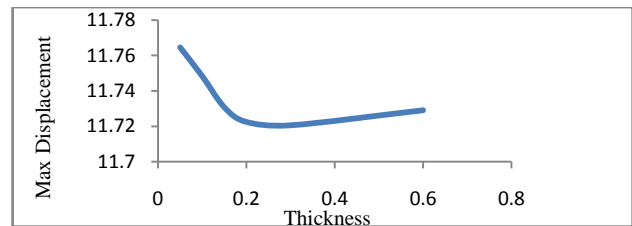


(b) Natural Frequency Vs Thickness

The above figure shows the frequency for third mode and the graph of frequency Vs thickness is almost a linear curve and falling downwards as the thickness increases ranging from 2.3863 to 2.3530Hz.



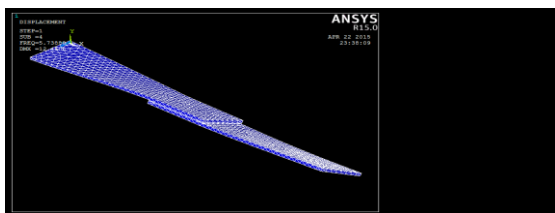
(c) Maximum Displacement



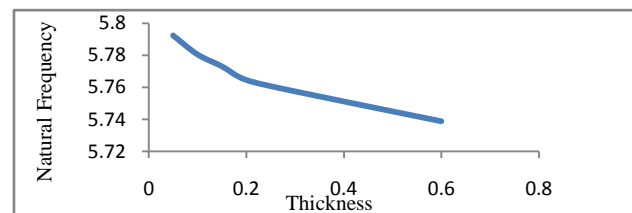
(d) Maximum Displacement Vs Thickness

The above figure shows max displacement for third mode and the graph of displacement Vs thickness is a non-linear curve falling downwards and then increasing as thickness increases and ranging from 11.7646 to 11.7291mm.

MODE 4:

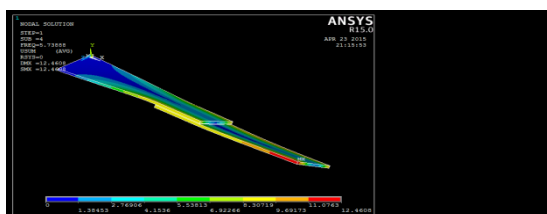


(a) Natural Frequency

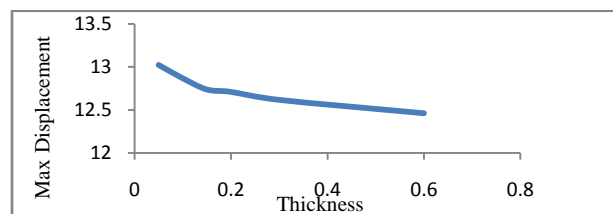


(b) Natural Frequency Vs Thickness

The above figure shows the frequency for fourth mode and the graph of frequency Vs thickness is almost a linear curve and falling downwards as the thickness increases and ranging from 5.7923 to 5.7389Hz.



(c) Maximum Displacement



(d) Maximum Displacement Vs Thickness

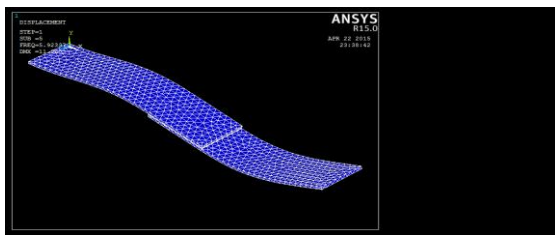
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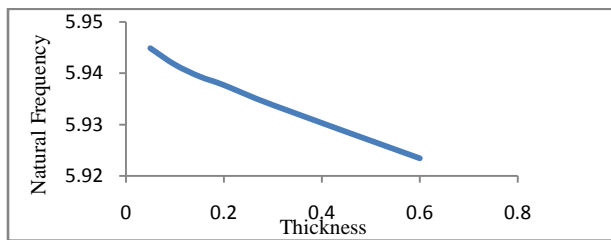
Vol. 4, Issue 6, June 2015

The above figure shows max displacement for fourth mode and the graph of displacement Vs thickness is almost a linear curve and falling downwards as thickness increases and ranging from 13.0226 to 12.4608mm.

