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EFFECT OF TEMPERATURE ON DYNAMIC CHARACTERISTICS OF NATURAL RUBBER USED AS TWO LAYERED DAMPING TREATMENT FOR VIBRATION CONTROL

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ABSTRACT

The dynamic characteristics of Natural rubber of 40, 50 and 60 shore A hardness were investigated to maximize the damping performance for the temperature range of interest and also the effect of temperature and hardness. For the three materials, viscoelastic properties were performed with DMA test on specimens. The Natural rubber of 60 shore A material showed better dynamic characteristics than those of the 40 and 50 shore A hardness. The results obtained from Dynamic Mechanical Analysis test in the temperature sweep mode are applied in the RKU analysis of two-layer damping system with 30mm thickness and loss factor of damped structures are found.

Keywords: *Natural rubber, Temperature, Hardness, Storage Modulus, loss factor.*

I. INTRODUCTION

Rubber is a material has both elastic and viscous characteristics. Therefore Rubber parts can function as shock and vibration isolators and as dampers. It is resilient and exhibits internal damping. This study provides information of dynamic properties of Natural rubber of different hardness which are of importance in vibration damping applications [1].

Natural rubber is a high molecular weight polymeric substance with viscoelastic properties. An interesting reaction of natural rubber is its combination with sulphur. This is known as vulcanization. This reaction converts the plastic and viscous nature of raw rubber into elastic. Vulcanized rubber will have very high tensile strength and comparatively low elongation. Its hardness and abrasion resistance also will be high when compared to raw rubber. Also it is high resistance to water and acids [2].

II. EXPERIMENTATION DETAILS

A. Hardness

Hardness is defined as the resistance to indentation. The Durometer is an instrument that measures the penetration of a stress-loaded metal sphere into the rubber. Hardness measurements in rubber are expressed in Shore A units according to ASTM procedures. Because of the viscoelastic nature of rubber, a Durometer reading reaches a maximum value as soon as the metal sphere reaches maximum penetration into the specimen and then decreases the next 5 to 15 seconds [3].

B. Dynamic testing

Many rubber products are used under dynamic conditions and for that reason it is interesting to be able to measure dynamic properties. Dynamic Mechanical Analysis (DMA) is a testing technique and related analytical instrument that measures the physical properties of solids, reports modulus and damping, and is programmable to measure force, stress, strain, frequency and temperature. DMA is also described as Dynamic Mechanical Thermal Analysis (DMTA) when combining the information with temperature response.

Damping is the dissipation of energy in a material under cyclic load. It is a measure of how well a material can get rid of energy and is reported as the tangent of the phase angle. It tells us how good a material will be at absorbing energy. It varies with the state of the material, its temperature, and with the frequency. Modulus values change with temperature and transitions in materials can be seen as changes in the Storage modulus (E') or tan delta curves.

As rubber is a viscoelastic material, modulus and damping vary with frequency, deformation and temperature. By dynamic testing the complex dynamic modulus and the loss angle are determined. The damping is expressed as tangent for the loss angle (δ). Damping is a measure of the energy loss and of heat generation in the test piece [4].

III. RESULTS AND DISCUSSIONS

A. Hardness of Natural rubber

Hardness of Natural rubber was evaluated by Durometer and the values are shown below in Table 1. The indentation hardness is inversely related to the penetration and is dependent on the modulus of elasticity and the viscoelastic properties of the material.

Table 1. Hardness values of Natural rubber

S.No.	Sample	Hardness (shore A)	
		Values	Average
1	Natural 40 A	40.2 41.3	40.6
2	Natural 50 A	49.8 51.3	50.2
3	Natural 60 A	58.9 61.9	60.8

B. Dynamic Mechanical analysis

In this technique, a small deformation is applied to a sample in a cyclic manner. This allows the materials response to stress, temperature, and frequency values to be studied. DMA measures stiffness and damping, these are reported as modulus and tan delta. A temperature sweep mode involves measuring the complex modulus at low constant frequency while varying the temperature.

In the present study the viscoelastic behaviour of Natural rubber samples were found by using DMA analyzer under temperature sweep mode. The plots exhibit the storage modulus and the loss factor as a function of temperature at constant frequency i.e. 10 Hz. These curves reveal the typical characteristics of the viscoelastic behaviour of Natural rubber of 40, 50 and 60 shore A hardness. The temperature sweep plots are shown in following figures.

