Analytical,Experimental and Numerical Analysis of Passive Damping Treatment of Butyl Rubber

PankajR. Beldar[1], Prof.D.V.Kushare[2]

[1]*prbeldar@kkwagh.edu.in*
[2]*kushare_dv@rediffmail.com*
[3]*NDMVP'SKBTCOE, Nashik,[Mechanical Department]*

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ABSTRACT- Vibrations of structures may cause many problems such as structural fatigue, unbalanced forces in machines, external excitations. It is important to reduce these unwanted vibrations, in order to increase the lifetime of structures. One of the technique adapted for the suppress severity of vibration is passive vibration technique which is used in structural dynamics to control vibration. Passive damping method is adding a layer of damping which is highly dissipative material like viscoelastic material and applied to metal objects to increase the damping in the total structure. Adding these materials to a structure or material system improves the vibration response by reducing the resonant peak response, reducing settling time of the response and reducing noise transmission. Effect of damping is considerable in machine components and structures.to avoid or eliminate structural vibration passive damping treatment comes in picture. For accounting the damping effects, lots of research and efforts have been done in this field to suppress vibration and to reduce the mechanical failures with different viscoelastic materials. Testing is performed on NI-LAB view with analytical modelling in MATLAB and fem analysis in ANSYS-15

keyword- damping treatment, CLD, FLD, Damping factor, loss factor

I. INTRODUCTION

Vibrations of structures are responsible for causing many problems such as unbalanced forces in machines, structural fatigue, external excitations. For better performances of machine components it becomes more essential to reduce or eliminate these unwanted vibrations, so that to lifetime of structures will increase. One of the efficient technique used for the suppress severity of vibration is passive vibration technique which is used in structural dynamics to control vibration. Passive damping method is adding a layer of damping which is highly dissipative material like viscoelastic material and applied to metal objects to increase the damping in the total structure.

Adding these materials to a structure or material system improves the vibration response by reducing the resonant peak response, reducing settling time of the response and reducing noise transmission.[1] Many polymers exhibit viscoelastic behavior. Viscoelasticity is a material behavior and combination of perfectly elastic and perfectly viscous behavior. An elastic material possesses perfect energy conversion, all the energy stored in a material during loading is recovered when the load is removed.Hence, elastic materials have an in phase stress-strain relationship. Contrary to an elastic material, there exists purely viscous behavior, A viscous material does not recover any of the energy stored during loading after the load is removed (the phase angle between stress and strain is exactly π/2 radians) lost as 'pure damping.' For a viscous material, the stress is related to the strain as well as the strain rate of the material. Viscoelastic materials have behavior which falls between elastic and viscous extremes. The rate at which the material dissipates energy in the form of heat through shear, the primary driving mechanism of damping materials, defines the effectiveness of the viscoelastic material. Because a viscoelastic material falls between elastic and viscous behavior, some of the energy is recovered upon removal of the load, and some is lost or dissipated in the form of thermal energy. The phase shift between the stress and strain maximums, which does not to exceed 90 degrees, is a measure of the materials damping performance. The larger the phase angle between the stress and strain during the same cycle. The more effective a material is at damping out unwanted vibration.

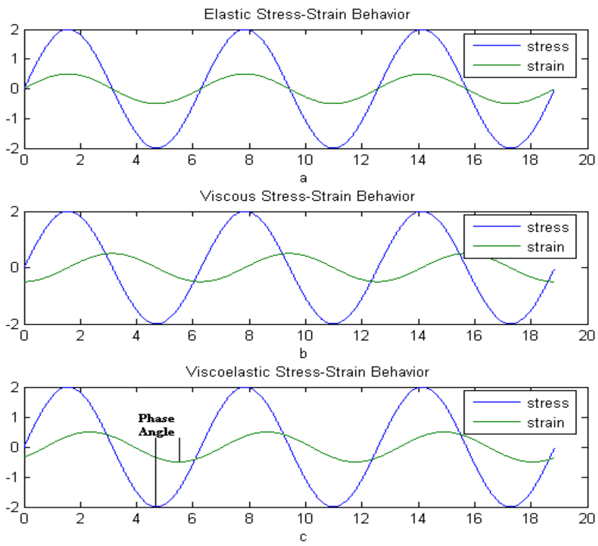

Fig 1- stress strain behavior

A. List of common viscoelastic polymeric materials

(Jones, "Handbook of Viscoelastic Damping," 2001)

