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Experimental Analysis of Dynamic Vibrations in Rails by Using Different Types of Vibration Absorption Pads

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Abstract: Railway pads are a type of component that is used in railway construction and maintenance. They are typically made of rubber or similar material and are placed between the railway sleeper and the rail itself. Railway pads provide a layer of cushioning and insulation between the rail and the sleeper, which helps to reduce noise and vibration from passing trains. Railway pads can also help extend the rail's life by reducing the wear and tear caused by constant friction between the rail and sleeper. They are especially useful in areas where noise pollution is a concern, such as residential areas or near hospitals and schools. Several types of railway pads are available, including continuous, discrete, and ribbed designs. The specific type of pad used will depend on factors such as the type of rail being used, the expected loads and speeds of passing trains, and the requirements of the railway system. Overall, railway pads are an important component in the construction and maintenance of railway systems, helping to reduce noise and vibration while also prolonging the life of the rail and other components. In this paper, we are testing three types of vibration rubber pads i.e., Ethylene Propylene Diene Monomer (EPDM), High-Density Polyethylene (HDPE), nitrile and comparing three vibration frequencies. The dynamic frequency of welded rails with HDPE pads has having 1190 Hz mean value. The dynamic frequency of rail tracks with single- and double-layer EPDM pads their mean values are 499 Hz and 335 Hz respectively. The experimental values clearly show that single- and double-layer EPDM pad dynamic frequencies are reduced by up to 58% and 71%, respectively, over the HDPE pad.

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 frequent train usage. However, these improved service provisions have brought new challenges to traditional railway track engineering, especially to track geotechnical dynamics. These challenges demanded a better understanding of the track dynamics. Railway pad rubber materials are a type of engineering material used to reduce the vibration and noise produced by trains. These materials are designed to withstand high compression loads and provide stable support for railway tracks.

The properties of railway pad rubber materials include high elasticity, low creep, excellent weather resistance, and good insulation properties. The development of railway pad rubber materials has been driven by the need to improve the performance of railway systems, enhance passenger comfort, and reduce environmental impact. This abstract briefly overviews railway pad rubber materials and highlights their importance in the modern railway industry.

Railway Rubber Pads

Railway rubber pads are an essential component of modern railway infrastructure. They are designed to provide a stable and durable foundation for railway tracks, reducing the impact of vibrations and noise caused by the passage of trains.

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Figure 1. Railway Rubber Pad [*Courtesy: https://banujmixing.com].

Railway rubber pads offer a number of advantages over traditional materials, including their ability to absorb shock and reduce the stress on the rails and sleepers. This helps prolong the tracks' life and reduces the need for maintenance and repairs. In addition to their technical benefits, railway rubber pads also contribute to the comfort of passengers, as they reduce the noise and vibration levels experienced in trains. This makes railway travel more enjoyable and helps to promote the use of public transportation. The development of railway rubber pads has been a major focus of research and development in the railway industry and their continued improvement is crucial for the sustainable growth of railway systems worldwide.

To reduce the frequency levels and deformation by introducing natural rubber to reduce the Vibration and improved life, an enhanced suspension system with natural rubber was developed in Pro-E model, and it was imported in Ansysto to evaluate the first six modes of the suspension system. The analysis is compared without a rubber and with rubber. The experimental results showed that the research on natural rubber is very low (Kumar et al., 2023).

The principal aim of this paper is to analyze the impact of rubber pad systems on levels of vibrations and values of stresses and deformations induced in the subway tunnel segments. Therefore, the proposed track system in the tunnel of line 4 of the Greater Cairo Metro has been selected as an analytical and simulation case study. The impact of using eight different values for the stiffness of the rubber pad system in the case of a single tunnel has been analyzed. The results showed that levels of vibrations are significantly affected and have a logarithmic correlation with stiffness (Khalil et al., 2021).

Dynamic response of railroad vehicles is a frequency domain approach. This paper likely explores the dynamic response of railroad vehicles using a frequency domain approach, which is a common method for analyzing vibrations and forces acting on mechanical systems like trains (Gangadharan et al., 2008).

Dynamic studies of rail track sleepers is a track structure system. This paper focuses on the dynamic behavior of rail track sleepers (also known as railroad ties) within the context of the larger track structure system. The study likely investigates how dynamic loads, such as those from moving trains, affect the performance and vibration characteristics of the sleepers, potentially leading to issues such as track degradation or noise (Kumaran et al., 2003).

Experimental analysis of waves is propagated in railway tracks. This study focuses on the experimental analysis of how waves propagate in railway tracks, which is essential for understanding the vibration and noise generation in rail systems. The paper likely addresses the interactions between the track structure and the various waveforms generated during train passage, which can include both elastic and acoustic waves (Thompson, 1997).

