DESIGN AND ANALYSIS OF RAIL DAMPING CHARACTER USING ABSORBERS

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ABSTRACT - The purpose of this thesis is to study the influence of design parameters on dynamic response of the railway track structure by implementing Finite Element Method (FEM). According to the complexity, different railway track systems have been simulated using rail absorber arrangement. Four types of rail absorbers and two types of without rail absorbers have taken into analysis. The finite element analysis is divided into two categories: eigenvalue analysis and dynamic analysis to find our resonance frequency. The Eigen frequencies and corresponding vibration modes were extracted from all the models. The main part of the finite element modeling involves dynamic analysis, in which resonance frequency were obtained and used as the criterion for evaluating the dynamic properties of track components.

Keywords: viscoelastic damping, vibrations, arrangement of dampers and rail.

Introduction

In recent decades, railway transport infrastructures have been regaining their importance due to their efficiency and environmentally friendly technologies. This has led to increasing train speeds, higher axle loads and more frequent train usage. These improved service provisions have however brought new challenges to traditional railway track engineering, especially to track geotechnical dynamics. These challenges demanded for a better understanding of the track dynamics. Due to the large cost and available load conditions limitation, experimental investigation is not always the best choice for the dynamic effect study of railway track structure. Comparatively speaking, an accurate mathematical modeling and numerical solution of the dynamic interaction of the track structural components reveals distinct advantage for understanding the response behavior of the track structure. Railway is seen as a means of environmental-friendly transportation by providing clean and efficient mass transit. However, noise and vibration problems due to railway operation become public, technical and administrative concern. The predominant source of noise from railway is associated with the rolling of the wheel on the rail. The roughness on the wheel and rail tread forms excitation and causes vibration of the wheel and track. When vibration propagates in the wheel and rail, the structure radiates noise. The aim of this thesis is to analyze the dynamic effects of the railway track. From the detailed finite element models created in ANSYS, more detailed information about the dynamic effects of the railway track can be made, such as rail track vibration modes and receptance functions. The results of the rail absorber system will be analyzed and suggestions will be made for the further study. Analysis is carried out for typical data obtained from Indian Railways. Analysis is carried out for only one side of the railway track. The rail cross-section is shown in Fig. 1 and parameters are shown in table below.

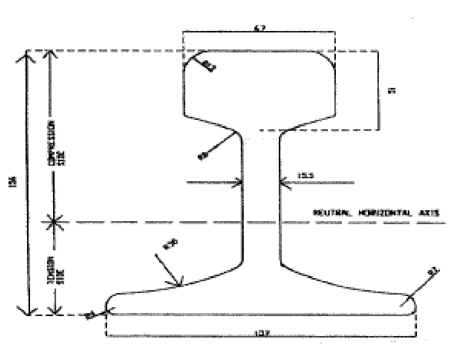


Fig 1:Rail section

The Design of Rail with Constrained Damped Dynamic Vibration Absorber

Constrained damped dynamic vibration absorber is a vibration system combined damp and spring. To absorb and dissipate the vibration energy, the rubber layers bonded with the rail waist are mainly used to perform as the distributing elastic components of the DVA; the steel plates are used as the quality layer and the constraints layer to form the distributing power quality of DVA, together with the rubber damping layer. Then the distributing elastic components and distributing power quality can jointly constitute a set of distribution parameters of the dynamic vibration absorber. The DVA can absorb the vibration and prevent the noise radiation when the rail waist is vibrating. Quality layer, damp layer and constrained can also function as a multi-constrained damper to reduce the vibration deformation of the distributing power quality, which is similar to the effect of damped rail. In the dynamic vibration absorber designing process, rubber sheet and plate materials are employed to make the DVA, because the rubber, with good elasticity and high damping ratio, after special treatment, can be effectively nanti-corrosion and can ensure the stiffness and damp which is needed to meet in the designing process. In addition, since steel plate has some characteristics like high density and relatively lower cost, it is chosen as the quality of unit. On selecting rubber sheet to replace the damper and stiffness, we take unilateral paste in account of the ease of installation and maintenance service. In this paper, the widely used standard 60 type rail is used, with installation of a single-layered and three-layered DVA on the outside of rail waist respectively. Both the steel and rubber sheet are 5.3mm for thickness, 350mm for length and 50mm for width. As the rail sections installed with damped dynamic vibration absorber shown in Figures below.

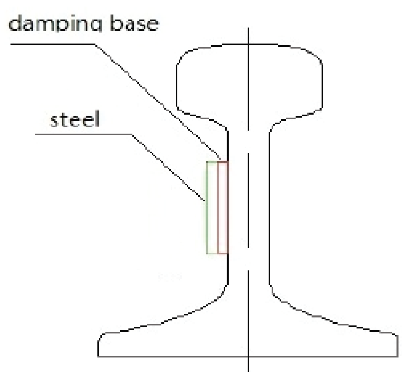


Fig 2a: single layered damping

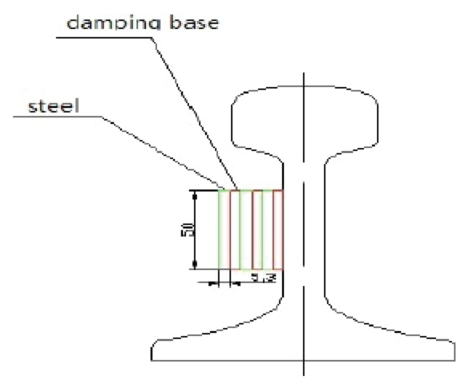


Fig 2b: Multi layered damping

The rail absorber studied consists of the steel mass bars and the elastomeric material layers between them and the rail. The elastomeric layers are glued to the lower part of the rail web and the upper surface of the rail foot, as shown in Fig. The absorber is attached to each side of the rail web, and may be either piecewise continuous or discrete along the rail. However, it is not always the case and other products exist, using masses and elastomeric layers, which look different. The rail absorber works as a vibration system of two degrees of freedom when the mass-bar is short, for example less than 0.15m in length. Under this condition, the mass-bar can approximately be regarded as a rigid body because its natural frequencies of bending vibration are above 3 kHz for the parameters used in the