1. Acrylic Rubber
2. Butadiene Rubber
3. Butyl Rubber
4. Chloroprene
5. Chlorinated Polyethylene
6. Ethylene-Propylene-Diene
7. Fluorosilicone Rubber
8. Fluorocarbon Rubber
9. Nitrile Rubber
10. Natural Rubber
11. Polyethylene
12. Polystyrene
13. Polyvinyl chloride (PVC)
14. Polymethyl Methacrylate (PMMA)
15. Polybutadiene
16. Polypropylene
17. Polyisobutylene
18. Polyurethane
19. Polyvinyl acetate
20. Polyisoprene
21. Styrene-butadiene (SBR)
22. Silicon Rubber
23. Urethane Rubber

Specimen preparation

The specimen is prepared by standard process ASTM standard E-756(05). It consists of two layers of aluminum and the viscoelastic material in the core composed of a 3M High-Strength Acrylic double face Adhesive. [1]

Experimental apparatus For vibration damping testing, there are two primary considerations when designing fixturing for testing materials. First, it is necessary that the specimen be isolated from its surroundings. No vibrational energy from external sources should be allowed to influence the vibrational response of the specimen being tested. Accomplishment of this likewise infers that the vibrational energy imparted to the specimen will not be dissipated by the fixturing as the result of an energy transfer from the specimen. Secondly, care must be taken to minimize all other possible sources of energy dissipation so that the measured damping is the material inherent damping loss factor.[2]The size of beam under investigation is 400 mm in length and 50 mm in width. The thickness of base structure, constraining layer is 2 mm and thickness of VEM layer is 1mm.The material of base structure, constraining layer is aluminium .The density of VEM is 1485 Kg/m3

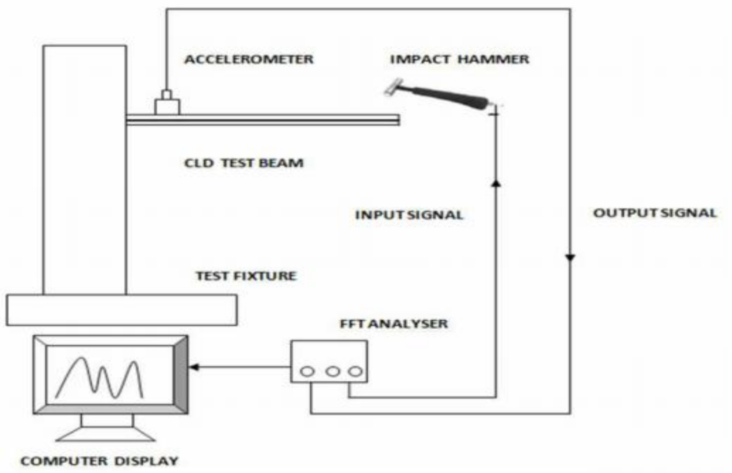

Fig 2 – experimental set up

1. Clamping test bench 4.Impact Hammer
2. Test Specimen 5.Data acquisition system
3. Accelerometer 6.Display

I. MATHEMATICAL MODELING

In order to approximate system loss factors and hence determine viscoelastic and constraining layer thickness required for maximum damping, an analysis based on the Ross-Kerwin-Ungar (RKU) equations was used .The equations are based on the analysis of a simple sandwich configuration shown in Figure

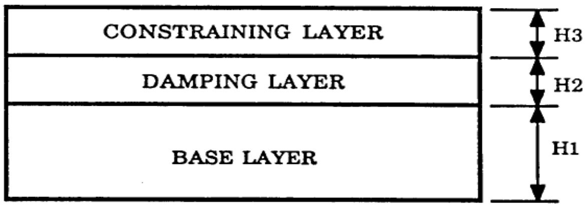

Figure 10.Elements of a Simple Sandwich Damping System.