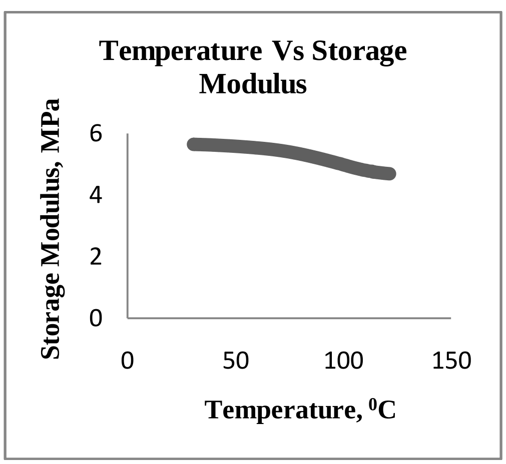

Fig. 1. Storage modulus against temperature of Natural rubber 40 shore A

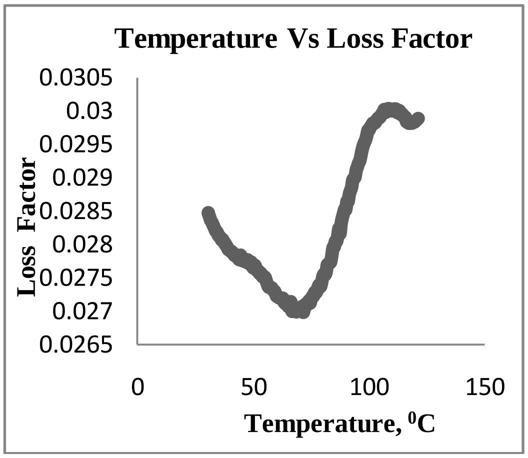

Fig. 2. Loss factor against temperature of Natural rubber 40 shore A

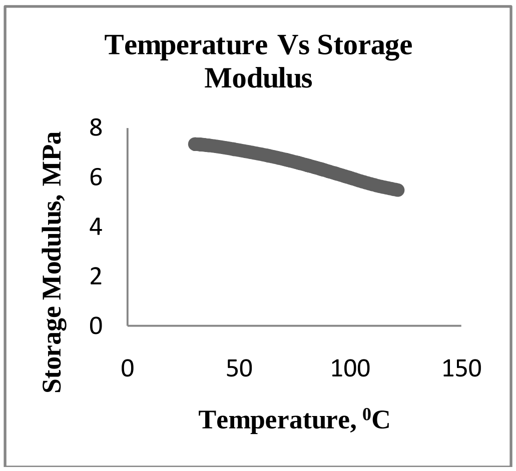

Fig. 3. Storage modulus against temperature of Natural rubber 50 shore A

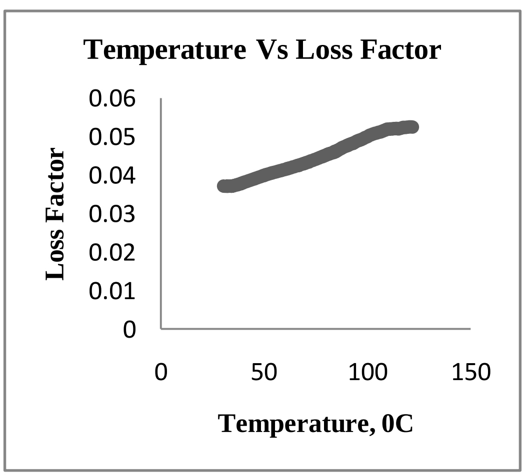

Fig. 4. Loss factor against temperature of Natural rubber 50 shore A

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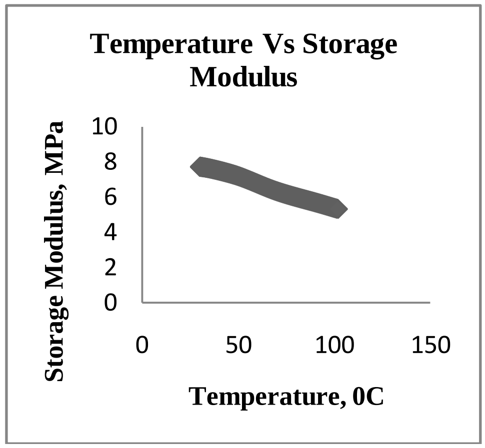