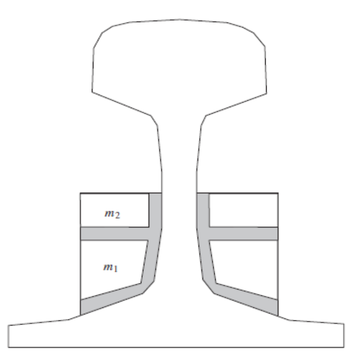


Fig 3:Cross-section of the rail with absorber

CATIA is software which is used for creation and modifications of the objects. In CATIA, design and modeling feature is available. Design means the process of creating a new object or modifying the existing one. Drafting means the representation or idea of the object. Modeling means create and converting 2D to 3D. By using CATIA software, model of the journal bearing assembles is created. Here all parts are created by using pad, and sketch. And final model is saved as I.G.E.S. format.

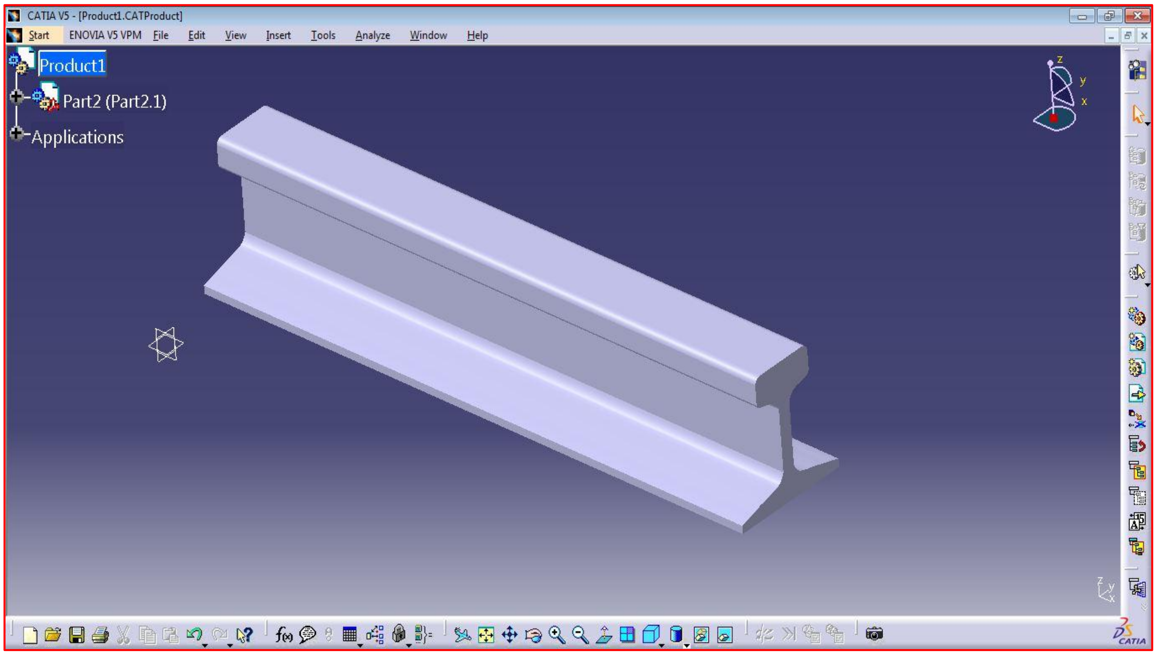


Fig 4: rail with out dampers.

The above image shows the three dimension model of Indian rail. Here all dimensions are considered according to Indian railway codes. Using this model is prepared in CATIA as shown above. Here pad command is used to extrude the sketch. Extruding value is considered as 700 mm.

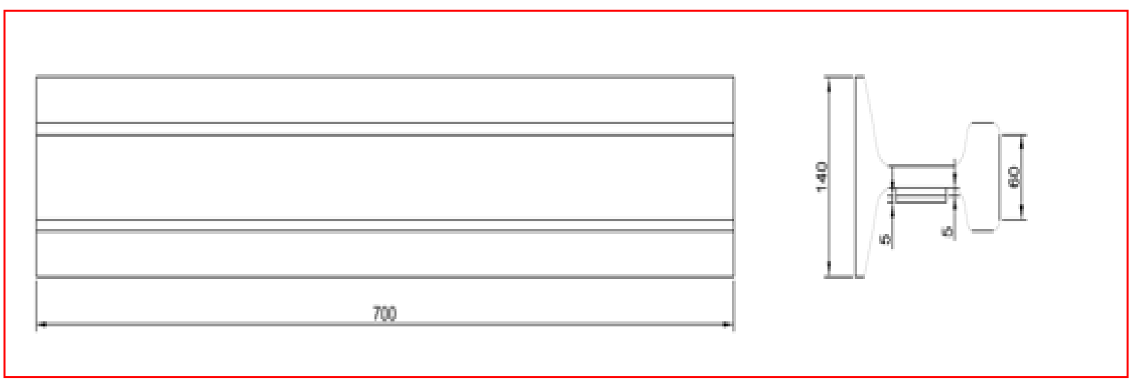


Fig 5: rail with single layered dampers.