MODE 5:

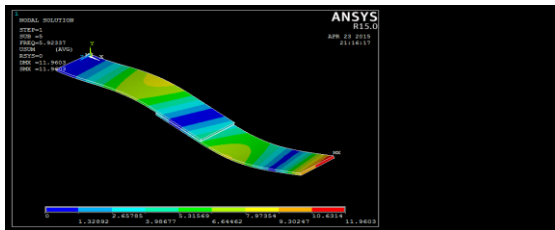


(a) Natural Frequency

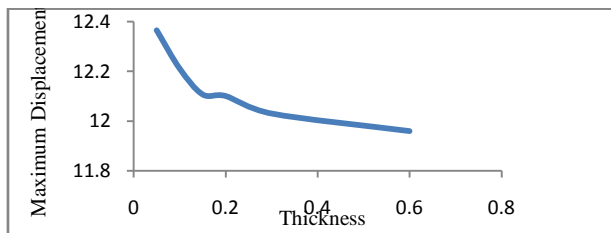


(b) Natural Frequency Vs Thickness

The above figure shows the frequency for fifth mode and the graph of frequency Vs thickness is almost a linear curve and falling downwards as the thickness increases ranging from 5.9449 to 5.9234Hz.



(c) Maximum Displacement



(d) Maximum Displacement Vs Thickness

The above figure shows max displacement for fifth mode and the graph of displacement Vs thickness is almost a linear curve and falling downwards as thickness increases ranging from 12.3654 to 11.9603

From the above results and graphs it is observed that natural frequency decreases with increase in thickness of adhesive layer for all modes except for second for which it initially increases and then decreases. Also the maximum displacement decreases with increase in thickness of adhesive layer for all modes.

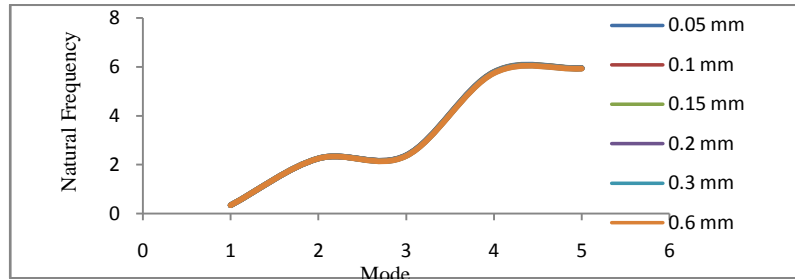
Table 4: Percentage Change in the natural frequency with change in thickness from 0.05mm to 0.6mm

Mode	Maximum Change (Hz)	Percentage Change
1	0.0019	0.55
2	0.0001	0.004
3	0.0333	1.40
4	0.0534	0.92
5	0.0215	0.36

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

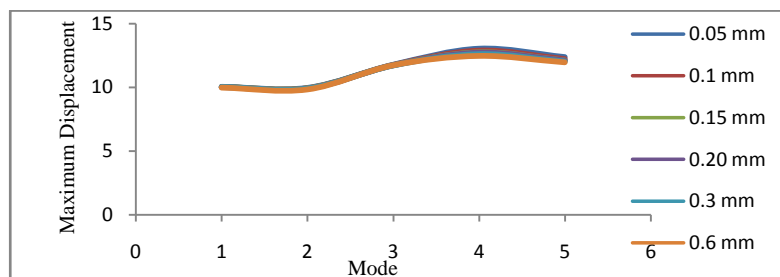


Natural Frequency Vs Mode

The above graph shows that natural frequency goes on increasing from mode 1 to mode 5 for all thicknesses.

Table 5: Percentage Change in the Maximum displacement with change in thickness from 0.05mm to 0.6mm

Mode	Maximum Change(mm)	Percentage Change
1	0.0520	0.52
2	0.1091	1.10
3	0.0355	0.30
4	0.5618	4.31
5	0.4051	3.28



Maximum Displacement Vs Mode

The above graph shows that that maximum displacement initially is constant and then increases and again starts decreasing from mode 1 to mode 5.

V. CONCLUSION

It has been observed that natural frequency decreases with increase in thickness of adhesive layer for all modes except for second for which it initially increases and then decreases. Natural frequency for 0.05mm and 0.6mm thickness is almost same. Natural frequency increases with mode number for all thicknesses.

Also the maximum displacement decreases with increase in thickness of adhesive layer for all modes. Also, maximum displacement occurs at same point for all thicknesses for same mode. Maximum displacement initially increases with increase in mode number and then starts decreasing for all thicknesses.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 6, June 2015

VI. FUTURE SCOPE

The future scope of this work is to take into consideration the importance of compactness and weightlessness of this joints that would serve to be much of valuable in future.

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