Analysis of Automotive Exhaust Muffler Silencer Using FEA & Experiment

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Abstract:

Muffler is a device for reducing the amount of noise emitted by the exhaust of an internal combustion engine. Muffler is engineered as an acoustic sound proofing device designed to reduce the loudness of the sound pressure created by the engine by way of acoustic quieting. Mufflers are designed to dampen the high intensity pressure pulse generated by the combustion process from an internal combustion engine. The present work describes various exhaust noises, vibration and their contribution. Frequency, vibration and noise technique is studied through energy flow. Hence, it is necessary to study the behavior of muffler by analyzing the vibration modes and vibration response. The muffler is modeled using CATIA V5 and FEM is carried out for muffler using Altair pre-processing tool. The analysis is done using ANSYS R15.0 the frequencies and mode shapes are found. The results obtained from CAE simulation is compared with experiment using FFT analyzer. The mode shapes and frequencies are found for both without modification and with modification and the results are compared with each other.

I. INTRODUCTION

Noise pollution created by vehicle engines becomes a vital concern when used a residential areas and areas where noise creates hazards and vibration. Due to the engine speed which is measured in rpm so the pressure also fluctuates and therefore sound produced may be of higher frequency and it creates vibration. The muffler is a device for reducing the amount of noise emitted by a machine. The engine exhaust Is connected through exhaust pipe to silencer called muffler to control or reduce the exhaust noise.The intensity and magnitude of the noise will vary depending upon the type of engine like naturally aspirated or turbocharged, horse power developed means of scavenging, type of fuel and number of cycles. The pressure pulses which are generated when exhaust valve repeatedly opens and lets high pressure gas into exhaust system this make sound which we hear. The insertion loss (IL), noise reduction (NR) and transmission loss (TL) are the parameters that describe the acoustic performance and vibration of muffler. The main objective when designing a muffler is its length, durability in terms of span and mileage. The modes of a muffler are to be analyzed in order to maintain a desired noise and comfortable ride. Any modes which occur near to a frequency that car engine operates it should be considered dangerous because they could cause harmonic oscillations. And it also creates vibration in vehicle. For analysis we are going to study the muffler silencer of Force Motors Minidor DI 6 Seater Passenger Vehicle. Minidor DI 6 Seater Passenger Vehicle muffler dimensions are measured and using this data the modeling using CATIA and the analysis is done using ANSYS R15.0. In order to find out modes of the muffler, impact test is performed. Impact testing is a fast technique for obtaining good approximations of systems modal properties and frequency response data.

Fig.1 Minidor Di, 6 Seater Passenger Vehicle Muffler.

II. LITERATURE REVIEW

2.1 Vibrational analysis of automotive exhaust silencer based on FEM and FFT Analyzer

When we finding the way of reducing vibration by analyzing automotive exhaust muffler using FEA & experiment the information are obtained by referring the following papers V.P. Patekar presented in July, 2012 and published in International Journal on Emerging Technologies. This paper postulates the first stage in the design analysis of an exhaust system. With the specified properties of the material, the exhaust system is modeled by using a conventional FEM package. The results are compared with the reading taken on FFT analyzer, so as to distinguish working frequency from natural frequency and avoid resonating condition.

2.2 Performance enhancement of automotive silencer using finite element analysis

Prof. Pravin P Hujare has presented paper along with August 2014 which is published in International Journal of Engineering Science Invention ISSN. This paper based on the design and modification of silencer in order to reduce the vibration which is secondary source of noise generation, by considering the specified material properties and FEM package. The experimental analysis is carried out with the help of FFT analyzer to evaluate the natural frequency and to distinguish it from the working frequency to avoid resonating condition. The dimensions of the existing model of the silencer are referred as benchmarking dimensions to create modified model. Frequency response analysis is carried out to study behavior of silencer at different frequencies.

2.3 Design, analysis and experimental validation of muffler in an automotive system

This paper presented by Madhu Kumar M, Aravind K U, Dr. Maruthi B H, Dr. Channakeshavalu K in August-2015. This paper based on the present work describes various exhaust noises, vibration and their contribution. Frequency, vibration and noise technique is studied through energy flow. Hence, it is necessary to study the behavior of muffler by analyzing the vibration modes and vibration response. The muffler is modeled using CATIA V5 and FEM is carried out for muffler using Altair pre-processing tool. The results obtained from CAE simulation is compared with experiment using FFT analyzer. The mode shapes and frequencies are found for both without stiffener and with stiffener and the results are compared with each other. A three-dimensional finite element approach for predicting the transmission loss in Mufflers and silencers with no mean flow.

