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ANALYSIS OF AUTOMOBILE EXHAUST MUFFLER SILENCER DESIGN USING ANSYS SOFTWARE

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Abstract -A silencer is a tool used to cut down on the noise produced by an internal combustion engine's exhaust. The purpose of the silencer, which is an acoustic soundproofing device, is to quiet the engine's sound pressure and lessen its volume. Mufflers are designed to reduce the high-intensity pressure pulse that an internal combustion engine's combustion process produces. The current study explains the different exhaust sounds, vibrations, and their respective contributions. Through energy flow, frequency, vibration, and noise method are explored. Therefore, it is essential to examine the vibration response and modes in order to understand how a silencer behaves. The muffler is modelled using CATIA V5, and the Altair pre-processing tool is used to do FEM for the muffler. ANSYS R15.0 is used for the analysis, and it finds the frequencies and mode shapes. Using an FFT analyzer, the outcomes of the CAE simulation are compared to those of the experiment. The frequencies and mode shapes are determined for both the modified and unmodified cases, and the outcomes are contrasted.

Index Terms: CAE Simulation, ANSYS, Muffler Design, CATIA V5 etc.

I. INTRODUCTION

When car engines are utilised in residential areas or other places where noise causes dangers or vibrations, it becomes a serious worry. The engine speed, which is expressed in rpm, causes pressure to change as well. As a result, vibration and higher-frequency sound may be created. A muffler is a device used to lessen the noise that a machine produces. To regulate or lessen exhaust noise, the engine exhaust is linked to a quieter known as a silencer via an exhaust pipe.Depending on the engine type (turbocharged or normally aspirated), the amount of horsepower used for scavenging, the fuel type, and the number of cycles, the noise level and intensity will change. We hear the pressure pulses that are produced when an exhaust valve opens repeatedly, allowing high pressure gas to enter the exhaust system. The characteristics that characterise the acoustic performance and vibration of a silencer are insertion loss (IL), noise reduction (NR), and transmission loss (TL). When developing a silencer, length, longevity in terms of span, and mileage are the primary considerations. To maintain the ideal noise level and pleasant riding, it is necessary to analyse the muffler's modes. Any modes that happen close to the frequency at which an automobile engine runs must to be taken seriously as they may result in harmonic oscillations. Additionally, it causes vibrations in the car. We will examine the Force Motors Minidor DI 6 Seater Passenger Vehicle's silencer silencer for examination. Impact testing is done to determine the muffler's modes. Minidor DI 6 Seater Passenger Vehicle muffler dimensions are measured, and utilising this data, CATIA is used for modelling and ANSYS R15.0 is used for analysis. Impact testing is a quick method to generate accurate estimates of frequency response data and the modal features of the system.

Figure 1: Muffler for a six-seater passenger vehicle, Minidor Di.

II. LITERATURE REVIEW

A. Automotive exhaust silencer vibration study using FEM and FFT analyzer

Referring to the following articles that V.P. Patekar presented in July 2012 and that were published in the International

Journal on Emerging Technologies, we may figure out how to reduce vibration by analysing car exhaust mufflers using FEA and experimentation. The initial step of an exhaust system's design analysis is hypothesised in this study. Using a standard FEM software, the exhaust system is modelled using the material's given parameters. To differentiate between the working and natural frequencies and prevent resonant conditions, the outcomes are compared with the reading obtained using an FFT analyzer.

B. Automotive silencer performance improvement by the use of finite element analysis

In August 2014, Prof. Pravin P. Hujare delivered a work that was published in the International Journal of Engineering Science Invention (ISSN). The design and modification of a silencer, which is a secondary source of noise production, is the focus of this study. The given material qualities and FEM package are taken into consideration. In order to prevent resonant conditions, the natural frequency is evaluated and separated from the working frequency using an FFT analyzer as part of the experimental investigation. To construct a modified model, the dimensions of the current silencer model are referred to as benchmarking dimensions. Analysis of frequency response is done to examine the behaviour of the silencer at various frequencies.