Fig. 5. Storage modulus against temperature of Natural rubber 60 shore A

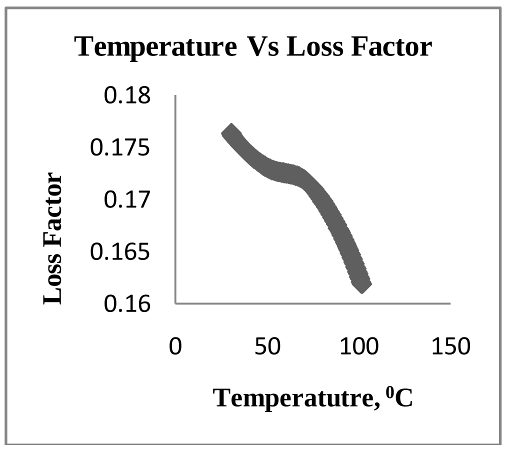

Fig. 6. Loss factor against temperature of Natural rubber 60 shore A

The figures 1 to 6, show the temperature effects on Storage Modulus and Loss Factor. It is observed that for all three Natural rubber samples, the storage modulus decreases with increasing temperature. But in case of loss factor, it is observed that the loss factor for Natural 40 shore A rubber decreases up to 0.02737 at the temperature 57.23^{0}C with increasing temperature. Further the loss factor increased up to 0.03003 at the temperature 106.74^{0}C. In case of Natural 60 shore A rubber, the loss factor decreases with increasing temperature.

As per the marine applications the temperature sweep test conducted and Storage modulus and Loss factor (Tan Delta) values were found against temperature. For a constant frequency of 10 Hz and at a temperature of 31°C, the storage modulus and Loss factor values are shown in the table 2.

Table 2. Viscoelastic properties of Natural rubber samples at temperature of 31°C

S.No.	Sample	Storage Modulus (MPa)	Loss Factor (η_2)
1	Natural 40 A	5.64	0.0285
2	Natural 50 A	7.33	0.0372
3	Natural 60 A	7.72	0.1761

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From the table 2, it is studied that at the temperature 31°C, the elastic response is more from Natural 60 shore A rubber than remaining two samples and the loss factor i.e. the ability of material to dissipate the energy also more for the same material.

As the hardness increased the viscoelastic properties also changed and the values are increased at the temperature 31°C. Loss factor is also observed that is more 0.1761 for Natural 60 shore A rubber compared with the remaining samples of different hardness. Increasing loss factor indicates that the material has more energy dissipation potential.

C. RKU analysis

Damping treatments are configurations of mechanical or material elements designed to dissipate sufficient vibrational energy to control vibrations or noise. The mechanism of energy dissipation in a free layer treatment is the cyclic extensional deformation of the imaginary fibers of the damping layer during each cycle of flexural vibration of the base structure.

The RKU equation can be applied to predict the performance of free layer damping treatment [5]. The expression relating the damping of a structure, in a particular mode, to the properties of the structure and the damping material layer is:

$$\eta / \eta_2 = \frac{eh(3 + 6h + 4h^2 + 2eh^3 + e^2h^4)}{(1+eh)(1 + 4eh + 6eh^2 + 4eh^3 + e^2h^4)}$$

where η is the damped structure modal loss factor, η_2 is the loss factor of the damping material i.e. Natural rubber, E_2 is the Young's modulus of the damping material and E_1 is that of the structure ($e = E_2/E_1$), and h_2 and h_1 are the thicknesses of damping layer and structure, respectively ($h = h_2/h_1$). The young's modulus values are found by conducting tensile tests on rubber samples and AA 6063. Young's modulus for AA 6063 material is E_1 = 68.9 GPa. The thickness values are h_2 = 30mm and h_1 = 3mm. From the calculations the loss factor of damped structure for three samples tabulated below.

Table 3. Loss factor for Damped Structures

S.No.	Layer Material	Young's Modulus E_2 (MPa)	Loss factor of Damped structure (η)
1	Natural 40 A	2.05	0.0034
2	Natural 50 A	3.02	0.0062
3	Natural 60 A	3.53	0.0335

From the results shown in table 3, we can observe that as hardness and young's modulus increases, the loss factor also increases. We can predict the performance of free layer damping treatment using the RKU equation for more structures by varying thickness of damping material and structure. In FLD with Natural rubber layer, the beam of Natural 60 shore A layer gives better value of loss factor [6][7].

IV. CONCLUSION

This paper presents the effect of temperature and hardness of viscoelastic damping treatments made by Natural rubber are efficient for noise and vibration control. The results showed better dynamic characteristics for the Natural 60 shore A rubber material than those of the Natural rubbers with 40 and 50 shore A hardness. The loss factors for the damped structures are evaluated using the three materials by RKU analysis and found that the structure treated with Natural rubber 60 shore A given better results than the remaining at a temperature of 31^0C.

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