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Experimental Evaluation of Some Dynamic Properties of Nanoparticles Reinforced Rubber

Muhammad Ramzan[1], Bimlesh Kumar[2]
[1](Department of Mechanical Engineering, MMANTC, Malegaon, India-42541)
[2](Sant Gajanan College of Engineering, Kolhapur, India)

Abstract: Nanocomposite natural rubber (isoprene) reinforced with nanoparticles performs with excellent dynamic characteristics. In its natural form, rubber is viscous as well as elastic; but the viscosity is dominant. Reinforcement provides enhanced energy dissipation through large surface-to-volume ratio. The nanocomposite material offers the potential to store kinetic energy by enhancing its stiffness. This study describes a novel experimental approach to investigate the stiffness by projectile method to characterize the dynamic stability of nanocompositerubber. Vibration damping is characterized by maximum amplitude and amplitude decay. It was found that nanocomposite rubber can damp the vibration more rapidly alongwith increase in stiffness.
Keywords : *Nan ocomposite, rubber, logarithmic decrement, stiffness, amplitude.* Introduction

I. Introduction

Rubber has elastic properties similar to those of a metallic spring and has energy absorbing properties like those of a viscous liquid.[1]Springs or dashpots shown in Fig.1 are frequently used to make theoretical models which illustrate the interaction of the elastic and viscous components of rubber. Rubber actually consists of an infinite number of such models with a wide spectrum of spring constants and viscosities.[2] Dynamic properties, which are a function of the elastomer and other compounding variables, determine the vibration isolation and damping characteristics of a rubber compound. Springs and dashpots are used to describe how the viscoelastic properties relate to the vibration isolation and damping properties. [3] In forced vibration methods,the dynamic properties (or viscoelasticity) of a rubber compound are determined by measuring its response to a sinusoidally varying strain. [4] Elastomers which do not strain-crystallize need reinforcement to obtain adequate tensile properties. [5] The mechanism of the reinforcement is believed to be both chemical and physical in nature. [6] Nanocomposites with metal, ceramic or polymer matrix [7,8] have been used in wide ranging applications such as aeronautics, transportations, automotive industry, machine tools, robotics, etc., where high dynamic loaded parts are needed [9]. The damping of the structure can be significantly improved by reinforcing the structure at molecular level to avoid dangerous oscillating loadings. [10,11] In this paper a sample of rubber reinforced with nanoparticles of alumina (Al_2O_3) is tested for some dynamic mechanical properties.

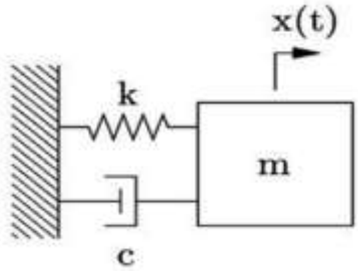

Fig.1 Spring-mass-dashpot system

II. Experimental Procedure

Alumina(Al_2O_3)nanoparticles were formulated by sol-gel synthesismethod. The precursor was obtained from $Al(NO_3)_2\,6H_2O$. The samples were dried in oven maintaining the ambient temperature at 24^0C for about48 hours and then dried at 70^oC for 4 hours. Finally the samples were treated at temperatures 900^oC for 3hours.The nanocomposite specimen-rubber reinforced with alumina nanoparticleswas prepared on two-roll mill as specified in the protocol [12], in the form of a rectangular strip of size 80mm x 25mm and 5mm thick.

III. Modeling Appearance

*Equation of Motion:*The experimental method consists of clamping the rectangular specimen of nanocomposite rubber in the form of simply supported beam. The equation of motion for this configuration at no load condition (undamped-free vibration) is given as shown in Eq.1.

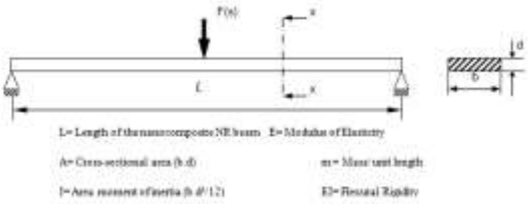

Fig.2. Model of nanocomposite simply supported beam

$$EI\ \frac{\partial^4 y}{\partial x^4} + \rho A\ \frac{\partial^2 y}{\partial t^2} = 0 \qquad (1)$$

The Eq. (1) can be simplified as;

$$a^2\ \frac{\partial^4 y}{\partial x^4} + \frac{\partial^2 y}{\partial t^2} = 0 \qquad (2)$$

where;

$$a = \sqrt{\frac{EI}{\rho A}} \qquad (3)$$

The solution of the Eq. (1) can be obtained as;

$$y(x,t) = Acosh\beta x + Bsinh\beta x + Ccos\beta x + Dsin\beta x \qquad (4)$$

where A, B, C and D are constants and can be determined from the boundary conditions. y, Eigenfunction for undamped free vibration; β, Eigenvalues corresponding to the specific boundary conditions;