The first step in determining the composite system loss factor is to determine the system flexural rigidity. The flexure rigidity, El, of the above system can be written

EI=

$$\frac{E_1H_1^3}{12}+\frac{E_2H_2^3}{12}+E_1H_1D^2+X-Y$$

$$X=E_2H_2(H_{21}-D)^2+E_3H_3(H_{31}-D)^2$$

Y=

$$\left[\frac{E_2H_2^3}{12}+\frac{E_2H_2^3}{12}(H_{21}-D)+E3H3(H_{31}-D)\right]\frac{(H31-D)}{1+g}$$

D=

$$\frac{E2H2(H21-H31*0.5)+g(E2H2H21+E3H3H31)}{E1H1+E2H2*0.5+G(E1H1+E2H2+E3H3)}$$

$$H_{31}=0.5(H_1+H_3)+H_2$$

$$H_{21}=0.5(H_1+H_2)$$

$g = \frac{G2}{E3H3H2K^2}$

E = Young's Modulus

G = Shear Modulus

I = Moment of Inertia

H = Member Thickness

K^2 = Modal Wave Number

$K^2 = w_n * \frac{1}{\sqrt{\frac{EH^3 g_C}{12(1-v^2)H\rho}}}$

Wn = Natural Frequency

gc = Gravitational Constant

v = Poisson ' s Ratio of Composite Body

p = Density of Composite Body

To introduce damping into the equations, it is necessary to use the complex modulus concept discussed in reference 11. In order to reduce the analytical burden, the following assumptions were made:

(1) Damping of the base structure is small (i.e., eta1 = 0).

(2) Extensional stiffness of damping layer is small compared to rest of composite (i.e., $E_1 >> E_2$ and $E3 >> E_2$).

(3) Damping of the constraining layer is small (i.e., eta3= 0).

Under these assumptions the total system loss factor can be calculated using

$$N_{SYS} = \frac{\frac{12}{a^2+b^2}}{EH^3}[A - B - C]_{IM}$$

$$EH^3 = E_1H_1^3 + E^1H_3^3 + \frac{12}{a^2+b^2}[A - B - C]_{RE}$$

$A = g\ E_1H_1E_3H_{31}^2[a+b*eta2+i(eta2*a)]$

B=ElH1E2H2H31[a+b*eta2+i(eta2*a)-b)]

$C=2gE2H2E3H2lH,l[a-(eta2)^2\ \ a+2b*eta2+i\ \ (2a*eta2-b+b*eta2)^2)]$

a=E1H1+g(ElHl+E3H3)