From the above literature views, the authors focus on the experimental analysis of how waves propagate in railway tracks, explore the dynamic response of railroad vehicles using a frequency domain approach, the dynamic behavior of rail track sleepers and focuses on the design and analysis of dynamic vibration absorbers (DVAs) aimed at reducing vibrations in railway tracks.

From the above context, our objective and aim of the study are to conduct experimental trails on rail tracks using different types of absorbers and choose the best among the absorbers.

Design

EPDM, NITRILE and HDPE railway rubber pads are materials used to construct and maintain railway tracks. EPDM stands for Ethylene Propylene Diene Monomer and is a synthetic rubber with excellent resistance to weathering, ozone, and UV radiation. EPDM railway rubber pads are known for their durability and are commonly used in high-speed and heavy-load railway applications. Nitrile, also known as Buna-N, is a type of synthetic rubber with high resistance to oils, fuels, and

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chemicals. Nitrile railway rubber pads are commonly used in areas where the tracks come into contact with oils or chemicals. HDPE stands for High-Density Polyethylene and is a thermoplastic polymer known for its strength and durability. HDPE railway rubber pads are used as an underlayment for railway tracks to help reduce vibrations and noise. Together, these materials are used to create railway rubber pads that help to absorb shocks, reduce vibrations, and provide a stable and safe foundation for railway tracks.

Design of Rail Track (I-Section)

The rail profile is the cross-sectional shape of a railway rail, perpendicular to its length. Early rails were made of wood, cast iron or wrought iron. All modern rails are hot rolled steel with a cross-section (profile) approximate to an I-beam but asymmetric about a horizontal axis. The head is profiled to resist wear and to give a good ride and the foot is profiled to suit the fixing system. Unlike some other uses of iron and steel, railway rails are subject to very high stresses and are made of very high-quality steel.

Design of Rail Track with Vibration Pads

Constrained damped dynamic vibration absorber is a vibration system that combines 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. 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.

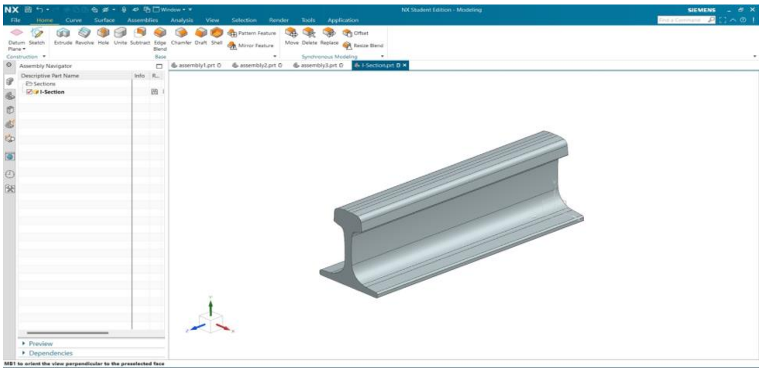
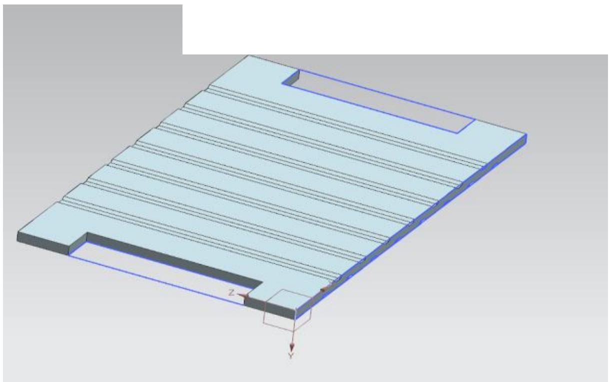
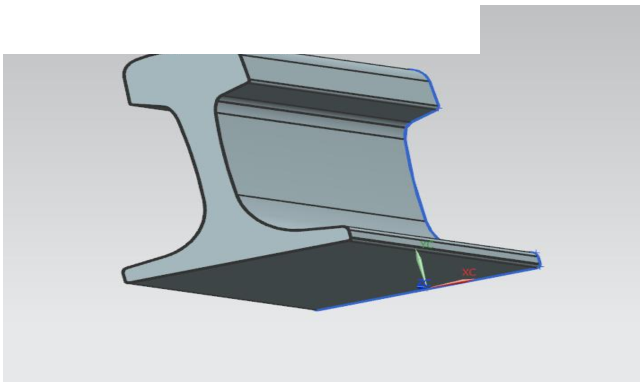


