Development of Procedure for Calculating Stiffness Properties of Elastomer Used In Vibration Isolation

[1]Mudassar A.S.Shaikh, [2]Dr.R.R.Arakerimath
Department of mechanical engineering,G.H.Raisoni college of engineering and management wagholi, pune, india

Abstract*: Vibration isolation is a most generally utilized vibration assurance technique. The solidness of vibration isolators in existing customary sort of vibration confinement framework is more often than not of settled esteem. This report/paper focuses on development of procedure for calculating the stiffness of elastomers/rubbers in three mutually perpendicular directions. This report focuses on calculation of stiffness for the purpose of doing linear analysis of elastomers/rubbers rather than nonlinear analysis in FEA software's, for this purpose Ansys workbench 2019 is used. The elastomers are modeled as linear material in Ansys workbench. The elastomers material which is used is nitrile rubber. The properties of rubber are modeled using ansys workbench. Nitrile is better than most elastomers as to pressure set or chilly stream, tear and scraped spot obstruction. Nitrile has brilliant protection from oil, gas, solvents, mineral and vegetable oils, pressure driven liquid, and powers. The stiffness results are calculated from formulas and compared with FEA results which are obtained from ansys workbench, Further the experimental analysis of elastomer geometry is performed to validate the results

Keywords: Vibration Isolator, Elastomers, CAE, Structural analysis, Vibration

I. INTRODUCTION

Vibration Isolators are to

1. Reduce the propagation of base vibration to the isolated object (machinery)

2. Restrict the transmission of vibration vitality of hardware to the base. In addition, in vehicular/marine, modern machines, (for example, mechanical presses), and additionally seismic applications, seclusion frameworks are likewise anticipated that would bring down the effect of stun from base to the disconnected protest as well as the other way around. By method for various precedents, we have shown that the high inclusion misfortunes anticipated for high frequencies by the crudest models are not really figured it out. That is on the grounds that, as we have effectively called attention to, the suspicions that underlie the basic models are not legitimate at high frequencies. Machines and establishments are not unbending, and isolators don't stay consistent. High vibration levels can cause hardware disappointment, and also frightful commotion levels. A typical wellspring of shocking commotion in structures is the vibration of machines that are mounted on floors or dividers. Clearly, the best place to mount a vibrating machine is on the ground floor.

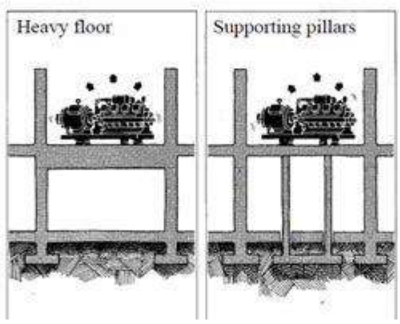

Fig.01 Vibration Trasformation

E.E. Ungar And C. W. Dietrich, Bolt Beranek[6]explained in there paper that The transmissibility and isolation effectiveness concepts pertaining to vibration isolation of one point of a linear system have been reviewed and generalized, both for massless isolators and for isolators in which mass effects are important. In particular, it has been demonstrated that the characteristics of the vibration source influence the effectiveness of an isolator and enter the relation between effectiveness and transmissibility. These two measures of isolation performance have been shown to be inversely proportional to each other for a given system operating at a given frequency, but to be reciprocals of each other essentially only for the case where the excitation is provided by a velocity source.

Pradeep K. Gupta,Juergen M. Tessarzik, Loretta Cziglenyi[8] in there paper said that Dynamic properties of a commercial poly-butadiene compound have been determined at constant temperature of 32 C by a forced-vibration resonant mass type of apparatus. The constant thermal state of the elastomer was ensured by keeping the ambient temperature constant and by limiting the power dissipation in the specimen. Experiments were performed with both-compression and shear specimens at several preloads (nominal strain varying from 0 to 5 percent) and the results are reported i n terms of a complex stiffness as a function of frequency.

chevalier-cleret[9] suggested a method to find the Young's modulus of rubber material in there research paper.

II. VIBRATION ISOLATOR

An isolator is a flexible help which decouples a protest from unfaltering state or constrained vibration. To lessen the transmitted vibration, isolators as springs are utilized. Normal springs utilized are pneumatic, steel loop, elastic (elastomeric) and other cushion materials.