$b = g*eta2(E_1H_1+E_3H_3)$

$i=(-1)^{0.5}$

eta2 = Viscoelastic Layer Loss Factor

IM = Imaginary Part

RE = Real Part

Nsys= System Loss Factor

C. Half-power bandwidth method

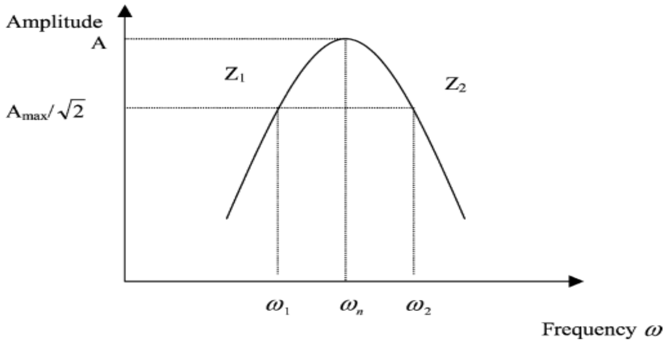

Fig 3.- Half-power bandwidth method

The most common method of determining damping is to measure frequency bandwidth, between points on the response curve, for which the response is some fraction of the resonance of the system. The usual convention is to consider points $Z_1$and Z_2 as in the Fig. 1below, to be located at frequencies on the response curve where the amplitude of response of these points is 0.707 times the maximum amplitude. The bandwidth at these points is frequently referred as 'half-power bandwidth'.The half-power points or 3 dB points for small damping correspond to the frequencies $\omega_1=\omega_n(1-\zeta)$ and $\omega_2=\omega_n(1+\zeta)$, where ζ the damping ratio. The frequency interval between these two half power points is $\Delta\omega= \omega_2- \omega_1$. Loss factor of this method is defined as