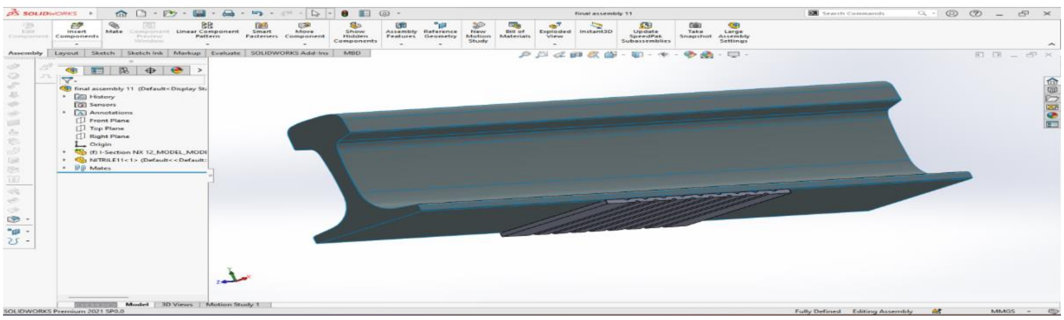
Figure 2. Isometric View of I-Section.



a) Rubber pad



b) Cross-section of rail



c) Rubber pad with Rail.

Figure 3. Isometric View of Rubber Pad with Rail.

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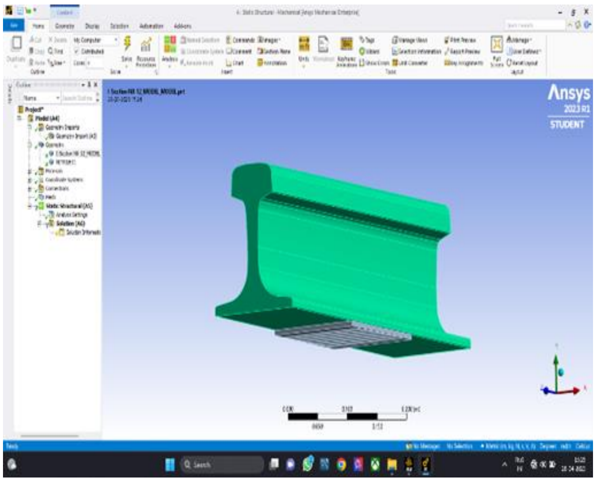
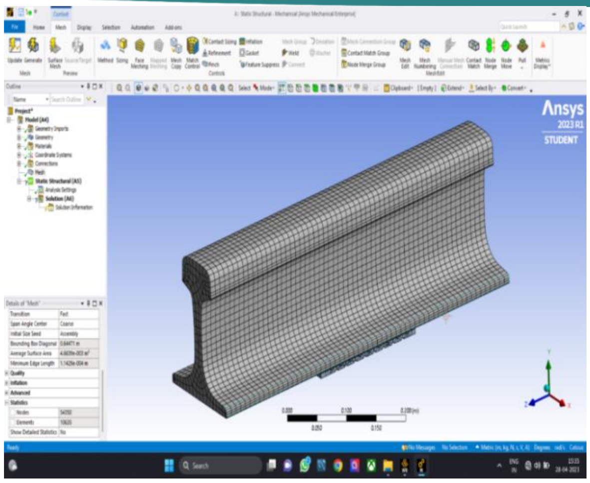
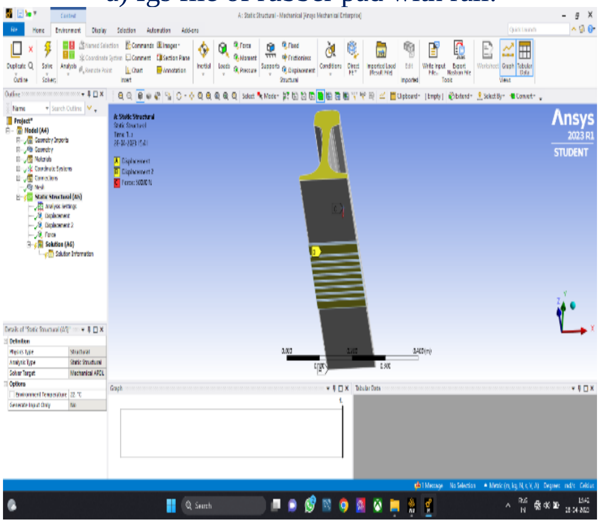


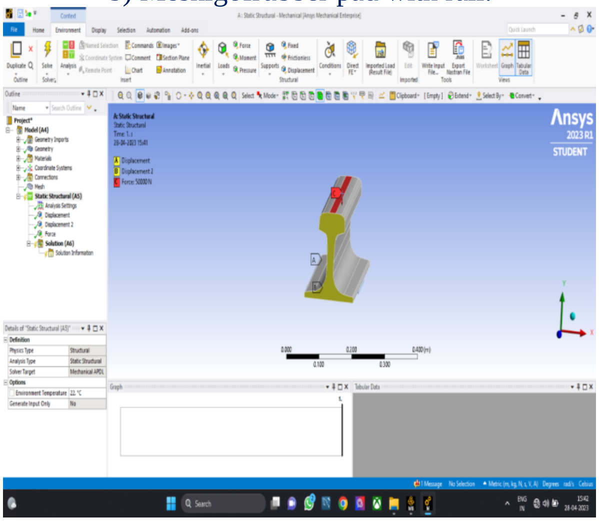
a) Igs file of rubber pad with rail.