The above image shows the drafting view of single layered absorbers. Here this model is considered using reference articles. If we provide the absorbers to the rail we can reduce the vibrations and improve the damping character.

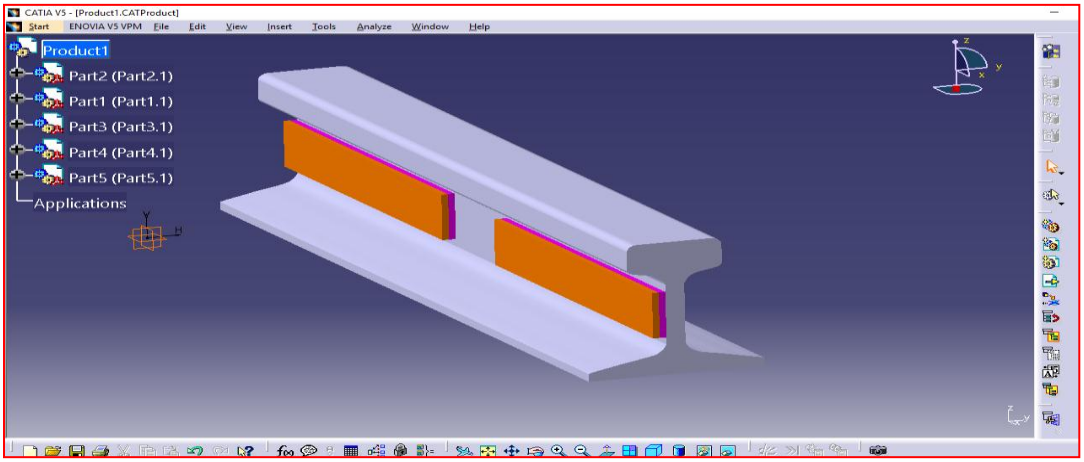


Fig 6: 3D model of rail with single layered dampers.

The above image shows the three dimension model of rail with single layered absorber. Here all dimensions are considered according to reviewed articles. Using this model is prepared in CATIA as shown above. Here pad command is used to extrude the sketch. Extruding value is considered as 700 mm. 5mm thickness of absorber is fixed to rail with 5mm thickness of steel plates. It length is considered as 300mm from both ends.

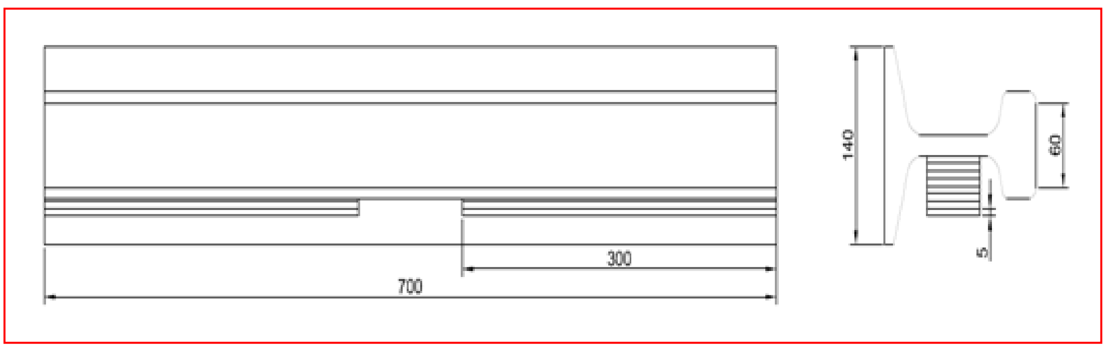


Fig 7: rail with Multi layered dampers.

The above image shows the drafting view of multi layered absorbers. Here this model is considered as extension of work. If we provide the absorbers to the rail we can reduce the vibrations and improve the damping character.

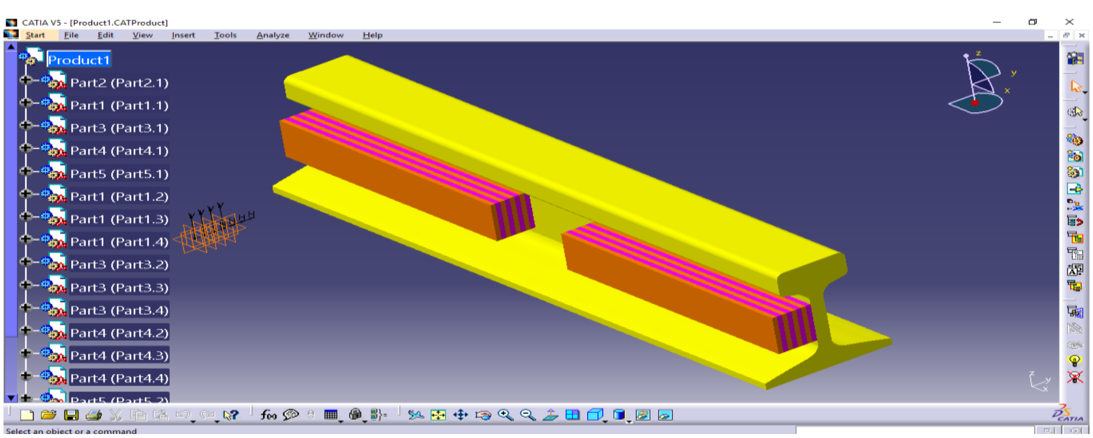


Fig 8:3D model of rail with Multi layered dampers.