C. Design, analysis, and experimental verification of a car system's silencer

In August of 2015, Madhu Kumar M, Aravind K U, Dr. Maruthi B H, and Dr. Channakeshavalu K delivered this article. This study explains different exhaust sounds, vibrations, and their contributions based on the current studies. Through energy flow, frequency, vibration, and noise method are explored. Therefore, it is essential to examine the vibration response and modes in order to understand how a silencer behaves. The muffler is modelled using CATIA V5, and the Altair pre-processing tool is used to do FEM for the muffler. Using an FFT analyzer, the outcomes of the CAE simulation are compared to those of the experiment. Both with and without a stiffener, the mode forms and frequencies are determined, and the outcomes are contrasted. An technique using three-dimensional finite elements to forecast gearbox loss in silencers and silencers without mean flow.

III. GOAL

Model analysis is the most effective way to explain natural characteristics including frequency, damping, model forms, and its dynamic features. In order to build a modal model of the response, it entails figuring out a structure's modal parameters. Theoretical and experimental approaches are two distinct technologies that address vibration and noise issues. In this experiment, modal analysis will be performed for the current model. If natural frequencies are greater than engine frequencies, weight optimisation may be recommended. In the event that natural frequencies fall outside of the acceptable range, we must modify the natural frequencies by suggesting changes to their geometry, mass, or boundary conditions. After that, frequency response analysis will be performed at the first resonance frequency to determine the stress levels, and the stress criterion must also be satisfied. We're going to add strips to the silencer silencer in the model analysis as a modification for this project.

IV. AREA

The current study has the following potential future applications:

- Muffler vibration may be decreased by changing the design of the muffler to increase its natural frequencies.
- A car with less vibration and improved comfort
- Preserve the intended level of comfort and noise level.
- The redesigned silencer silencer will vibrate at a lower frequency than the current silencer.

V. METHODS

A. Representation

CATIA V5R20 was used to model the exhaust silencer silencer. Figure 2 displays an imported exhaust manifold model in ANSYS..

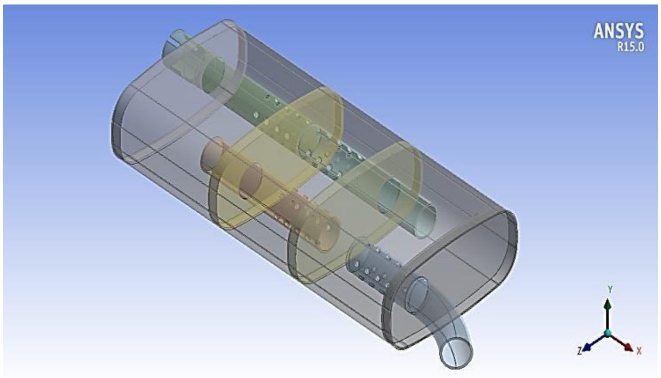

Figure 2. ANSYS Imported Exhaust Muffler Model.

B. Analysis of Finite Element

The Finite Element Method is a computational technique for approximating engineering issue solutions. This technique discretizes the complicated body or area that defines a continuum into basic geometric forms. Usually, a set of linear or nonlinear equations is formed when the loads and boundary conditions are applied. An approximative solution to the issue may be obtained by solving these equations. In this paper, natural modes of vibration are identified by modal analysis of the silencer using a FEA approach. The investigation of dynamic frequency response is also carried out to determine the localised stresses that are created in the silencer.

C. Analysis of Modalities

A technique for characterising a structure's dynamic properties—frequency, damping, and mode shapes—is called modal analysis. A dynamic system's intrinsic modes of vibration are entirely dictated by its physical characteristics and how they are distributed spatially in ANSYS after the model has been imported from CATIAV5. Next, mesh the provided model.

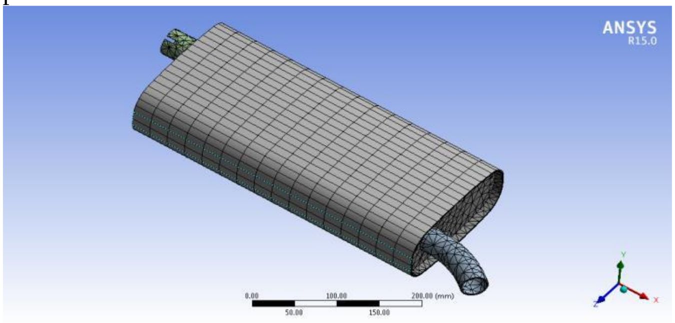

Fig. 3. The current muffler's mesh model

This model has 14920 components, including tetrahedral and hexahedral elements, in addition to 35840 nodes.

