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Dynamic analysis of laminated rubber-metal spring using finite element method

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ABSTRACT – Laminated rubber-metal spring (LRMS) is widely applied in buildings, vehicles and to protect sensitive equipments. In this study, the dynamic performance of such isolator was analyzed. The dynamic analysis was carried out using finite element method. Five models of rubber based isolators with different number of interlayer metal plates was analyzed using Abaqus 6.10 software. Transmissibility ratio was determined from the displacement changes of isolators. The results show the rubber bearing with embedded metal plate layers can improve the transmissibility ratio at high frequency.

1. INTRODUCTION

Rubber based isolators had been widely applied around the world especially for places with high possibility of ground movement such as earthquake. The isolator is used to decouple a structure from the moving component or ground motion. This is important to reduce damages caused by any vibrational force. LRMS was invented to function as an isolation system while withstanding the load applied on it for wide range of periods. It can extend the lifetime of the isolator and prevent bulging effects during the static pre-load[1].

It appears from the aforementioned investigations that most attention has been paid to seismic isolation studies regarding earthquake which is mainly for horizontal and low frequency vibration problems[2], [3]. Furthermore, it can be seen only few studies have discussed the performance measurement focussing on axial vibration. The purpose of this study is to determine the axial vibration transmissibility performance of the solid rubber isolator and LRMSs using dynamic analysis of finite element method. The vibration characteristics of the isolator were defined in term of transmissibility frequency response function which is ratio of output to the input excitation. The Finite Element Analysis (FEA) results will be validated to the experimental results study. The findings of this study will help to use FEA to model future laminated spring products which not only able to sustain large deflection but also demonstrate good isolation performance.

2. METHODOLOGY

The finite element approach is adopted in this paper for various model of isolator from LRMS type.

2.1 Geometrical model

The isolator model studied is a cylindrical sandwiched mounts consisting of alternate layers of steel and rubber discs. All the isolators had the same total length, t_T which was 0.1m and 0.1m for the diameter, D. The flange plate located at both isolator ends is 5mm in thickness. Each metal plate embedded inside the isolator had length, t_S of 3mm and radius of 0.05m. In the whole analysis, the total length of isolators and metal plates were maintained thus only the thickness of rubber discs was varied according to the changes of metal plate number. The rubber sections length, t_R for solid rubber to 4 metal plates isolator were 0.1m, 0.049m, 0.031m, 0.023m and 0.018m respectively. Isolator without metal plate was labeled as solid rubber while LRMS were labeled according to the number of plate layers exist which were LRMS 1 to LRMS 4. Figure 1 shows the example configuration of the LRMS 1 assembly.

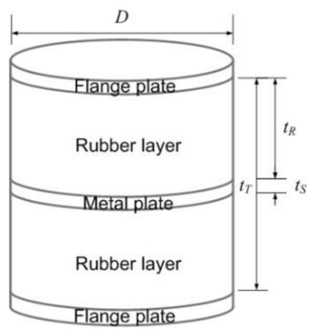

Figure 1 Example of LRMS 1 assembly configuration.

2.2 Finite element model

The finite element modeling of the rubber bearing was carried out using ABAQUS finite element analysis (FEA) software. Both metal end plates were modeled using fully integrated axisymmetric solid elements which is CAX8 while the rubber sections used CAX8H. CAX8H elements are fully integrated axisymmetric solid from hybrid type. Hybrid is formulated for incompressible or nearly incompressible material behavior.

The procedure type used was direct steady state dynamic analysis that provides the steady-state amplitude of the response of a system due to harmonic excitation at a given frequency. The transmissibility results were obtained from the ratio of the displacement response of the output end plate to the input displacement excitation applied to the input end plate.

2.3 *Material properties*

The material used in the rubber sections were Natural Rubber (NR) which has Young Modulus, E =1.4 MPa and density, ρ=920kgm^{-3}. For the metal plate, the material properties involved are E=211GPa and ρ=7850kgm^{-3}. Rigid mass of 0.3Kg is applied to the metal plate where the part is defined as rigid body.