$\eta=\Delta\omega/\omega_n$

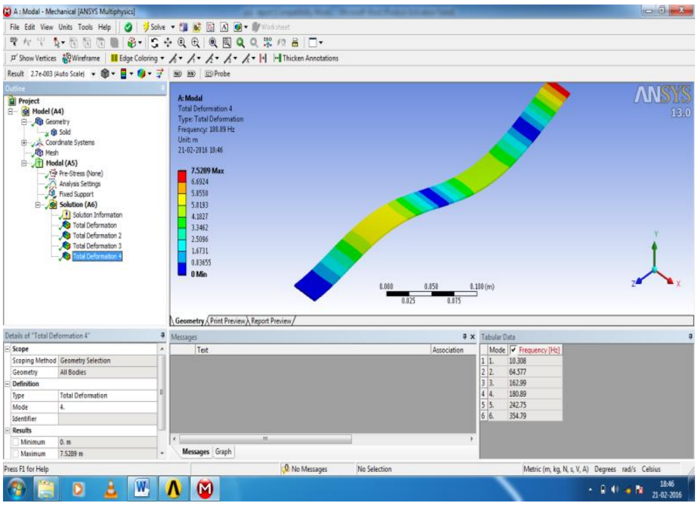

FIG 4- Undamped beam modal analysis- 4th mode

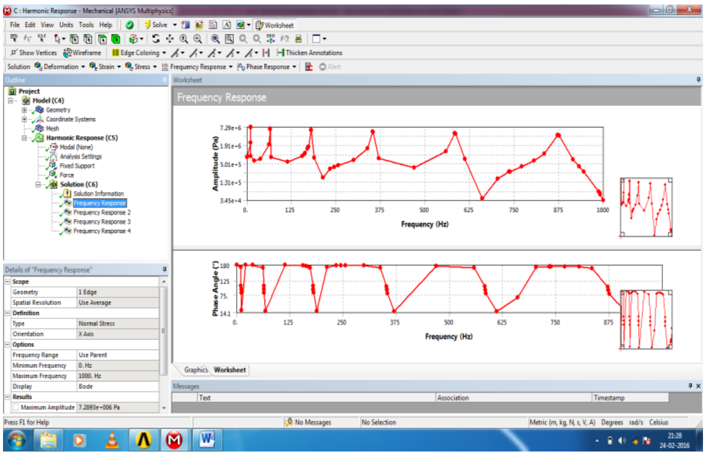

FIG 5- Undamped beam harmonic analysis

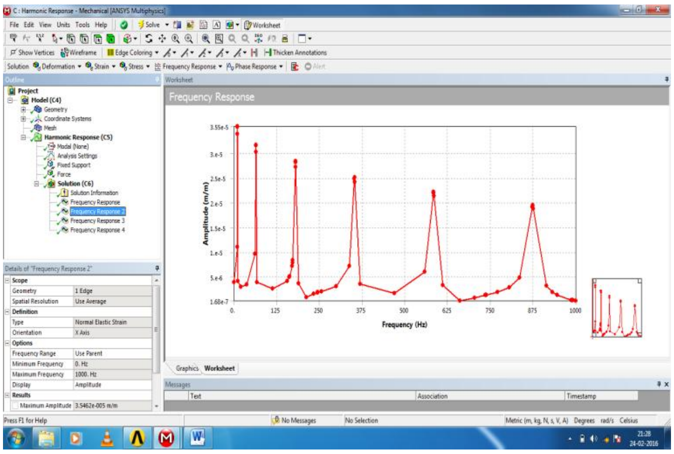

FIG-6 Undamped beam harmonic analysis

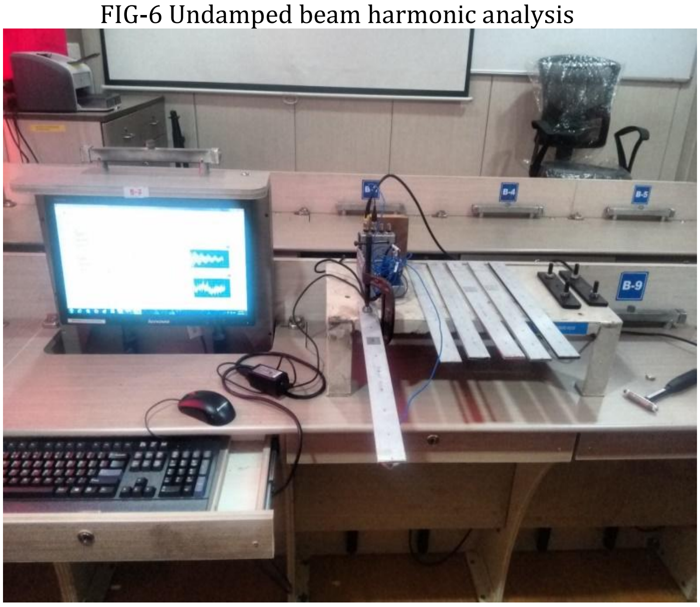

FIG-7 Experimental set up

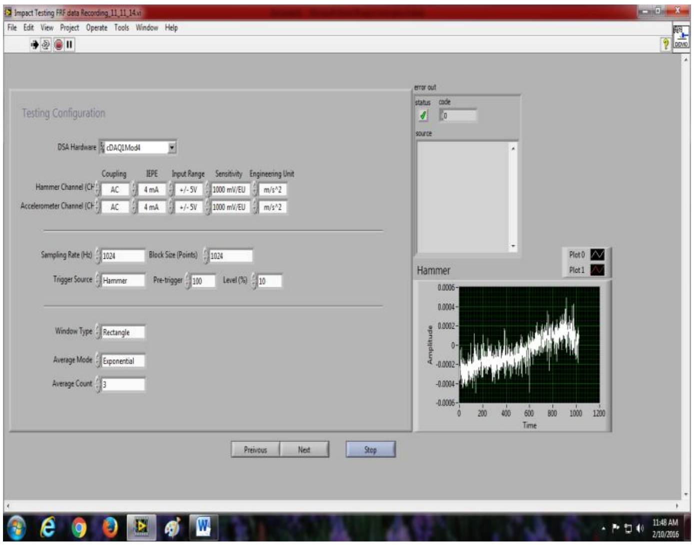

FIG 8- Presetting in NILABVIEW

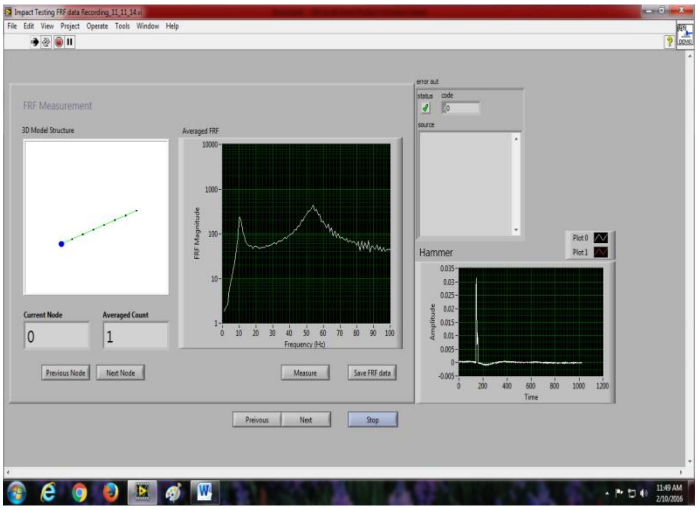

FIG 9- NI-LAB VIEW Results

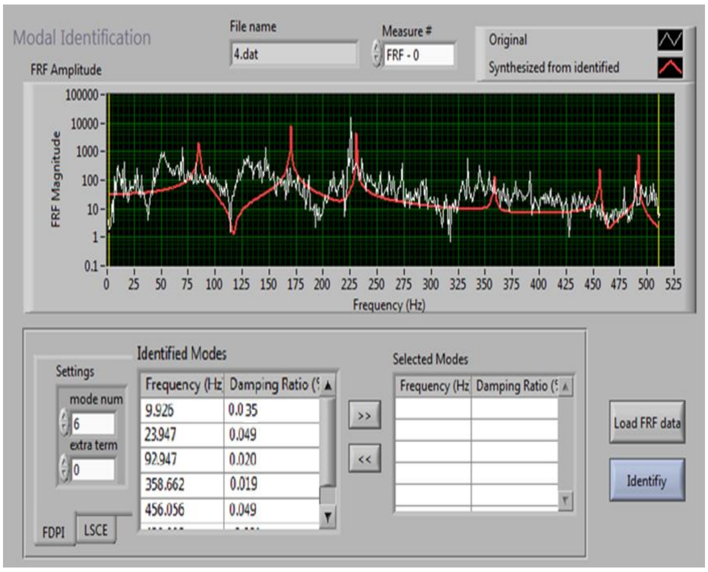

FIG-10 NI-LAB VIEW Results

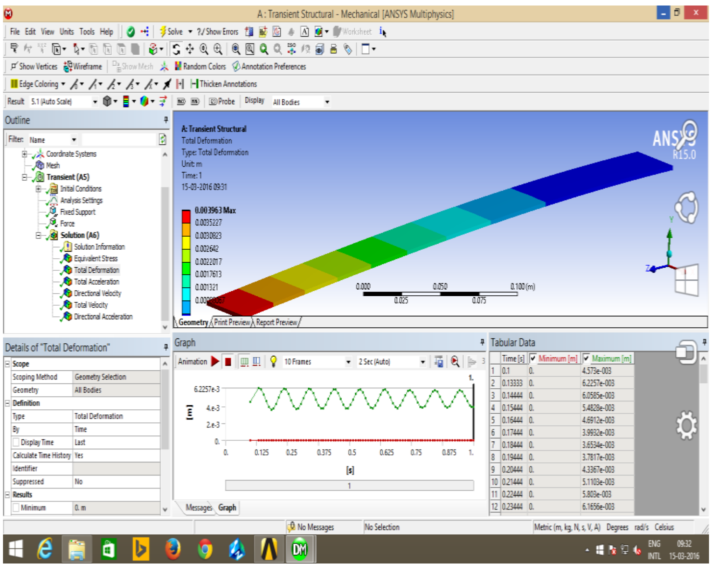

FIG 11- FEM analysis of undamped beam

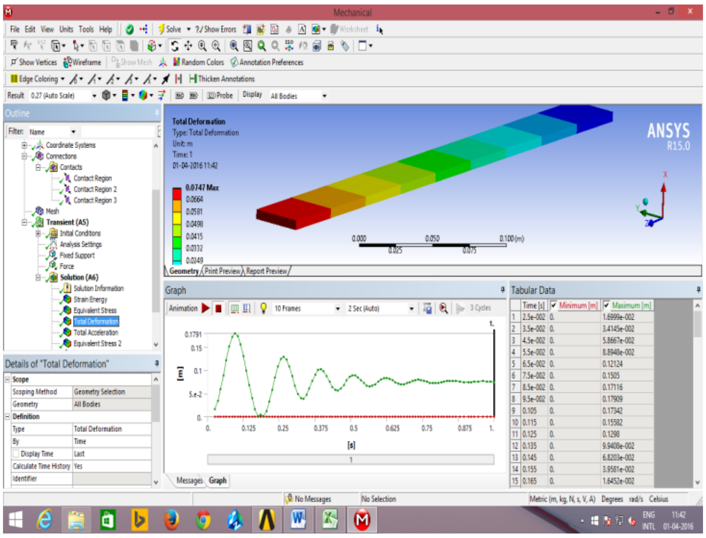

FIG-12 FEM analysis of cld butyl rubber beam

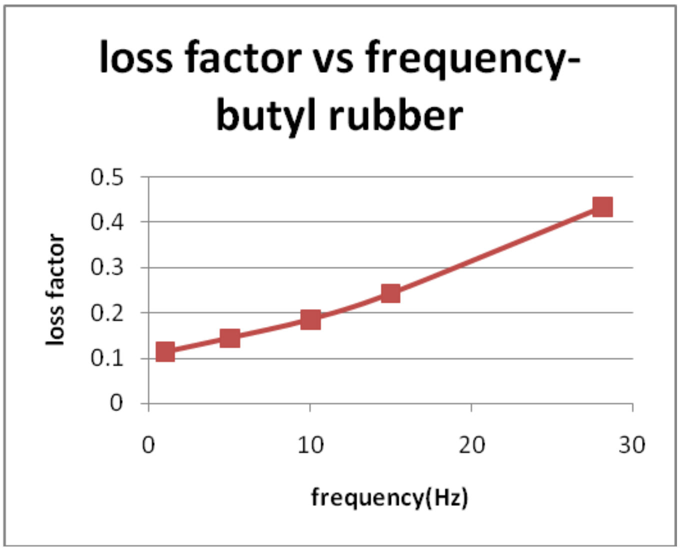

FIG-15 Loss Factor Vs Frequency- Butyl Rubber