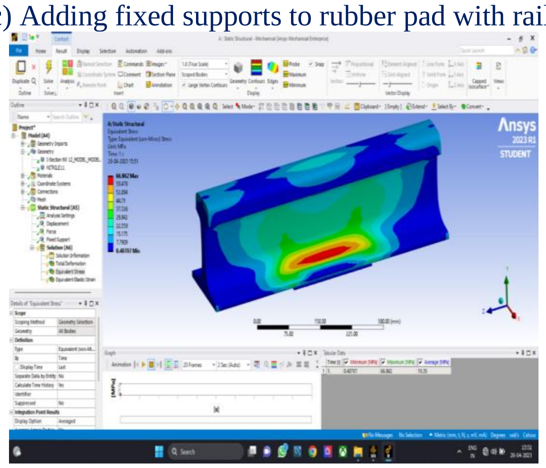
b) Meshigofrubber pad with rail.



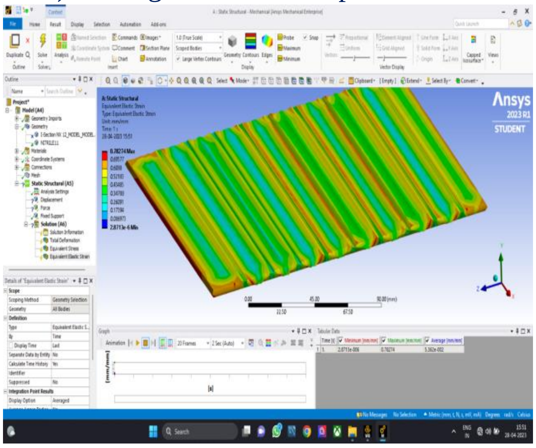
c) Adding fixed supports to rubber pad with rail.



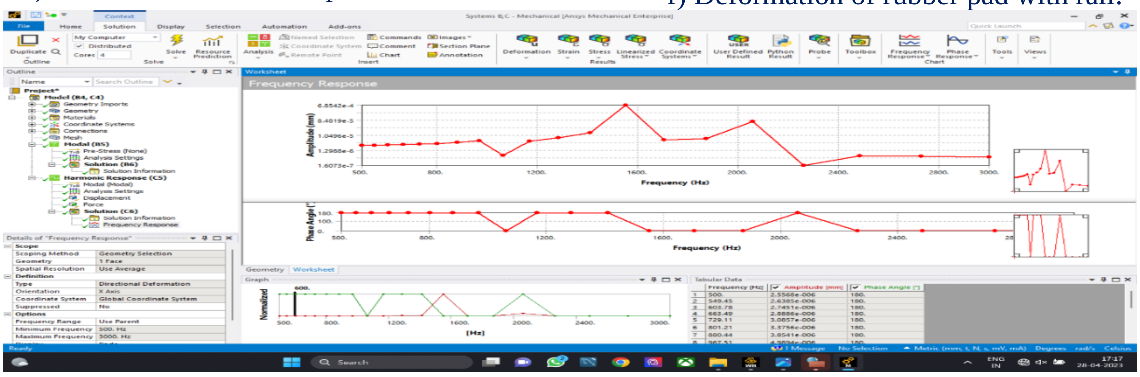
d) Addingloadsto rubber pad with rail.



e) Deformation of rubber pad with rail.



f) Deformation of rubber pad with rail.



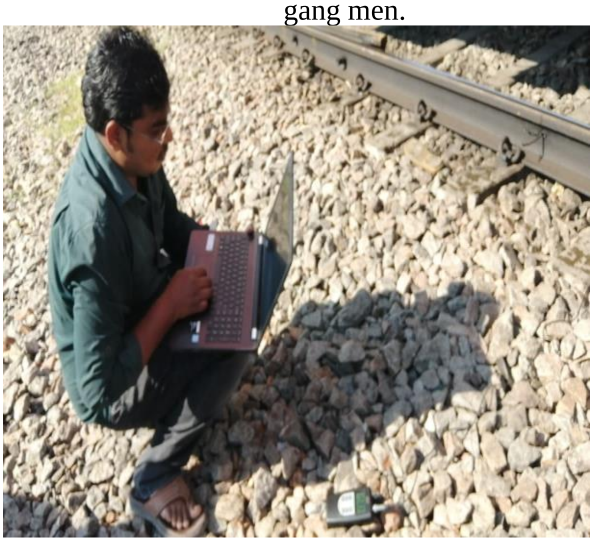
g) Harmonic analysis of rubber pad with rail.