III. OBJECTIVE

The best method to describe the natural characteristic such as frequency, damping, model shapes and its dynamic properties is Model analysis. It involves process of determining the modal parameters of a structure in order to construct a modal model of the response. Both the techniques like theoretical and experimental are different technologies for solving noise and vibration problem. In this experiment Modal analysis will be done for existing model on the basis of modal analysis, we can suggest weight optimization if natural frequencies are higher than the engine frequencies. If natural frequencies are not within the acceptable limit then we have to shift the natural frequencies out of concerned zone by suggesting some modifications (Change in geometry or mass or boundary conditions) and then frequency response analysis will be done at first resonance frequency to check the stress levels, stress criterion should also satisfy.in this project as modification we are going to apply strips on muffler silencer in model analysis.

IV. SCOPE

The present work having following future scope:

- Vibration of muffler can be reduced by increasing the natural frequencies of muffler by change in geometry.
- Reduced vibration of automobile and offering good comfort
- Maintain a desired noise and comfortable ride.
- The vibration frequency of modified muffler silencer will be less than existing silencer.

V. METHODOLOGY

5.1 Modeling

The modeling of the exhaust muffler silencer was done using CATIA V5R20. The fig.2 shows imported model of exhaust muffler in ANSYS.

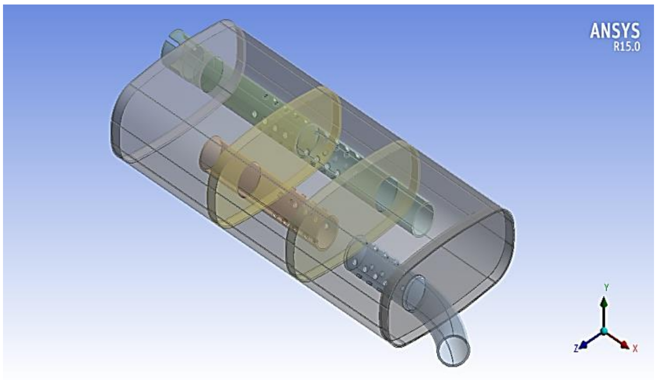


Fig.2. Imported Model of Exhaust Muffler in ANSYS.

5.2 Finite Element Analysis

Finite Element Method is a numerical method used for obtaining the approximate solution of engineering problems. In this method, the complex region or body defining a continuum is discretized into simple geometric shapes. When the loads and boundary conditions are applied, a set of linear or nonlinear equations is usually obtained. The solution of these equations gives an approximate solution of the problem. In this work, modal analysis of the silencer is performed with an FEA methodology to find out natural modes of vibration. Dynamic frequency response analysis is also performed to find out the localized stresses induced in silencer.

5.3 Modal Analysis

Modal analysis is a method to describe a structure in terms of its dynamic characteristics, which are frequency, damping and mode shapes. The natural modes of vibration are inherent to a dynamic system and are determined completely by its physical properties and their spatial distributions.in the ANSYS after importing the model from CATIAV5. Then mesh the given model.

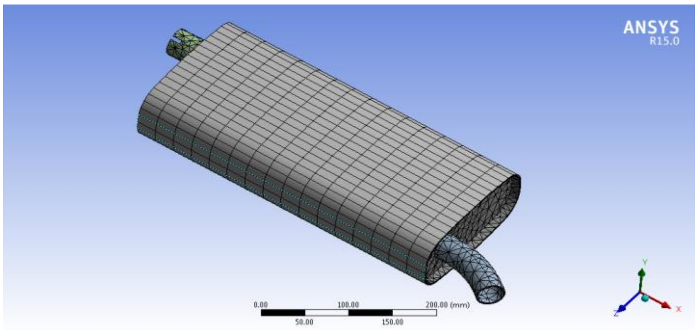


Fig.3. meshed model of existing muffler.

This model having 35840 nodes and also having 14920 elements in which tetrahedral and hexahedral types of elements.

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

Table 1. Material properties of structural steel

5.4 Boundary Condition

Boundary condition for given muffler silencer which is existing now is as shown in given figure, which shows that it is fixed at one end.