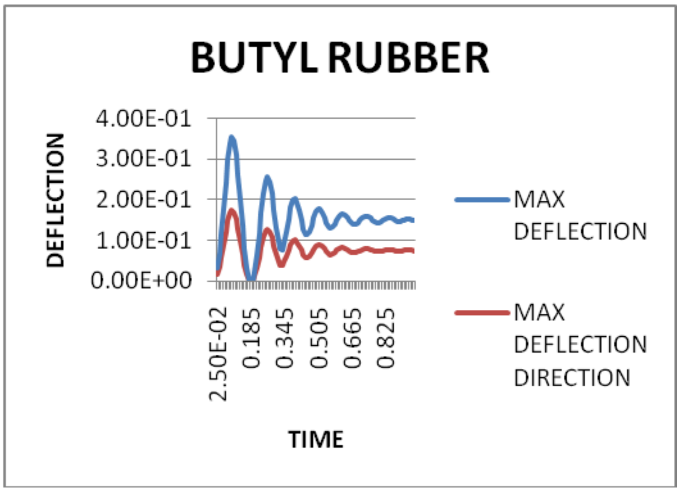

FIG 13-Logarithmic decrement for cld beam

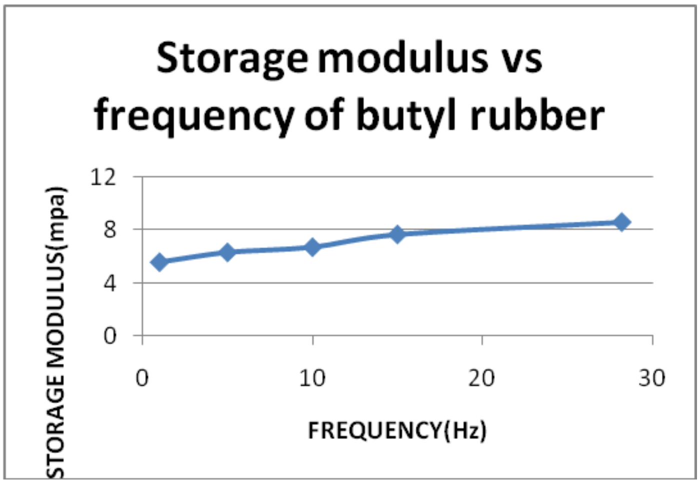

FIG-16 Storage Modulus Vs Frequency Of Butyl Rubber

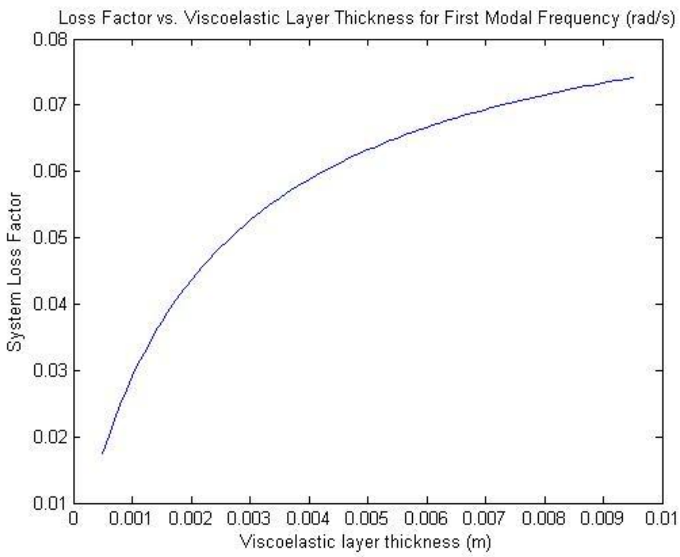

FIG-14 Matlab prediction

II. RESULTS

Damping treatment	Loss factor by experiment	Loss factor by FEM	Loss factor by matlab
Undamped beam	0.00023	0.00019	-
Cld damped	0.0789	0.0689	0.07
Free layer	0.0568	0.0498	-
Patched layer	0.0345	0.0328	-

III. CONCLUSION

Butyl rubber is viscoelastic under transition region. Constrained layer treatment has better damping performance than free layer and patched layer damping. Thickness for damping treatment is to be decided as

1mm.FEM results are varying because we don't consider properties od adhesive. Results can be improved by considering adhesive properties.