Figure 4. Design of Rubber pad with Rail.

a) A trail track with absorber pads.

b) Inserting the absorption pads along with gang men.

c) Placing rubber pads with gang men.



d) Testing the rubber pads placed under the rail track with vibro-meter.

Figure 5. Testing the absorption pads at railway track (near Renigunta railway station, Tirupati, Andhra Pradesh).

From the above figures, it gives a clear view that absorption rubber pads are taken at the rail track to conduct experimental trials. Rubber pads are inserted along with the gang men, testing is conducted when the train passes along the track, and readings are obtained using a vibrometer and software.

Modal Analysis

The modal analysis was done on the I-section with nitrile to find out the natural modes of frequencies. Model analysis is used to determine a structure's natural frequencies and mode shapes. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. Meshing is applied to assemble using tetrahedron and brick Mesh 200 elements, the model having 21539 nodes and 9818 elements. Fixed Boundary conditions are applied at the bottom of the rail and a rigid connection is arranged between rail and pads. Model and harmonic analysis are performed. Natural and resonance frequencies are noted to find an optimum model to arrange the pads.

The natural frequencies NITRILE are shown in the following Table 1.

Table 1. Natural Frequencies of NITRILE at Different Modes.

Mode	Frequency (Hz)
1	1042.3
2	1546.6
3	1641.8
4	2011.3
5	2052.0
6	2150.3

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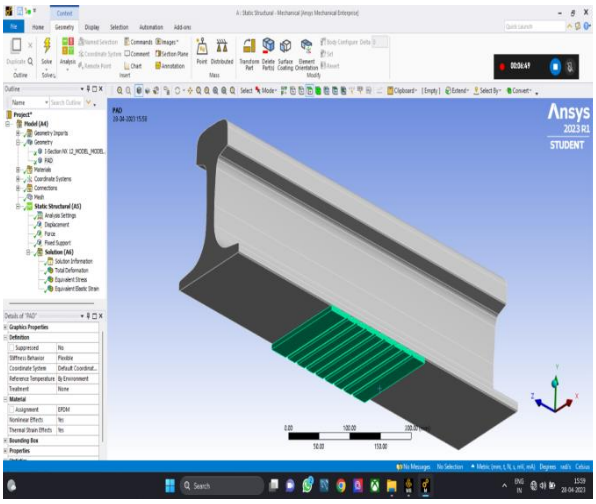
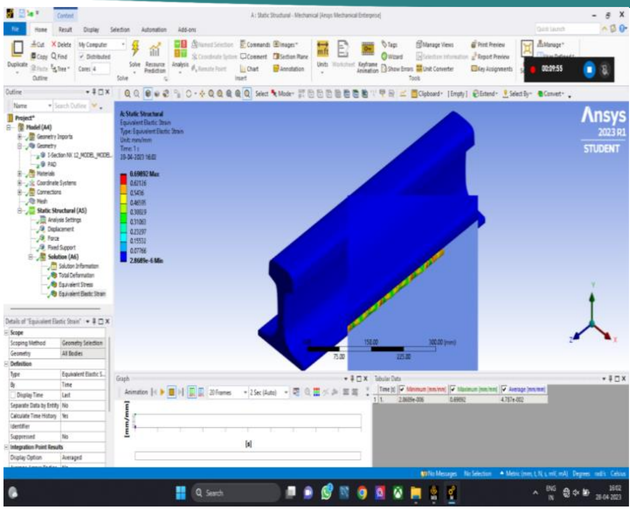
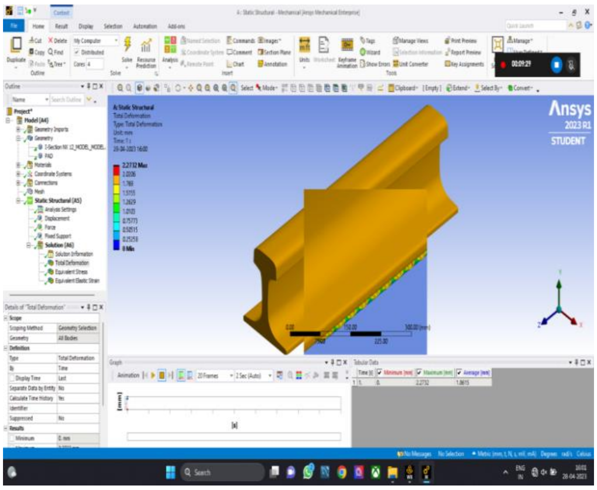