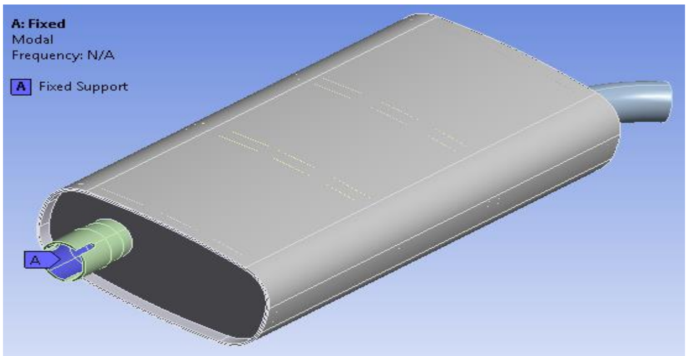


Fig.4 Boundary Condition Apply For Existing Model of Muffler

VI. RESULTS OF EXISTING MODEL

After meshing and applying boundary condition the results of total deformation are obtained and we can get the frequency in HZ of muffler silencer at different mode shapes. These frequencies at different mode shapes are given bellow.

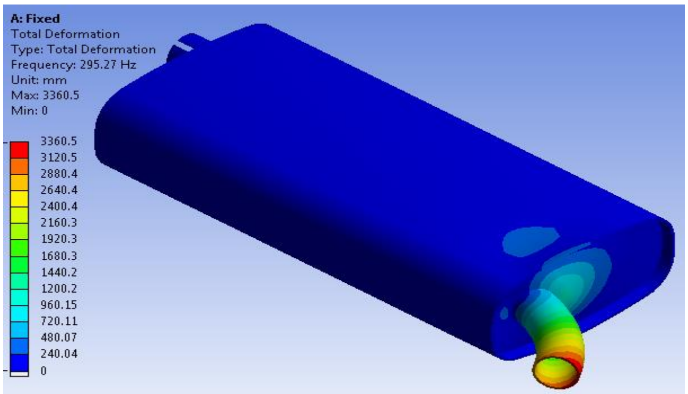


Fig.5. Frequency at Mode 1(295.27 Hz)

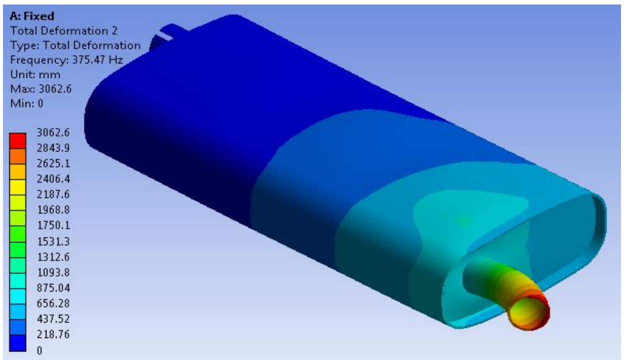


Fig.6.Frequency at Mode 2, (375.47Hz)

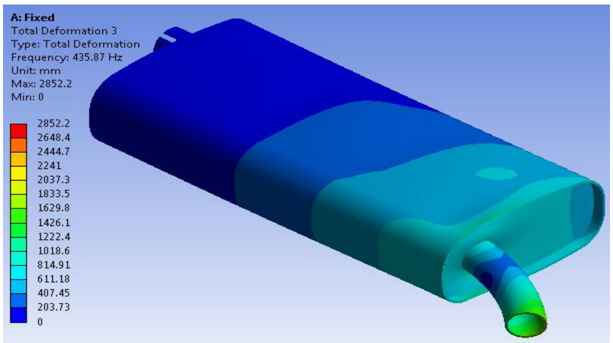


Fig.7. Frequency at Mode 3, (435.87Hz)

6.1 Harmonic Response of Existing Silencer

After this we determine harmonic response of given model at 0 Hz. For this model having acceleration 9810 mm/s^2 and components are 0,9810,0 mm/s^2 are shown in given diagram.