Table 1: Structural steel material characteristics

Properties	**Value**
Young's modulus	2×10^5 psi
Poisons ratio	0.3
Density	7890 kg/m^3

D. Delimitation Situation

The provided figure illustrates the boundary condition of the supplied silencer silencer, which is fastened at one end..

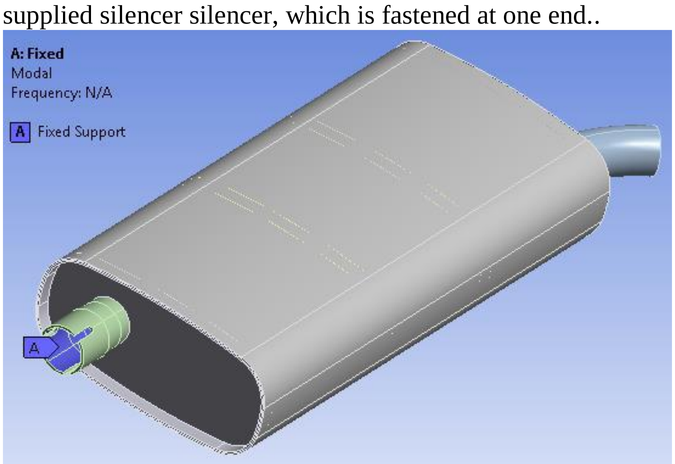

Fig. 4: Applying Boundary Conditions to the Current Muffler Model

VI. OUTCOMES OF THE CURRENT MODEL

The results of complete deformation are acquired after meshing and applying a boundary condition, allowing us to determine the frequency of the silencer silencer in hertz (Hz) at various mode forms. Below are these frequencies at various mode forms.

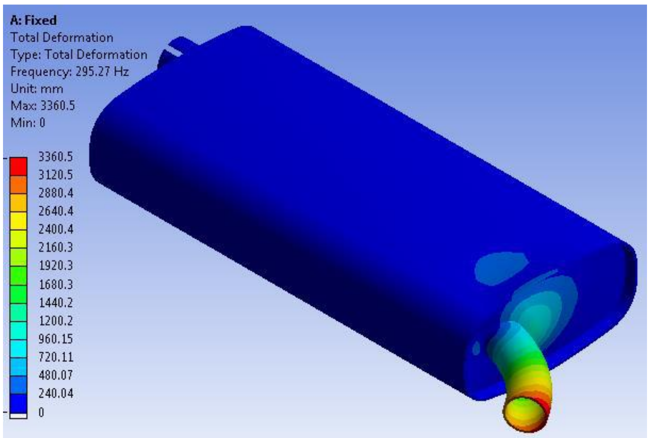

Fig.5. Frequency at Mode 1(295.27 Hz)

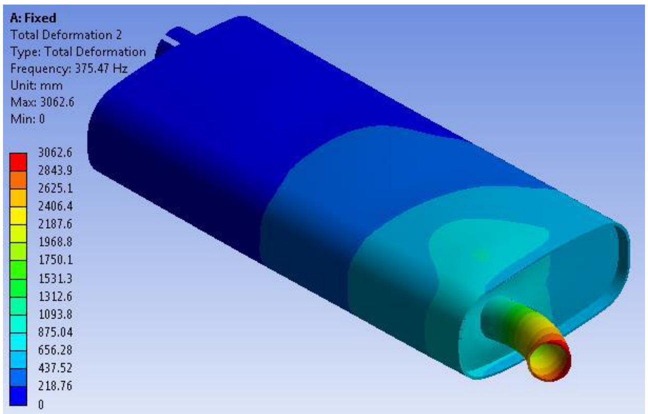

Fig.6.Frequency at Mode 2, (375.47Hz)