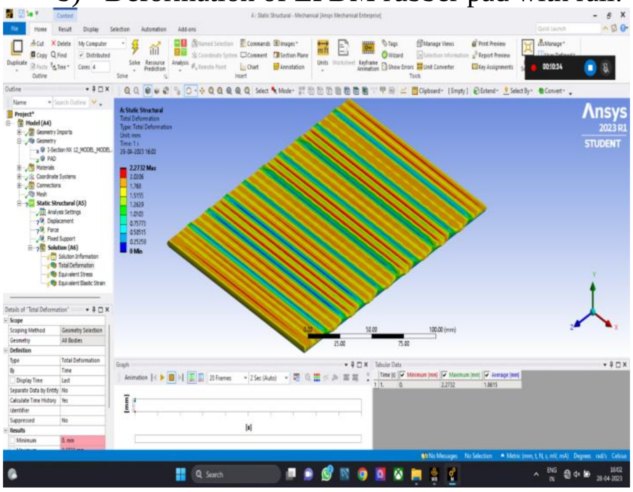
a) Igs file of EPDM Rubber Pad.



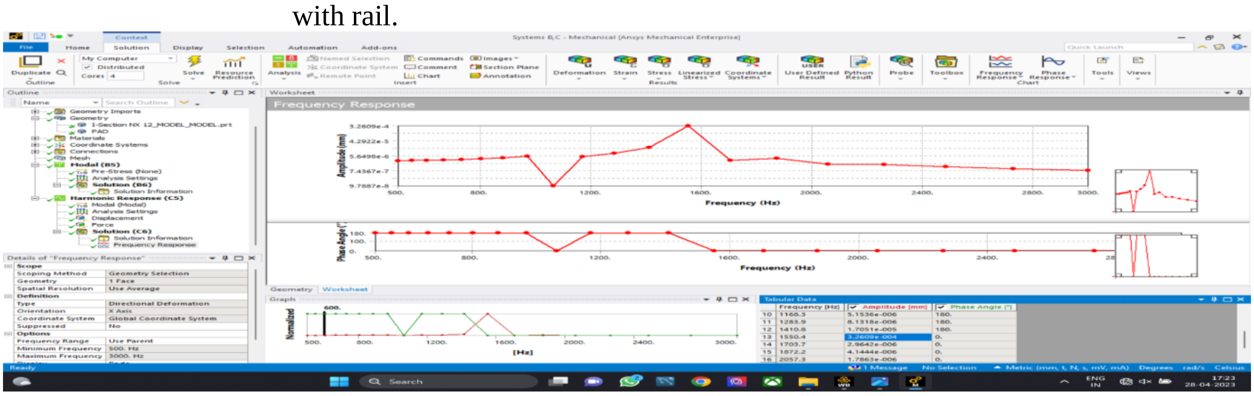
b) Deformation of EPDM rubber pad with rail.



c) Deformation of only EPDM rubber pad with rail.



d) Deformation of EPDM rubber pad.



e) Harmonic analysis of EPDM rubber pad with rail.

Figure 6. Modal analysis on EPDM rubber pad.

Table 2. Natural Frequencies of EPDM at Different Modes.

Mode	Frequency (Hz)
1	1042.0
2	1541.6
3	1633.5
4	1984.8
5	1998.4
6	2005.4

The modal analysis was done on the I-section with single-layered DVA to find out the natural modes of frequencies. The harmonic analysis was done on the I-section with a single layer.