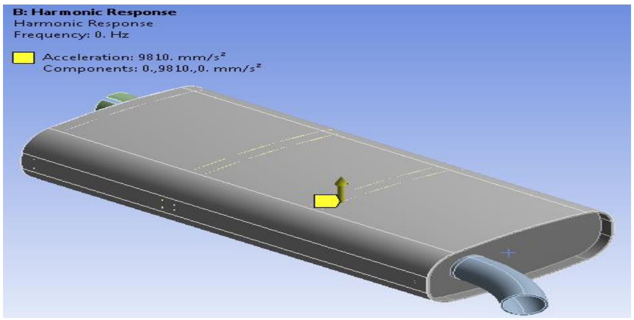


Fig.8. Acceleration for Harmonic Response

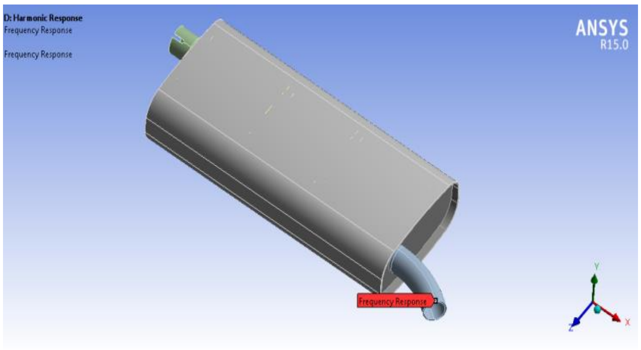


Fig.9. Point at Which Harmonic Response Derived.

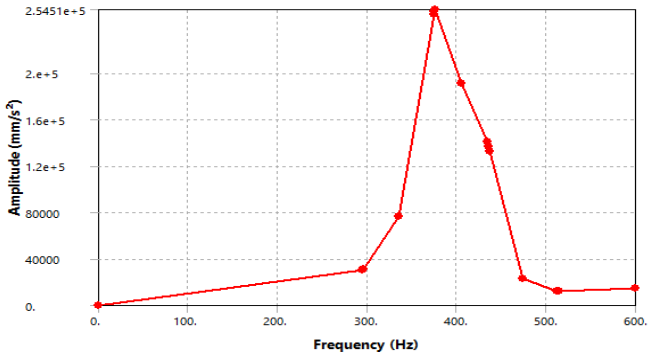


Fig.10. Frequency Response of existing model.

In given graph of frequency response of existing muffler silencer is shown where the amplitude is maximum at frequency near about 400 Hz.

VII. RESULTS OF MODIFIED MODEL OF MUFFLER SILENCER

After model analysis of existing model we get the natural frequency is 295.27 Hz at first mode and at third mode natural frequency is 435.87 Hz is obtained and for increasing the natural frequency of muffler silencer we did modification in existing model and for getting maximum natural frequency we attached two strips on the periphery of silencer as shown in figure.

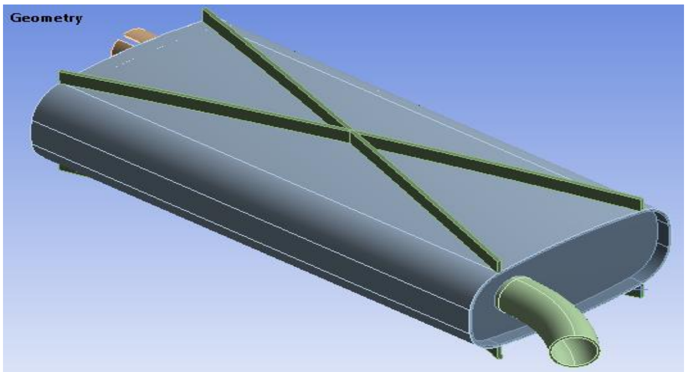


Fig.11. modified model of muffler silencer

After making of modification in existing muffler silencer in CATIA V5R20 this modified model import in ANSYS workbench. And the material properties of this model are same as in previous existing model. After assigning the material then meshing is carried out of the model in this model the nodes are 41387 and 18975 are meshing elements in which tetrahedral and wedge type elements. The meshed model is as shown in figure.

