Theoretical Analysis of Non Linear Behavior of Rubber Bush for Optimum Shape Form

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Abstract- In modern day's customer's requirement of comfort is increasing day by day. This paper is related to damping of vibration caused by engine by designing a rubber bush. For an internal combustion engine, there exist two basic dynamic disturbances: the firing pulse due to the explosion of the fuel in the cylinder; the inertia force and torque caused by the rotating and reciprocating parts (piston, connecting rod and crank). To damp out such forced vibration engine is supported by rubber bush. In this study theoretical analysis is done with using suitable formulae to investigate the static deflection, behavior of rubber bush with focusing on the effect of material compressibility on numerical results.

Keywords – Rubber Bush, Axial Stiffness, Lateral Stiffness.

I. INTRODUCTION

Nowadays, people require high quality for everything. Certainly the comfort in the moving vehicles is peoples concern so it is desirable to have high performance suspension systems for vehicles. Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. Vibration is undesirable, wasting energy and creating unwanted sound, noise. For example, the vibrational motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations can be caused by imbalances in the rotating parts, uneven friction, the meshing of gear teeth, etc. Careful designs usually minimize unwanted vibrations. [1]

Forced vibration is when a time-varying disturbance (load, displacement or velocity) is applied to a mechanical system. The disturbance can be a periodic, steady-state input, a transient input, or a random input. The periodic input can be a harmonic or a non-harmonic disturbance. Examples of these types of vibration include a shaking washing machine due to an imbalance, transportation vibration (caused by truck engine, springs, road, etc. Natural rubber consists of suitable polymers of the organic compound isoprene, with minor impurities of other organic compounds plus water. Forms of polyisoprene that are useful as natural rubbers are classified as elastomers. Rubber is a unique material that is both elastic and viscous. Rubber parts can therefore function as shock and vibration isolators and/or as dampers. Although the term rubber is used rather loosely, it usually refers to the compounded and vulcanized material. Rubber like material exhibit a highly nonlinear behavior characterized by hyper elastic deformability and incompressibility. It is a material which can withstand very large strain from 100% to 1000% without any permanent deformation. Theoretical formulation is carried out in this seminar work and CAD model is prepared as per the dimensional requirement. The axial and lateral loads are considered to calculate the stiffness. Future work contains FEA analysis and Experimental validation with theoretical analysis. [13]

II. PROBLEM DEFINITION

The main purpose of rubber bush in automobile is to support the engine firmly and to eliminate the noise & vibration. The rubber bushes supporting the engine are subjected to forced vibrations caused by moving parts of engine and unbalanced forces. This unbalanced forces cause's failure of rubber bush. The main aim is to increase the life cycle of the rubber bush for engines and to determine the optimum shape form of the rubber bush reducing manual iteration for those by using ABAQUS Software. By using this FEA tool Optimum shape form of rubber bush can be achieved.

III. Rubber

Natural rubber consists of suitable polymers of the organic compound isoprene, with minor impurities of other organic compounds plus water. Forms of polyisoprene that are useful as natural rubbers are classified as elastomers. Currently, rubber is harvested mainly in the form of the latex from certain trees. The latex then is refined into rubber ready for commercial processing. Natural rubber is used extensively in many applications and products, either alone or in combination with other materials. In most of its useful forms, it has a large stretch ratio, high resilience, and is extremely waterproof. Rubber is a unique material that is both elastic and viscous. Rubber parts can there-fore function as shock and vibration isolators and/or as dampers. To improve the mechanical properties of rubber Natural rubber is compounded, vulcanized along with anti-degrading agents, reinforcement agents.

Vulcanization forms chemical bonds between adjacent elastomeric chains and subsequently imparts dimensional stability, strength, and resilience. Rubber like material exhibit a highly nonlinear behavior characterized by hyperelastic deformability and incompressibility. It is a material which can withstand very large deformation more than 100% of its original shape. The typical stress-strain curve in tension is noticeably nonlinear so that Hook's law cannot be used and it is not possible to assign a definite value to the young's modulus except in the region of small strains. Rubber exhibit complicated mechanical behavior as it can undergo large deformations.