The above image shows the three dimension model of rail with Multi layered absorber. Here all dimensions are considered according to reviewed articles. Using this model is prepared in CATIA as shown above. Here pad command is used to extrude the sketch. Extruding value is considered as 700 mm. 5mm thickness of absorbers is fixed to rail with 5mm thickness of steel plates. It length is considered as 300mm from both ends.

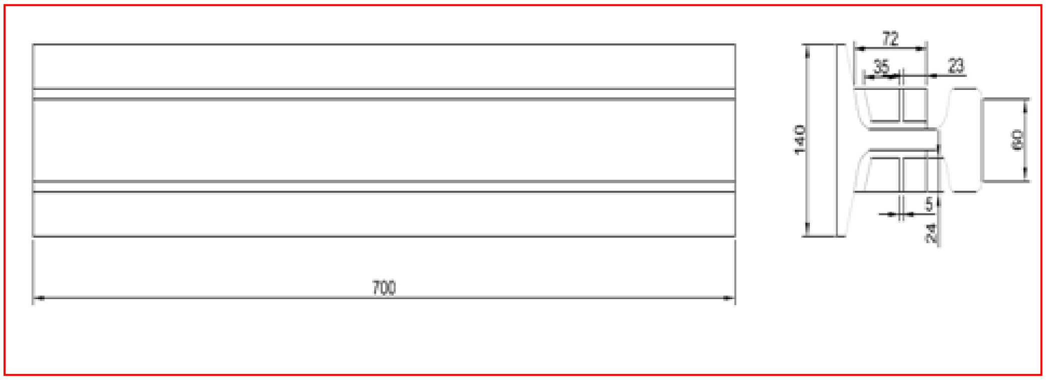


Fig 9: rail with Double layered dampers.

The above image shows the drafting view of Double absorbers. Here this model is considered as extension of work. If we provide the absorbers to the rail we can reduce the vibrations and improve the damping character.

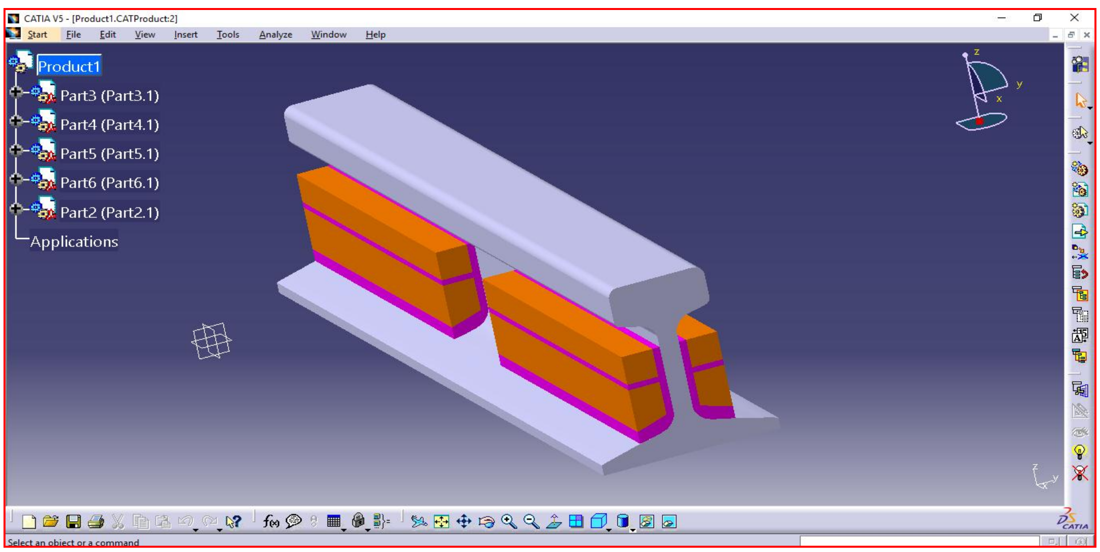


Fig 10:3D model of rail with Double layered dampers.

The above image shows the three dimension model of rail with double mass absorber. Here all dimensions are considered according to space what we have on rail structure. Using this model is prepared in CATIA as shown above. Here pad command is used to extrude the sketch. Extruding value is considered as 700 mm. 5mm thickness of absorbers is fixed to rail with suitable steel componets. It length is considered as 300mm from both ends.

To run the Analysis, 64 bit operating system, 4GB ram And ANSYS 19.0 is used. Without any problem, to run analysis software this configuration is very apt. The previously created IGS file is imported on ANSYS file geometry. In ANSYS, static structure and modal analysis are performed. The table which is shown below, different materials for different components are used bicycle seat assembly. Solid mesh 200 element are used to divide the geometric body in to small strips (Finite elements)

Table 6.1: steel material properties

	steel
Young's modulus	210e9 Pa
Poisons ratio	0.3
Density	7860 Kgm^-3

In the present work, the entire rail model components are divided into 20276 tetrahedron elements and 5261 nodes. In real time, the position where we place the rail model in its exact location, likewise in ANSYS software same location we applied the boundary condition. Fixed boundary conditions are applied at the bottom of rail.

Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis.

Modal analysis is the procedure of determining a structure's dynamic characteristics; namely, resonant frequencies, damping values, and the associated pattern of structural deformation called mode shapes. It also can be a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis.

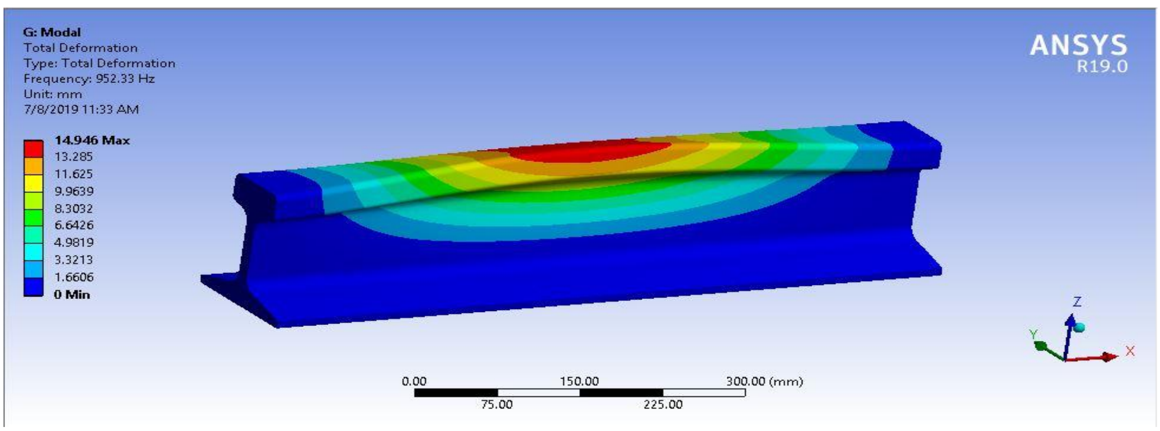


Fig11:1st mode of rail model.

The above image shows the 1st mode of natural frequency. In this mode shape rail are bending towards X- direction at having 952.3 Hz natural frequencies. Red colour shows the maximum deformation it means bending of rail.

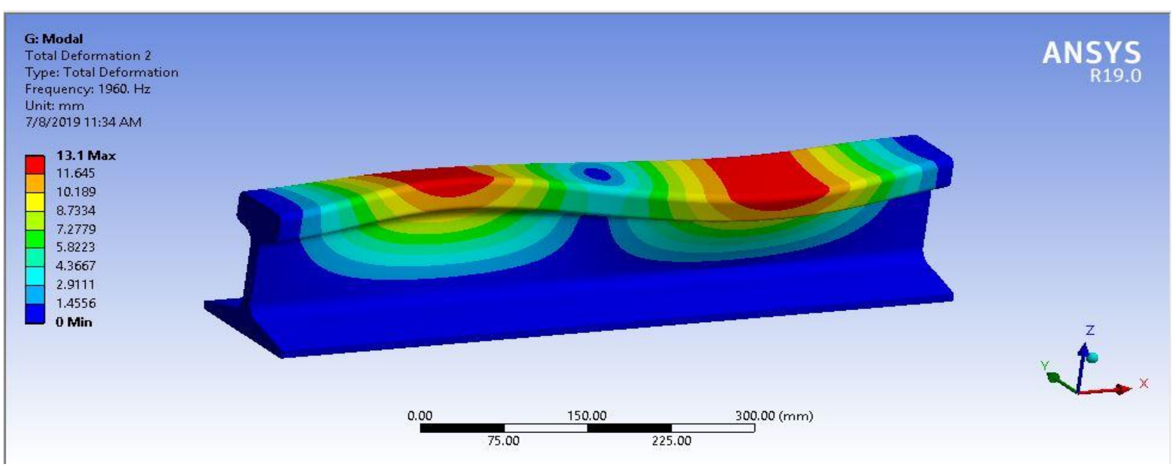


Fig12:2nd mode of rail model.

The above image shows the 2nd mode of natural frequency. In this mode shape rail are bending towards X- direction at having 1960 Hz natural frequencies. Red colour shows the maximum deformation it means bending of rail.

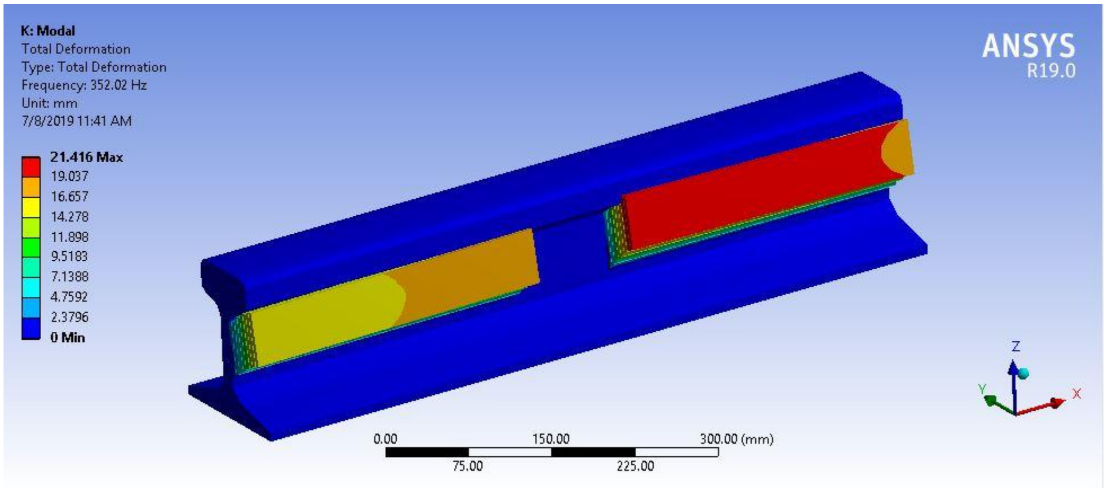


Fig13:1st mode of rail 4th model

The above image shows the 1st mode of natural frequency. In this mode shape rubber dampers are bend along towards Z-direction at having 352.02 Hz natural frequencies. Red color shows the maximum deformation it means bending of rail.