Normal recurrence and damping are the fundamental properties of an isolator which decide the transmissibility of a framework intended to give vibration as well as stun detachment. Also, other essential variables must be considered in the determination of an isolator/seclusion material.

The easiest type of mechanical vibration to consider depends on a straight framework. While applying straight hypotheses, the estimations of uprooting, speed and increasing speed have corresponding connections to the mechanical firmness (spring rate) of the vibration isolation system.

Regularly, to make plan and examination less demanding, the reaction of isolators which are not genuinely straight, (for example, elastomers, stopper, felt) are approximated by utilizing direct connections.

Not all isolators whose isolation qualities depend on mechanical redirection have a straight connection among load and avoidance. A typical oversight is that Equation 1 can be utilized to ascertain the characteristic recurrence for all isolators if the spring rate (k) and bolstered mass (m) are known.

Equation 1

$$F_N = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

If the spring rate (k) is not known, the equation can be rewritten (Equation 2) so that the calculated natural frequency of the isolator is a function of its static deflection.

This results in a determination of the isolator's static natural frequency where (g) represents the gravitational constant.

Equation 2

$$F_N = \frac{1}{2\pi}\sqrt{\frac{g}{\delta_s}}$$

Where,

F_N = Natural Frequency , K = spring rate/Stiffness

M = Mass coming on isolator,

G =Acceleration due to gravity, δs =Static Deflection

III. OBJECTIVE

- To proposed an theoretical method to find the stiffness of elastomers in three direction which are used in vibration isolation
- To find a method in which we can analyse rubber as a linear method instead of nonlinear to save time of analysis

IV. Modeling of Geometry

A simulation model for analysis of the geometry is required to predict the deformation which will helpful to the stiffness of elastomer. The 3D model and finite element models of the elastomer geometry are made by using CATIA and ANSYS WORKBENCH 2019

4.1. 3D Geometrical model isolator

The 3D mode and 2D sheet of vibration isolator geometry is shown in figure below,

Fig.02 3D CAD model of vibration iolator

As from above 3D model it is clear that our rubber material is sandwiched between two steel plates.

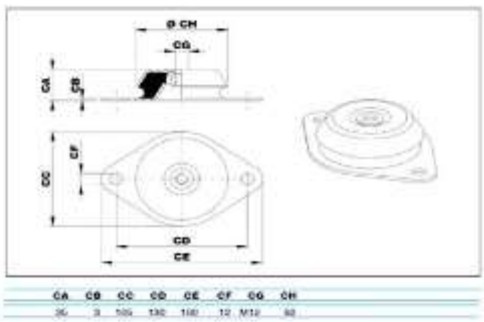

Fig.03 2D Drawing sheet of vibration isolator geometry

4.2. Finite Element Modeling of isolator

The rubber model considered is analysed for particular load (i.e. of bodies) which is coming on isolator.

The geometry is meshed & analysed in ansys workbench 19

Consider weight of body coming on isolator is 3580 Kg and if there are 10 isolators in the geometry, then we need to divide the total wt with no. of isolators present in the assembly.

Weight of geometry above vibration isolator is 3580

Kg Total number of isolator is equal to 10

Weight per unit isolator is = 3580/10== 358 Kg

A) Meshing

Higher order tetrahedral and hex meshing is used.

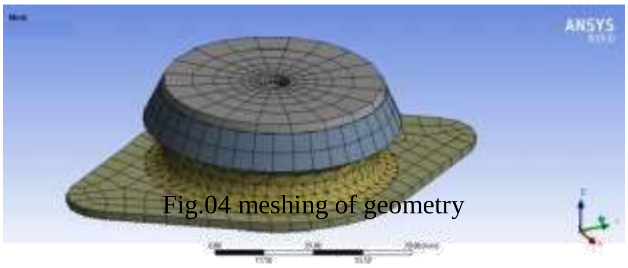

Fig.04 meshing of geometry

V. MATERIAL PROPERTIES

Sr. No.	Material	Young's Modulus Mpa	Poisons ratio	Density Kg/m^3
1.	Structural Steel	2E+05	0.3	7850
2.	Nitrile Rubber	5.5	0.499	1000

VI. Analysis

6.1. Structural Analysis

A) Boundary Conditions

The isolator is fixed at bottom position and provide with gravity and force of 3512 N