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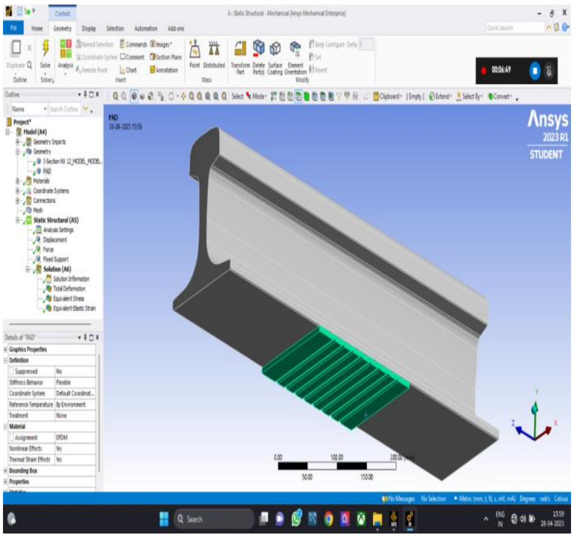
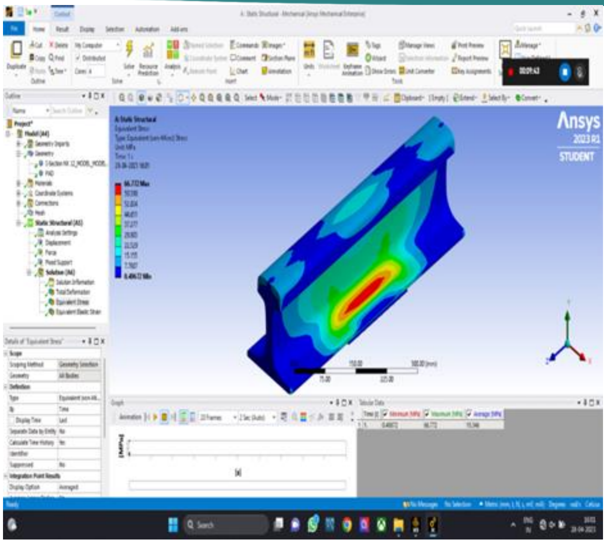
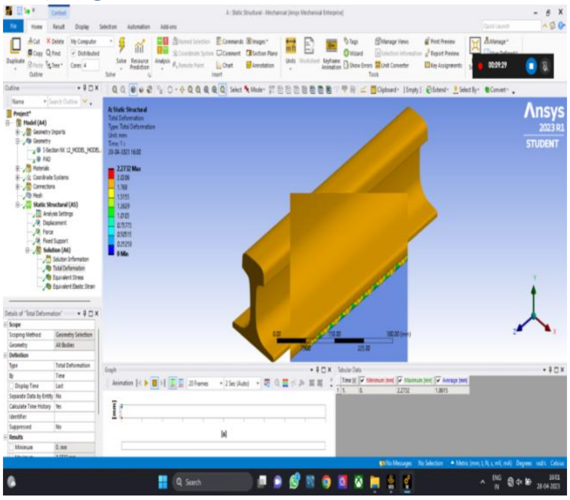


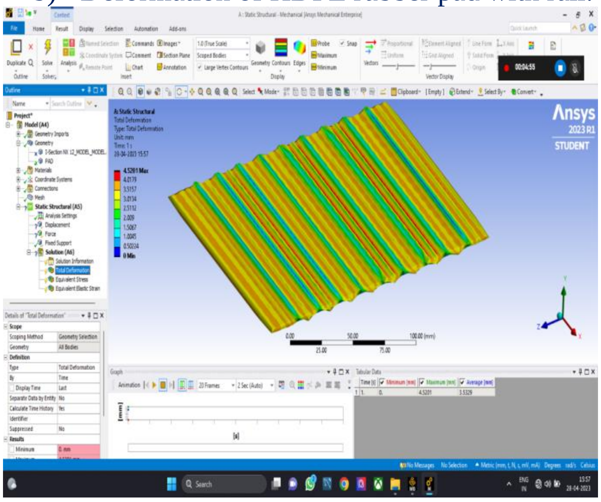
a) Igs file of HDPE Rubber Pad.



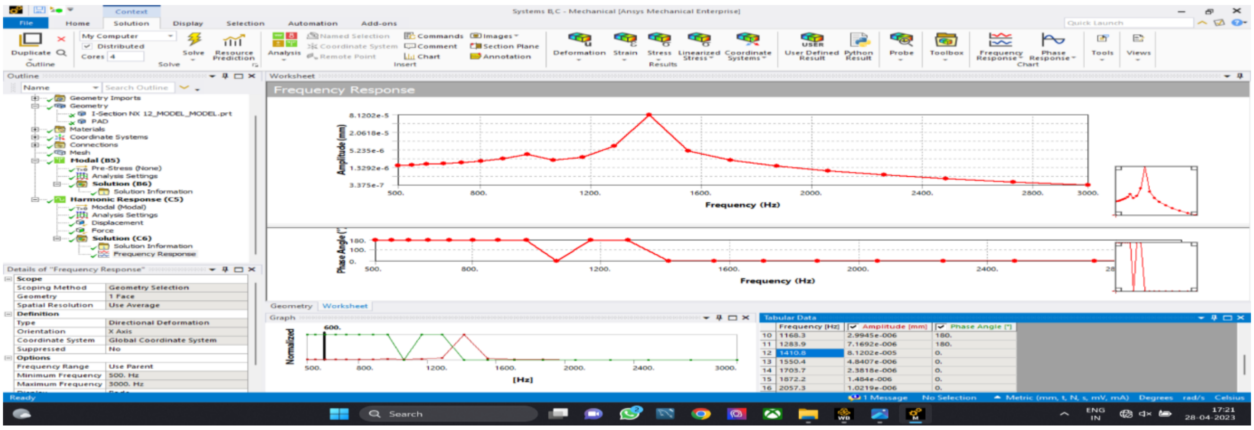
b) Deformation of HDPE rubber pad with rail.



c) Deformation of only HDPE rubber pad with rail.



d) Deformation of HDPE rubber pad.



e) Harmonic Response of HDPE rubber pad with rail.