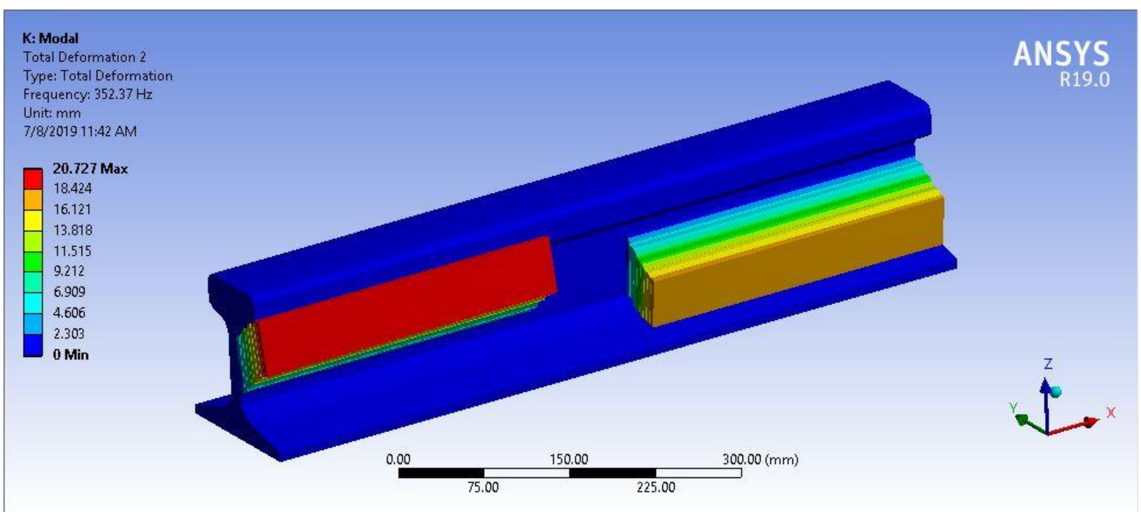
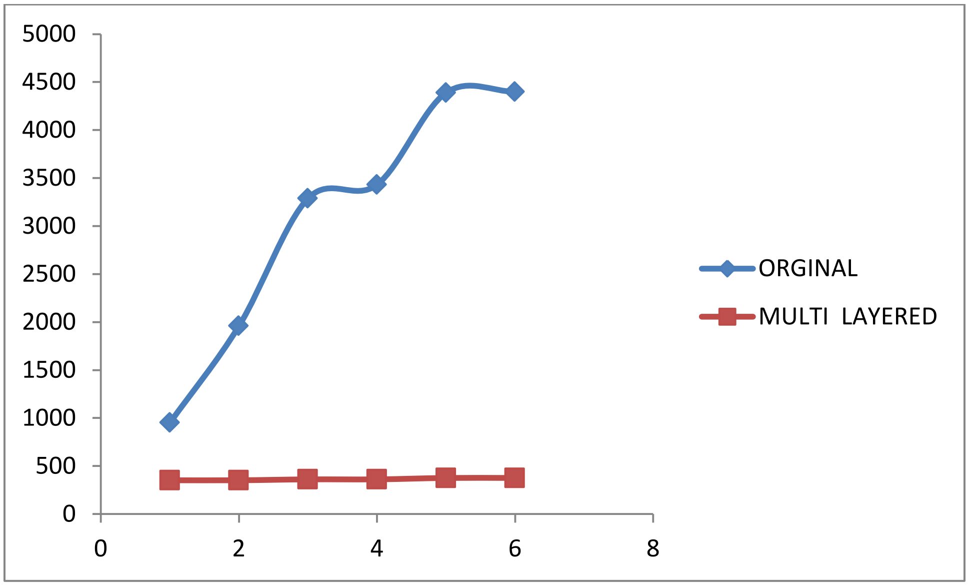