IV. Rubber Bush

A bushing or rubber bushing is a type of vibration isolator. It provides an interface between two parts, damping the energy transmitted through the bushing. A common application is in vehicle suspension systems, where a bushing made of rubber (or, more often, synthetic rubber or polyurethane) separates the faces of two metal objects while allowing a certain amount of movement. This movement allows the suspension parts to move freely, for example, when traveling over a large bump, while minimizing transmission of noise and small vibrations through to the chassis of the vehicle. A rubber bushing may also be described as a flexible mounting or anti-vibration mounting.

A. Silent Bush:

Silent bushes are used in automobile to support engine along with engine mount. These types of bushes are bonded by metal sleeve with the help of proper adhesives. Two metal sleeves are used one at inner portion and other at outer in between the both rubber is molded.

B. Inner Bush

These bushings often present in the form of an annular cylinder of flexible material outside and metallic tube inside. It is having metal in just inner portion.

V. Formulation of Rubber Bush

Consider an annular rubber bush of axial length L_1 & L_2 which is bonded internally and externally to rigid circular cylindrical metal sleeves of radii r_1 and r_2, respectively. The outer sleeve is subjected to axial load of constant magnitude P_a. [2] [5]

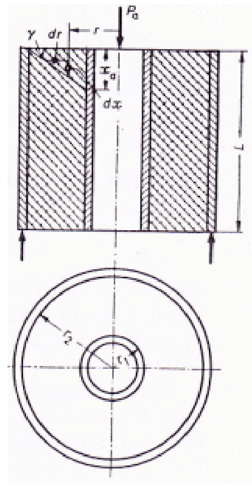


Figure No.1 Rubber Bush Subjected to Load P_a

Table No 1. Specifications of Rubber Bush

Specification	Dimensions
Inner radius r_1	9 mm
Outer radius r_2	18.8mm
Length of outer sleeve L_2	24mm
Length of inner sleeve L_1	31.8mm
Height of rubber h	9.8

A. Axial Stiffness K_a

The shear angle is *γ* thus *A* being the cylindrical surface area at distance r.

$$\tau = G \ \tan \ \gamma \tag{1}$$

For axial stress the rubber bush is considered as rubber spring. Through the action of force P_a one sleeve moves in relation to the other by a distance X_a. [8][12][16]

$$K_a = \frac{P_a}{X_a} = \frac{2\pi G\,(L_1 r_2 - L_2 r_1)}{(r_2 - r_1)(\ln L_1 r_2 - \ln L_2 r_1)} \tag{2}$$

B. Lateral Stiffness Kr

The outer sleeve does not participate. The change of position of a point of the rubber layer under load Pr is considered as shear and tension or compression. [8][12][16]

From Hooke's law

$$\varepsilon = \sigma / E \qquad \sigma = \tau / G \tag{3}$$

Hence,

$$K_r = \frac{P_r}{X_r} = \frac{7.5\, h\, \pi\, G}{\ln(r_2/r_1)}\, k_1$$

(4)

V. RESULT AND DISCUSSION

For Axial stiffness

Table no 2. Values of K_r When Outer Radius r_2 Varied

Sr. No	Outer radius *r_2 (mm)*	Height of rubber *h (mm)*	Axial stiffness *K_a (N/mm)*
1	18.6	9.6	195.1665
2	18.7	9.7	193.759
3	18.8	9.8	192.3793
4	18.9	9.9	191.0266
5	19	10	189.7001

Table no 3. Values of Kr When Outer Radius L1 Varied

Sr. No	Length of inner sleeve *L_1 (mm)*	Height of rubber *h (mm)*	Axial stiffness *K_a (N/mm)*
1	31.6	9.8	191.6728
2	31.7	9.8	192.0262
3	31.8	9.8	192.3793
4	31.9	9.8	192.7321
5	32	9.8	193.0845