3. RESULTS AND DISCUSSION

Figure 2 illustrate the results obtained from the FEA done on solid rubber and LRMS isolator. The solid grey line represents the FEA while the dashed black line represents the experimental results. It was observed that the FEA results have good agreement with the experimental data and the presented methodology has good accuracy for analyzing solid rubber and LRMS isolator.

a)

b)

c)

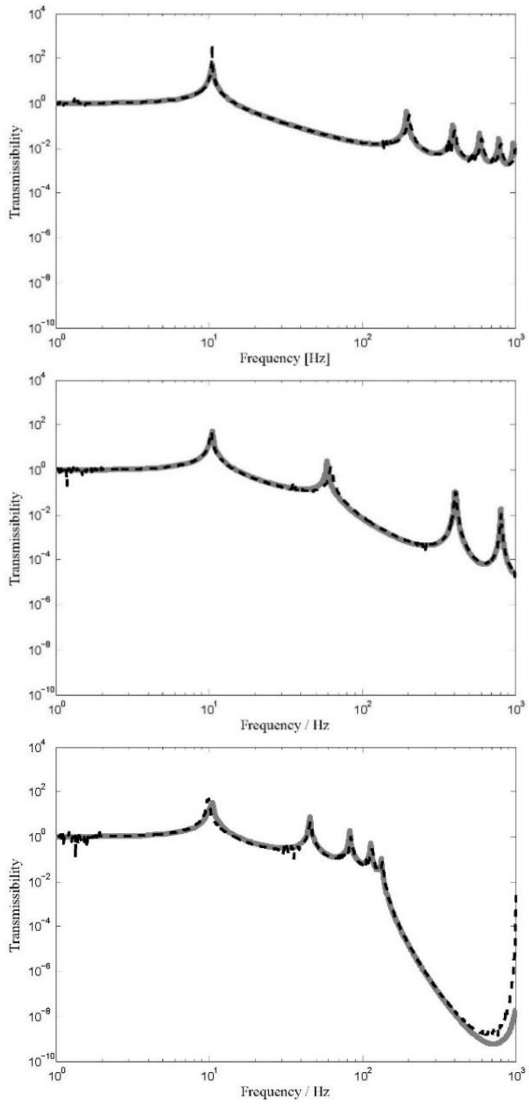

Figure 2 Transmissibility curve for a) solid rubber, b) LRMS 1, c) LRMS 4 (dashed line: experiment, solid line: FEA).

Figure 3 presents all the FEA results in single plot for performance comparison. All isolators maintained the same natural frequency at low frequency while exhibit better high frequency performance for bigger number of metal plates. LRMS 4 had the best dynamic performance among the tested models. This is influenced by stiffness changes of isolator structure with the presents of interlayer metal plates. Greater stiffness results in better isolation performance especially at high frequency.

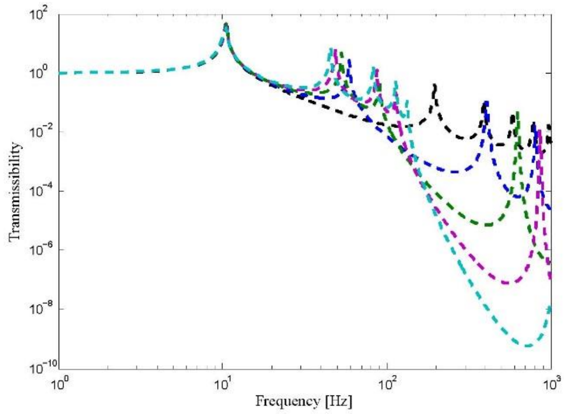

Figure 3 Comparison of transmissibility performance for: solid rubber (black), LRMS 1 (blue), LRMS 2 (green), LRMS 3 (pink) and LRMS 4 (light blue).

4. CONCLUSIONS

The dynamic analysis of solid rubber isolator and LRMSs was carried out using finite element method in Abaqus. The transmissibility curve was successfully validated with the experiment and highlighted few performance characteristics such as:

a) The FEA method has good accuracy for analyzing cylindrical solid rubber and LRMS isolators.
b) More interlayer metal plate inside LRMS has better transmissibility performance at higher frequency.

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