Fig14:2nd mode of rail 4th model

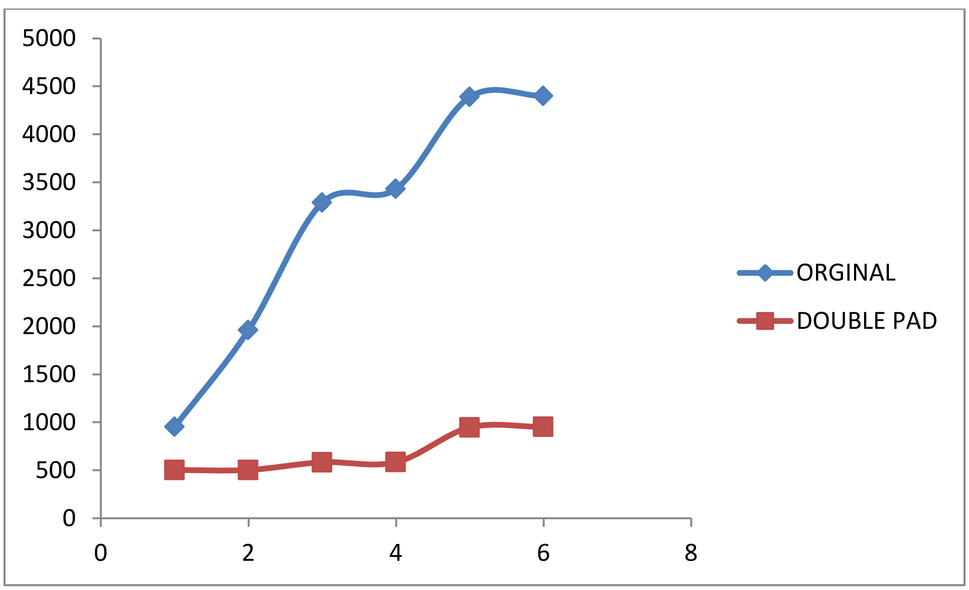
The above image shows the 2nd mode of natural frequency. In this mode shape rubber dampers are bend along towards Z-direction at having 352.37 Hz natural frequencies. Red color shows the maximum deformation it means bending of rail.

Four type of models are created in CATIA V5 R20 and saved as IES formet. And imported in to ANSYS workbench. Here model analysis is performed to find out natural frequencies and frequencies response analysis also performed to find out resonance frequency. The first model dimensions and materials have taken from article. And present analysis results are compared with article results. Absorbers arrangement considered from previous articles. And results are noted in tables below.



Graph1: natural frequencies comparison for original rail and multi layered absorbers

From the above results without absorbers are having 952 Hz minimum natural frequency and 352 Hz minimum natural frequency for with absorbed 1st model. Here natural frequencies are reducing with arranging absorbers nearly 30%.



Graph2: natural frequencies comparison for original rail, double layered absorbers.

Graph: natural frequencies comparison for original rail and multi layered absorbers

From the above results without absorbers are having 952 Hz minimum natural frequency and 503 Hz minimum natural frequency for with absorbed 1st model. Here natural frequencies are reducing with arranging absorbers nearly 19%.

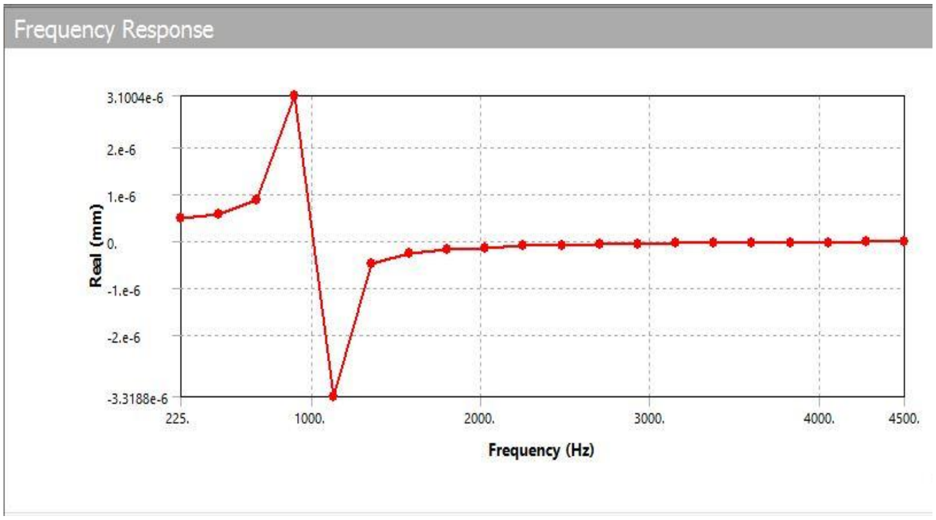


Fig3: Harmonic response of 1ST model.

The above image shows the frequency excited analysis on original dimension model of rail. Here bottom of rail is fixed to concrete trapezoidal member. The same boundary conditions are given at the bottom of rail. From 0 to 4500 Hz artificial frequencies are tested on the rail using ANSYS. Here rail structure is having maximum amplitude at the 900 Hz.

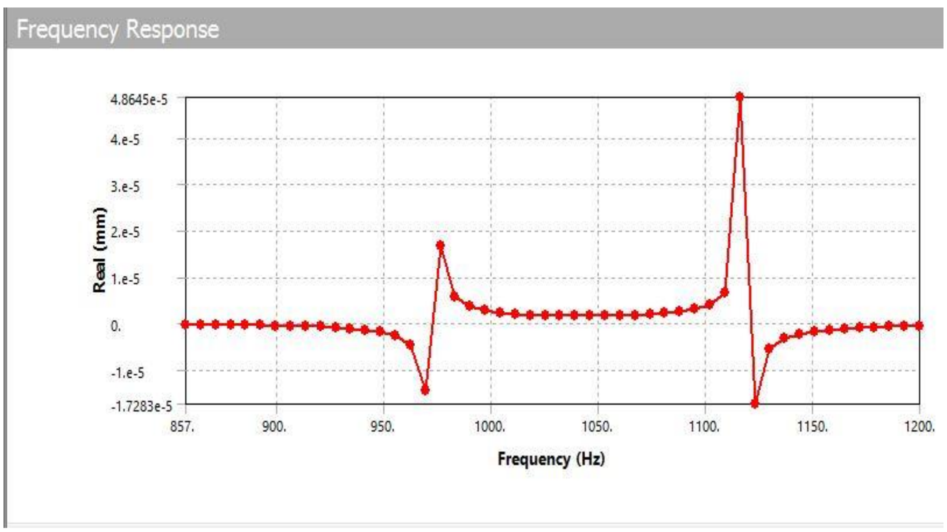


Fig4: Harmonic response of 2nd model.