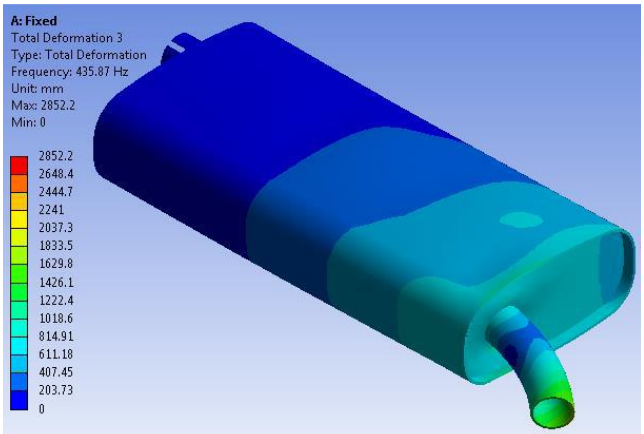

Fig.7. Frequency at Mode 3, (435.87Hz)

A. Current Silencer's Harmonic Response

Next, we ascertain the model's harmonic response at 0 Hz. The provided graphic illustrates this model, which has an acceleration of 9810 mm/s2 and components of 0,9810,0 mm/s^2.

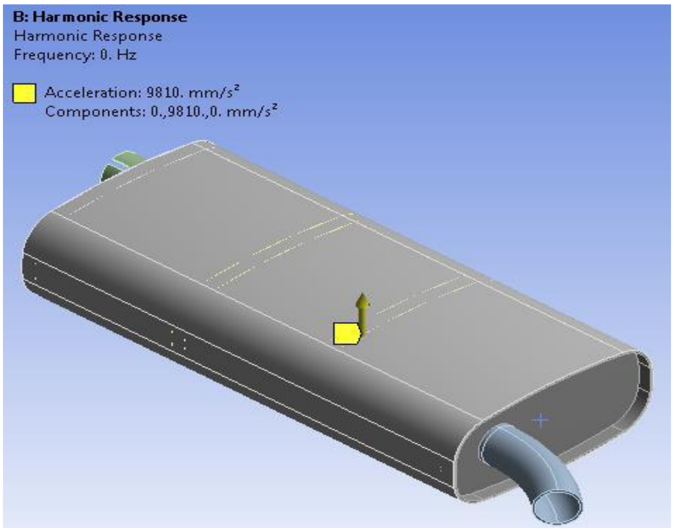

Fig.8. Acceleration for Harmonic Response

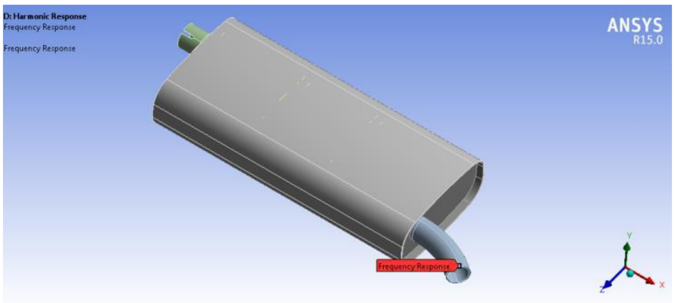

Fig.9. Point at Which Harmonic Response Derived.

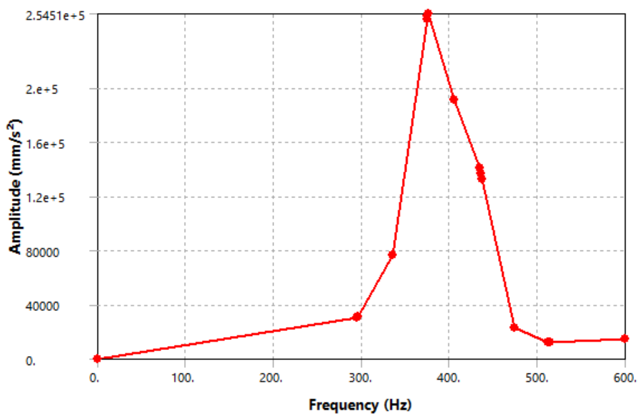

Figure 10 shows the current model's frequency response.

The current silencer silencer's frequency response graph is shown, with the highest amplitude occurring at a frequency of around 400 Hz.

VII. OUTCOMES OF MUFFLER SILENCER MODIFIED MODEL

The natural frequency of a silencer silencer is 295.27 Hz in first mode and 435.87 Hz in third mode, according to model analysis of the existing model. We altered the current model to raise the silencer's natural frequency, and as shown in figure, we added a pair of strips to the silencer's perimeter to achieve the maximum natural frequency.