IV. FUTURE SCOPE

Different types of viscoelastic materials can be checked for damping treatment. Finding more efficient new materials for damping of high amplitude. To Study effect of thickness on damping and finding correlation between thickness and damping loss factor

REFERENCES

1. Pravinhujure and anilsahstrabudhe, 'experimental verification of viscoelasticconstrained layer damping', international conference on advances in manufacturing and materials engineering amme 2014.
2. Ashish m. Dharme, pravin p. Hujare, 'analysis of performance of fld and cld technique', international journal of engineering sciences & research technology, july, 2014.
3. Nirmalkumarmandal, roslanabd. Rahman,m. Salman leong, 'experimental study on loss factor for corrugated plates by bandwidth method',Elsevier science direct, 23 august 2013.
4. Scott j.i. Walker, guglielmo s. Aglietti, paulcunningham,'a study of joint damping in metal plates', science direct, 13 january 2009
5. Mohan d. Rao, recent applications of viscoelastic dampingfor noise control in automobiles and commercial airplanes, science direct, journal of sound and vibration 262 (2003) 457–474.
6. Avinashkadam, pravinhujare, optimization of segmented constrained layer damping literature review international journal of engineering and advanced technology (ijeat)issn: 2249 – 8958, volume-3, issue-5, june 2014
7. Hasankoruk, on measuring dynamic properties of damping materials using oberst beam method ,proceedings of the asme 2010 10th biennial conference on engineering systems design and analysis esda2010 july 12-14, 2010, istanbul, turkey.