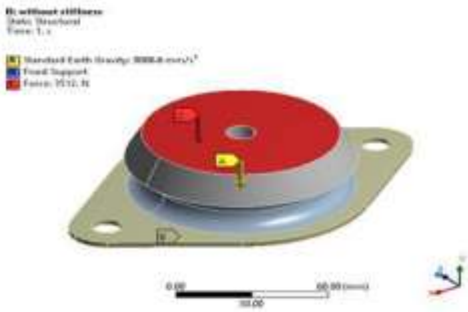

Fig.05 Boundary conditions

B) Results

Total Deformation

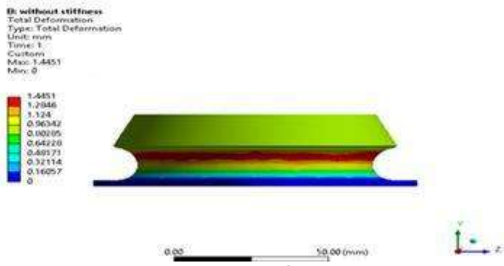

Fig.06 Total deformation

Deflection in X direction

Deflection of rubber in X direction= 0.960 mm

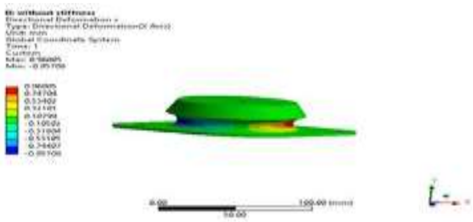

Fig.07 Deformation in X direction

Deflection in Y direction

Deflection of rubber in Y direction= 1.267 mm

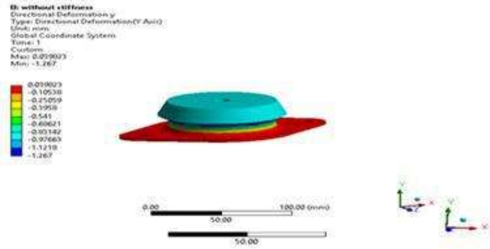

Fig.08 Deformation in Y direction

Deflection in Z direction

Deflection of rubber in Z direction= 0.968 mm

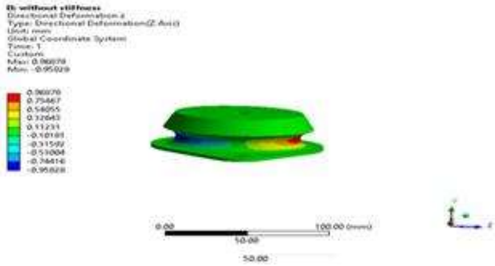

Fig.09 Deformation in Z direction

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6.2. Stiffness calculation from above results

We know that,

F=K x i.e. k = f / x

Where f = force applied, x is directional

deflection, K is stiffness

Therefore, Stiffness is Y direction

Ky = f / x = 3512 / 1.267 = **2771.90 N/mm**

Similarly we can find stiffness in remaining direction i.e. X and Z

K_x = 3658.33 N/mm K_z = 3628.09 N/mm 7.

Theoretical stiffness calculation

As per the theoretical formulas which we have taken under our studies, stiffness is calculated as,

$$f = \frac{1\sqrt{k/m}}{2\pi} \quad \text{Or} \quad f = \frac{1\sqrt{g/\Delta}}{2\pi} \quad \text{Where}$$

m- mass of assembly above isolator body

Δ-Deflection

Stiffness in Y direction,

Δ = 1.267 mm = 0.001267

m g = 9.81 m/s^2

$$f = \frac{1\sqrt{9.81/0.001267}}{2\pi}$$

f=14.011Hz

Now from second formula,

$$f = \frac{1\sqrt{k/m}}{2\pi}$$

k = 27717721.9558 N/m

K_y = 2771.721 N/mm

Similarly we can find stiffness in remaining direction i.e. X and Z

K_x = 3658.1428 N/mm **K_Z = 3625.178 N/mm**

VII. CONCLUSION

The stiffness calculated from theoretical calculation and with the help of FEA software is approximately same. Hence we can say that we can perform the linear analysis on rubber with stiffness as the input parameter to avoid the nonlinear analysis, which in turns saves computational time and cost of analysis.

Hence we can conclude that the development of stiffness is possible for rubber/elastomers according to the method we have established.

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