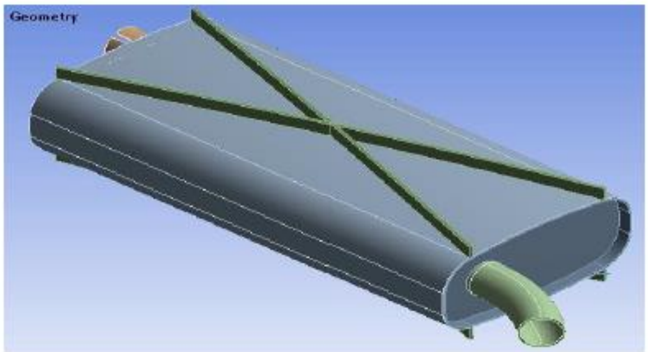

Fig.11. modified model of muffler silencer

Once the silencer silencer in the CATIA V5R20 was changed, the modified model was imported into the ANSYS workbench. Additionally, this model's material attributes are the same as those of the earlier model. Following the assignment of the material, the model begins meshing. The meshing components in this model are tetrahedral and wedge-type nodes, 41387 and 18975. The figure 12 mesh represents the meshed model.

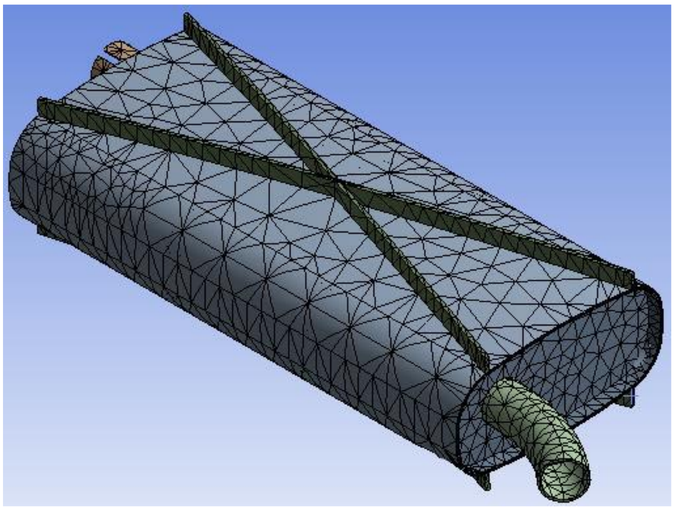

Fig. 12. Modified Muffler Silencer Meshed Model

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A. Modified Model Boundary Conditions

The boundary requirements of the modified silencer silencer model are that it is fixed in one end and with the stiffeners, as shown in the provided figure.

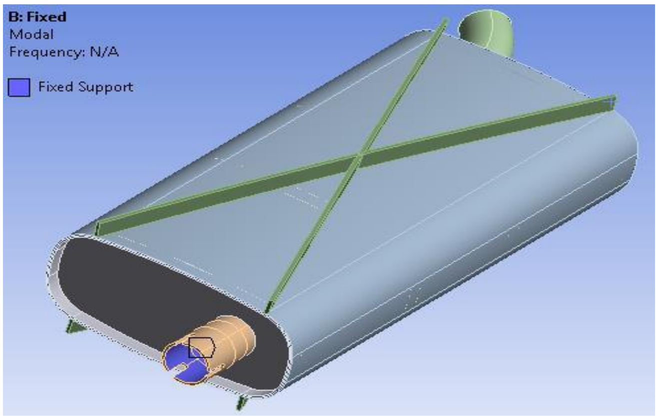

Fig. 13 Boundary conditions apply to the redesigned model of the exhaust system.

B. Frequency of Modified Muffler Silencer

The muffler silencer with natural frequency modification at various modes are shown in the illustration.

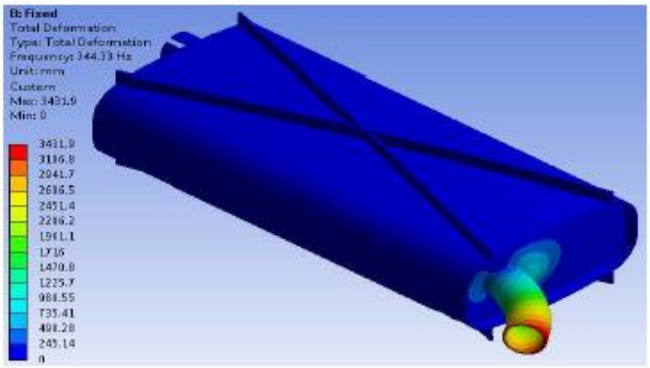

Fig. 14. Modified model frequency at Mode 1 (344.33 Hz)