Table no 4. Values of Kr When Length of Outer Sleeve L2 Varied

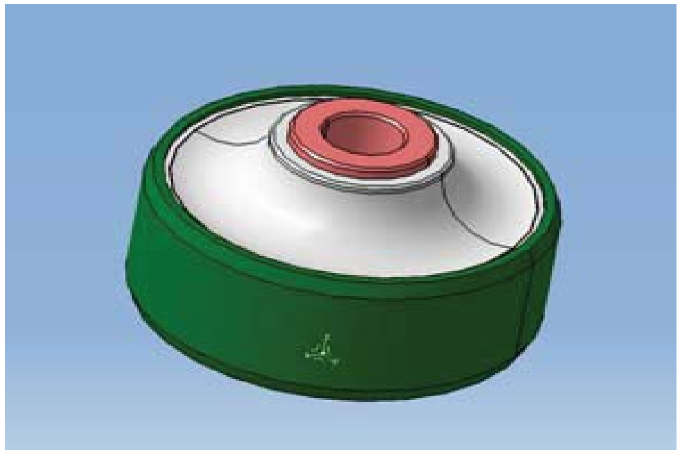
Sr. No	Length of outer sleeve *L_2 (mm)*	Height of rubber *h (mm)*	Axial stiffness *K_a (N/mm)*
1	22	9.8	185.5862
2	23	9.8	189.0119
3	24	9.8	192.3793
4	25	9.8	195.6918
5	26	9.8	198.9530

For Lateral stiffness

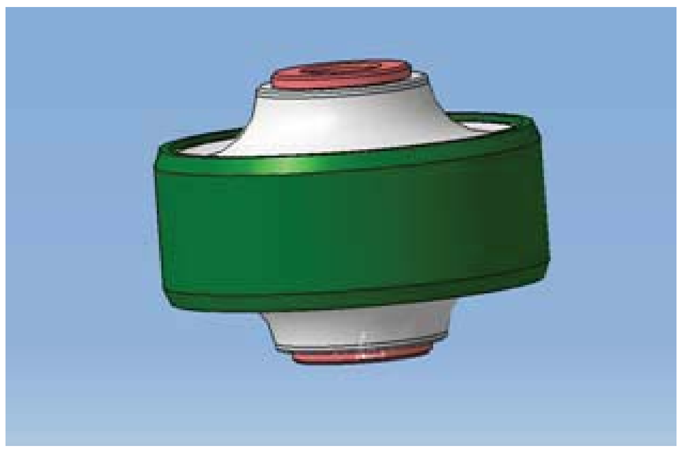
Table no 5. Values of Kr When Outer Radius r2 Varied

Sr. No	Outer radius *r_2 (mm)*	Height of rubber *h (mm)*	Lateral stiffness *K_r (N/mm)*
1	18.6	9.6	324.0535
2	18.7	9.7	325.0284
3	18.8	9.8	326.0016
4	18.9	9.9	326.9734
5	19	10	327.9437

From above table by changing the parameters of rubber bush the axial stiffness comes out to be K_a = 192.3793N/mm and Lateral stiffness K_r = 326.0016 N/mm. The CAD Model is drawn in CATIA V5 and general views are shown in this paper further FEA analysis is to be done with the help of ABAQUS and finally will be validated by experimentation.



(a)



(b)

Figure No.2 (a) CAD Model of Rubber Bush showing general views (b) Front View of Rubber Bush

VI. CONCLUSION

This paper covers introduction and properties of rubber. Natural rubber consists of suitable polymers of the organic compound isoprene, with minor impurities of other organic compounds plus water. Forms of polyisoprene that are useful as natural rubbers are classified as elastomers. Viscoelastic behavior of rubber is studied critically. The rubber bush is being used to support engine firmly and to reduce noise and vibration. Theoretical modeling of rubber bush subjected to both axial and lateral loads are considered and the static stiffness of rubber bush is calculated by using standard formulation. CAD models were prepared by using dimensions as per customer requirement by using CATIA V5.

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