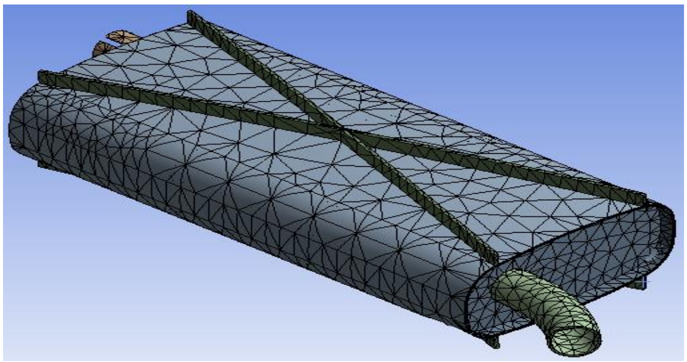


Fig. 12. Meshed Model of Modified Muffler Silencer

7.1 Boundary Condition for Modified Model

In the modified model of muffler silencer the boundary conditions are this model is fixed at one end and at the stiffeners as shown in given figure.

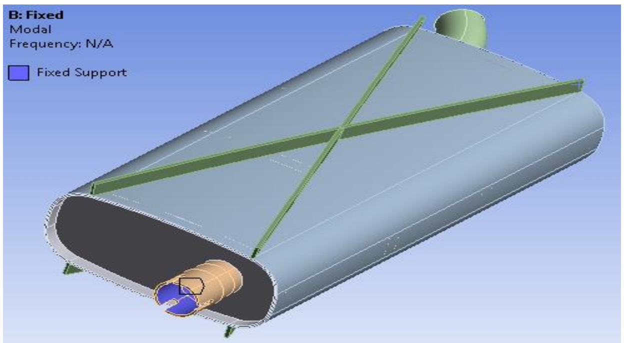


Fig.13. Boundary condition applies for modified model of muffler.

7.2 Frequency of Modified Muffler Silencer

The natural frequency modified muffler silencer at different modes is shown in figure.

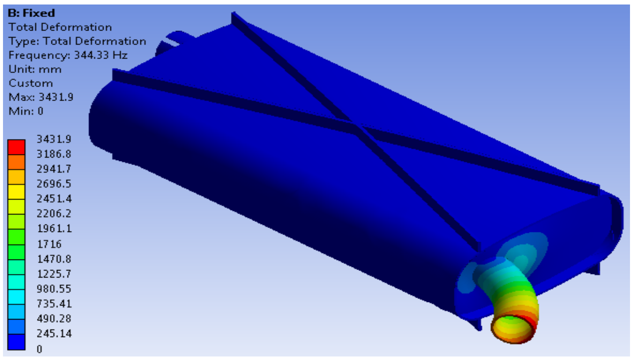


Fig.14. Frequency of modified model at Mode1, (344.33Hz)

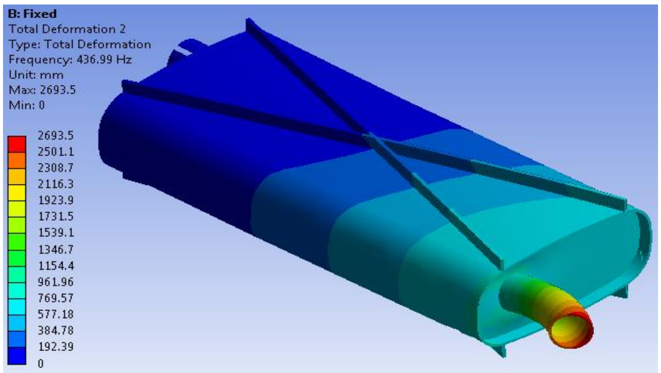


Fig.15. Frequency of modified model at Mode2, (436.95Hz)

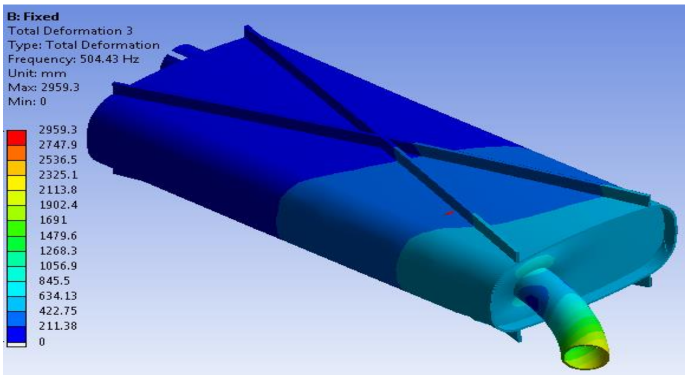


Fig.16. Frequency of modified model at Mode 3, (504.43Hz)

7.3 Harmonic Response of Modified Silencer

After this we determine harmonic response of given model at 0 Hz. For this the boundary conditions are having acceleration 9810 mm/s^2 and components are 0., 9810,0. mm/s^2 are shown in given diagram.