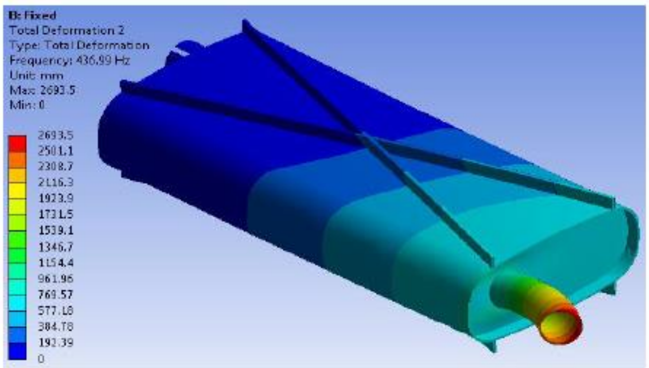

Fig. 15. Modified model frequency at Mode 2 (436.95 Hz)

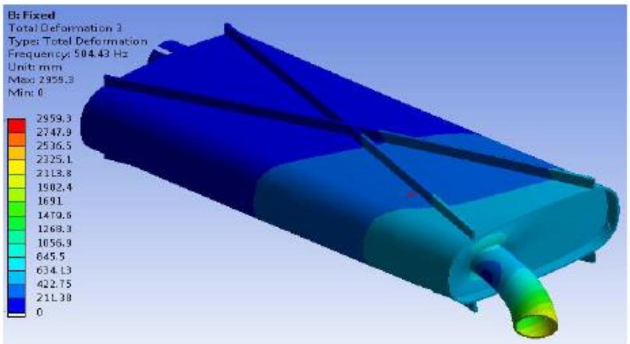

Fig. 16. Modified model frequency at Mode 3 (504.43 Hz)

C. The Modified Silencer's Harmonic Response

Next, we ascertain the model's harmonic response at 0 Hz. The accompanying graphic illustrates the acceleration of 9810 mm/s2 and the components of 0, 9810, and 0 mm/s2 as the boundary conditions.

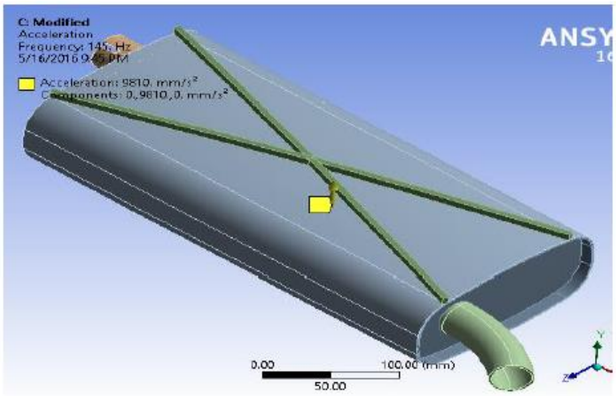

Fig. 17. Modified Model's Acceleration for Harmonic Response

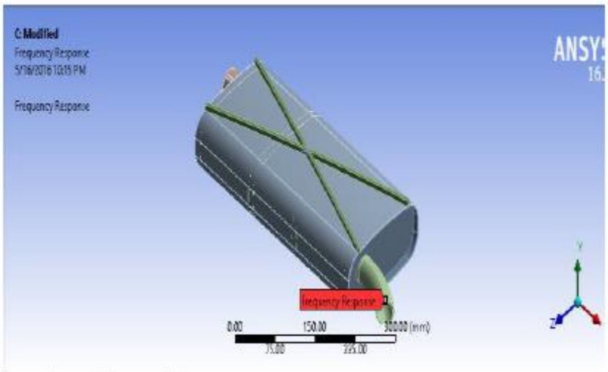

Fig. 18. Harmonic Response Derived Point

Following this, we get the graph that is shown in the picture, which shows the frequency response of the current silencer

silencer. The amplitude of the curve reaches its maximum at a frequency that is roughly between 400 and 500 Hz. Figure 19. Response of the Modified Model in Frequency.