$\beta = n\pi/L$; (n = 1 to ∞)

Applying the boundary conditions of simply supported beam to Eq. (4);

At x= 0; y (0, t) = 0 $\left[\frac{\partial^2 y}{\partial t^2}\right]_{x=0} = 0$

At x = L; y (L, t) = 0 $\left[\frac{\partial^2 y}{\partial t^2}\right]_{x=L} = 0$

Constants A, B and C are zero and the solution of Eq. (4) is given by;

$$y\ (x,t) = \sum_{n=1}^{\infty} D_n \sin\left(\frac{n\pi}{L}\right)x \qquad (5)$$

Drop weight test:

In this test the specimen was fixed horizontally in a fixture and supported at the ends along the longitudinal axis. An analyser is fixed in the bottom side of the plate to measure the time response. A sharp nose projectile of mass 550 grams was fixed in a circular plate and dropped from a height to strike the nano composite rubber beam with a velocity of 3.13 m/s (initial height of projectile was 0.5 m). The same procedure was repeated for sample without nanoparticles and with 3 % reinforced nanoparticles. The damping factor of the rubber nanocomposite sample was calculated using logarithmic decrement method as illustrated by Eqs. 6 and 7and shown in Fig.3:

$$\zeta = \frac{\delta^2}{(4\pi^2 + \delta^2)^{0.5}} \qquad (6)$$

Where

$$\delta = \frac{1}{n}\ln\frac{x}{x_{n+1}} \qquad (7)$$

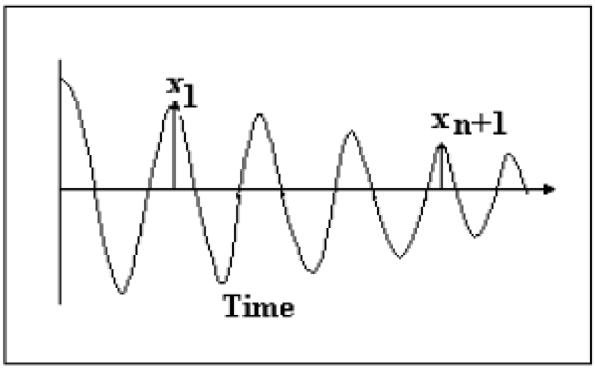

Fig.3 Logarithmic Decrement of amplitude

IV. Results And Discussion

The time response curves of the specimen with and without reinforcement is shown in the Figs 4 and 5 respectively.

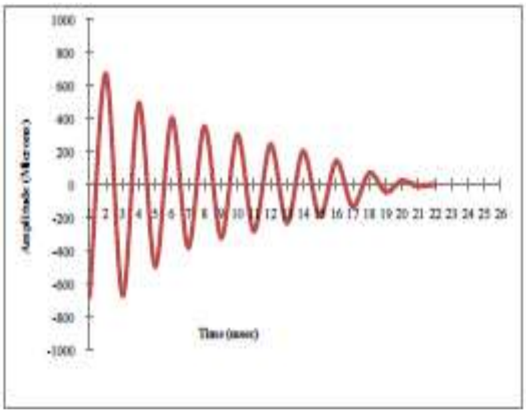

Fig.4 Time response with 3 % reinforcement of nanoparticles

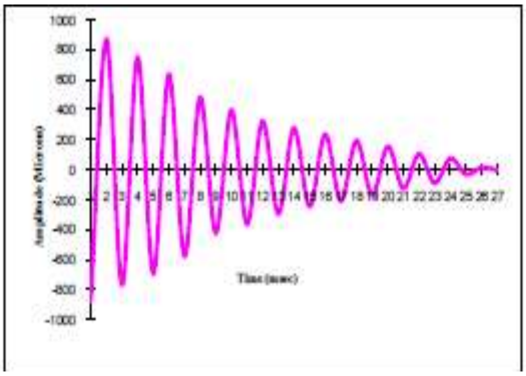

Fig.5 Time response without reinforcement

It is clearly depicted from the time response curves that the nanocomposite rubber sample is stiffer as indicated by decreased amplitude compared to that of without reinforcement. Similarly the amplitude decay time is also reduced in case of nanocomposite sample as a consequence of enhanced vibration damping characteristics. For 3.1 m/s velocity without reinforcement, the damping factor is 0.03642and for 3% reinforcement it is 0.08023 which is 1.2 times greater than that without reinforcement.

V. Conclusion

Reinforcement of nanoparticles into elastomers improves significantly their damping characteristics and dynamic mechanical properties. The nano particle size and the high aspect ratio yield an extraordinary enhancement of the properties of rubbery materials. The uniform dispersion of nanoparticles in elastomer matrix is an efficient and general prerequisite for achieving desired mechanical and physical characteristics. In recent developments in the field of vibration damping, elastomer nanocomposites reinforced with nanoparticles attracted a great interest of researchers.

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