Figure 7. Modal analysis on HDPE rubber pad.

Results and Discussions

The values of I-section frequencies are compared with the natural frequencies of I-section with NITRILE, EPDM and HDPE. The percentage reduction in frequency is shown in the following tables.

From the above table.3 shows the difference between rail tracks with and without nitrile pads in different modes. Natural Frequency of Nitrile has a high frequency of 2150.3 Hz and lowest frequency of 1042.3 Hz. The table shows that the (%) reduction of frequency of rail track with and without Nitrile pad is 4.26%.

Table 3. Natural frequency of rail track with and without Nitrile pads at Different Modes.

Mode	Natural Frequency of I-section	Natural Frequency of Nitrile	Reduction in Frequency (%)
1	1043.2	1042.3	0.08
2	1557.8	1546.6	0.72
3	1659.5	1641.8	1.06
4	3015.4	2011.3	10.20
5	2460.6	2052.0	3.41
6	2393.1	2150.3	10.14

Table 4. Natural frequency of rail track with and without EPDM at Different Modes.

mode	natural frequency of i-section	natural frequency of EPDM	reduction in frequency (%)
1	1043.2	1042.0	0.11
2	1557.8	1541.6	0.71
3	1659.5	1633.5	0.15
4	2015.4	1984.8	1.51
5	2060.6	1998.4	3.01
6	2393.1	2005.4	16.57

Table 5. Natural frequency of rail track with and without HDPE at Different Modes.

mode	natural frequency of i-section	natural frequency of hdpe	reduction in frequency (%)
1	1043.2	1041.5	0.16
2	1557.8	1390.6	3.70
3	1659.5	1407.9	4.16
4	2815.4	2411.3	9.97
5	2860.6	2414.1	12.37
6	2993.1	2414.7	14.88

Mechanical properties of Nitrile, EPDM, HDPE Pads

Table 6. Testing Parameters of Nitrile Pads.

Sl. no	test parameters	unit	test method	results
1.	Specific gravity	--------	ASTM D792	1.01
2.	Hardness	SHORE A	ASTM D2240	43,44,45
3.	Compression strength	MPA	ASTM D 695	1.58

Table 7. Testing Parameters of EPDM Pads.

Sl. no	test parameters	unit	test method	results
1.	Specific gravity	--------	ASTM D792	1.30
2.	Hardness	SHORE A	ASTM D2240	69,70,71
3.	Compression strength	MPA	ASTM D 695	1.60

Table 8. Testing Parameters of HDPE Pads.

s. no	test parameters	unit	test method	results
1.	Specific gravity	--------	ASTM D792	1.28
2.	Hardness	SHORE A	ASTM D2240	76,77,78
3.	Compression strength	MPA	ASTM D 695	2.25

From the above table.4 shows the difference between rail tracks with and without EPDM at different modes. Natural Frequency of EPDM pad has a high frequency of 2005.4 Hz and a lowest frequency of 1042.0 Hz. The table shows that the (%) reduction of frequency of rail track with and without EPDMpad is 3.67 %.

Table 5 shows the difference between rail tracks with and without HDPE in different modes. Natural Frequency of HDPE pad has a high frequency of 2414.7 Hz and lowest frequency of 1041.5 Hz. The table shows that the (%) reduction of frequency of rail track with and without EPDM pad is 7.49%.

Conclusion

From the above experimental results, the natural frequencies of NITRILE, EPDM and HDPE rubber pads are 1740.7 Hz,1700.9 Hz, 1846.6 Hz (mean values). Comparing the three rubber pads EPDM rubber pad has low natural and is best suited for the reduction of vibration in rail joints.

The dynamic frequency of welded rails with HDPE pads has an 1846.6 Hz mean value. The dynamic frequency of rail track is 1700.9Hz and NITRILE dynamic frequency is 1740.7 Hz. The experimental values clearly show that EPDM pad dynamic frequencies are decreasing over NITRILE and HDPE pads. displacement values of HDPE pad, EPDM and NITRILE pads are 7.4 mm, 3.6 mm, and 4.2 mm respectively. The modal analysis values clearly show single- and double-layer EPDM pad displacement is reducing compared with HDPE and NITRILE pad.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflicts of Interest

The authors declare no conflict of interest.

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