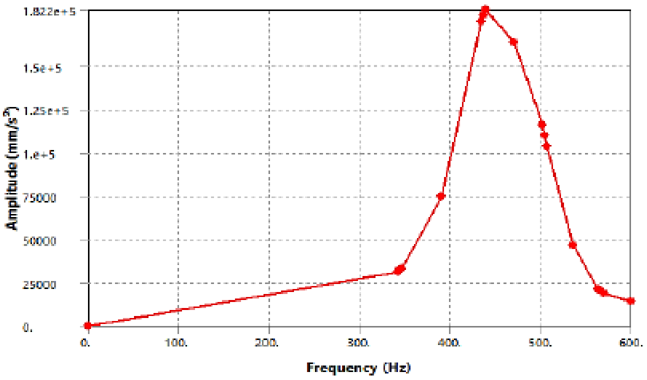

Figure 19 shows the updated model's frequency response

VIII. EXPERIMENTAL ANALYSIS

Thus, we deduce that the current model of silencer silencers has a considerably lower natural frequency and is thus unable to support resonances created by noise and road jerks, which in turn cause vibrations in the silencer that make riding uncomfortable. However, by altering the silencer silencer, the inherent frequency in various modes is increased beyond what is now there, and this frequency may lessen vibration and provide a comfortable and effective ride

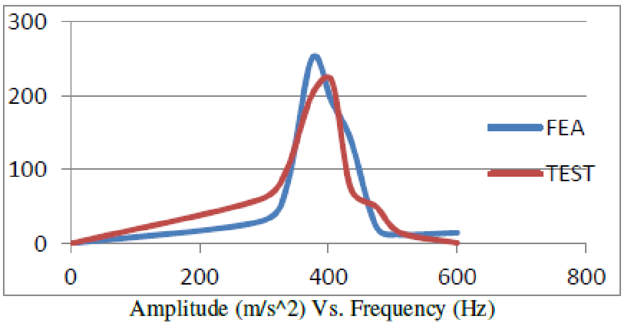

Fig.20: FEA and experimental findings compared

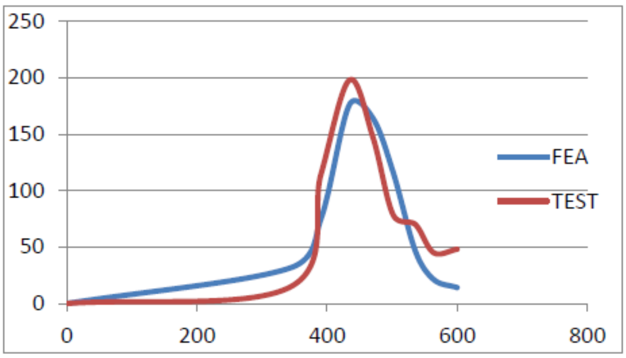

Fig. 21: Comparison of the improved model's FEA with experimental findings.

Table:2: Outcomes Of The Current Model

Frequency	Amplitude of FEA analysis m/s^2	Amplitude of experimental analysis m/s2
295.27	28.81	50.2
375.47	200.71	180.00
435.87	150.13	175.12

Table 3: Modified Model Outcomes

Frequency	Amplitude of FEA analysis m/s^2	Amplitude of experimental analysis m/s2
344.33	35.12	21.82
496.99	172.17	130.51
504.43	107.20	76.81

IX. RESULTS AND DISCUSSION

The findings of the model analysis of the current and modified silencer silencer models show that the natural frequency values vary from the modified model. This indicates that the natural frequency of the existing model has increased as a consequence of the modifications made to it. Additionally, it works well and effectively to keep the muffler silencer vibrating. The provided table displays a comparison of the natural frequency in the original and changed models.

Table 4: Frequency comparison of the original and modified model.

Mode	Frequency of existing model (Hz)	Frequency of modified model (Hz)
1	295.27	344.37
2	375.47	436.99
3	435.87	504.43

X. CONCLUSION

Thus, we deduce that the current model of silencer silencers has a considerably lower natural frequency and is thus unable to support resonances created by noise and road jerks, which in turn cause vibrations in the silencer that make riding uncomfortable. However, by altering the silencer silencer, the inherent frequency in various modes is increased beyond what is now there, and this frequency may lessen vibration and provide a comfortable and effective ride.

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