The above image shows the frequency excited analysis on Single layered Damping absorber on rail. Here bottom of rail is fixed to concrete trapezoidal member. The same boundary conditions are given at the bottom of rail. From 0 to 1200 Hz artificial frequencies are tested on the rail using ANSYS. Here rail structure is having maximum amplitude at the 1115 Hz.

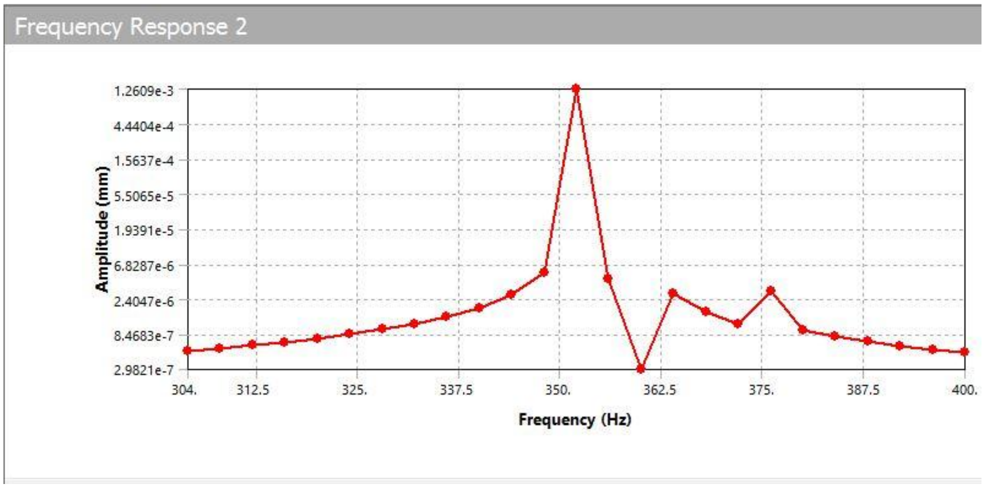


Fig5: Harmonic response of 3rd model.

The above image shows the frequency excited analysis on multi layered Damping absorber on rail. Here bottom of rail is fixed to concrete trapezoidal member. The same boundary conditions are given at the bottom of rail. From 0 to 400 Hz artificial frequencies are tested on the rail using ANSYS. Here rail structure is having maximum amplitude at the 352 Hz.

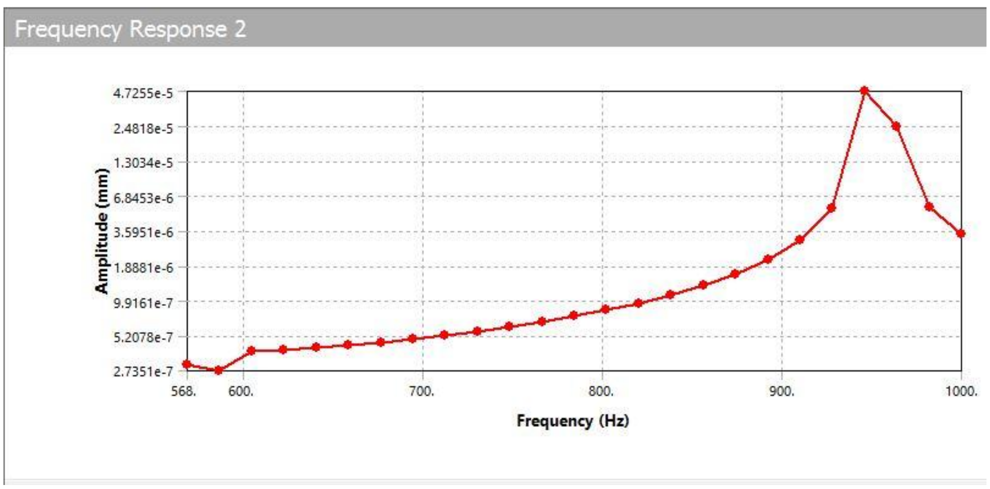


Fig6: Harmonic response of 4th model.

The above image shows the frequency excited analysis on Double mass absorber on rail. Here bottom of rail is fixed to concrete trapezoidal member. The same boundary conditions are given at the bottom of rail. From 0 to 1000 Hz artificial frequencies are tested on the rail using ANSYS. Here rail structure is having maximum amplitude at the 950 Hz.

Conclusion

The rubber chosen has high property to withstand high heat dissipated due to friction and high wear resistance. It also deals with the fatigue testing which will be analyzed by the software. Thus the dynamic vibration absorber is designed in such a way that it reduces the vibration comparatively high rate than others by the collected details from the literature survey. The details consist of various parameters of the absorbers arrangement used in this project. The high frequency vibrations are reduced to their maximum extent using absorbers arrangement. Here 5th model (multi layered absorber arrangement) having minimum natural frequencies and frequencies response analysis has performed as 360 Hz was resonance frequency. Finally from the present work multi layered absorber arrangement is an optimum model to reduce the vibrations.

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