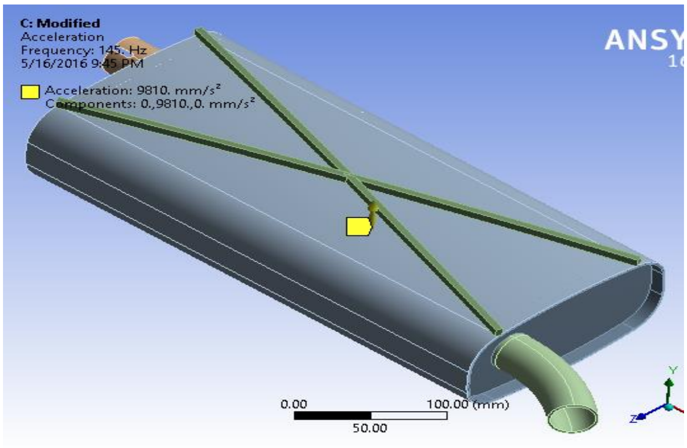


Fig.17. Acceleration for Harmonic Response of Modified Model.

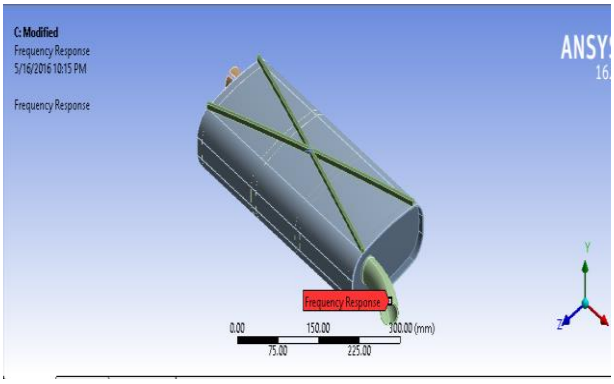


Fig.18. Point at Which Harmonic Response Derived

After this we get graph which is shown in figure in given graph of frequency response of existing muffler silencer is shown where the amplitude is maximum at frequency between 400 Hz to 500 Hz approximately.

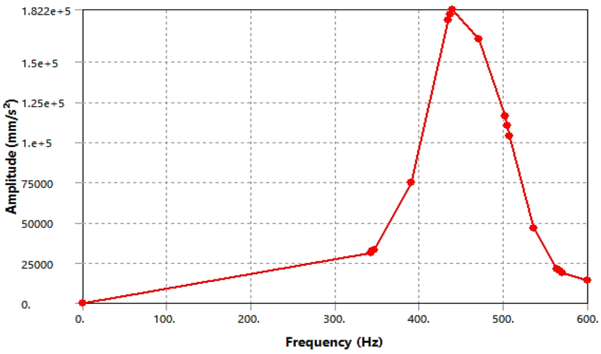
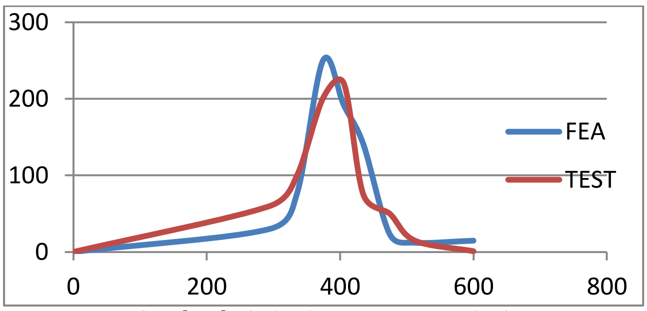


Fig.19. Frequency Response of modified model.

VIII. EXPERIMENTAL ANALYSIS

In experimental analysis we are going to validate FEA results with experimentally. The natural frequencies which are obtained in FEA and harmonic response at acceleration 9.81m/s^2 of existing model and modified model are correlated experimentally. Following graph shows the experimental as well as FEA results. For experimental we use LDS V830 shaker bed which gives 1g means 9.81m/s^2 acceleration and which sampling frequency rate is 1000 Hz. And accelerometer is of DYTRAN.



Amplitude (m/s^2) Vs. Frequency (Hz)

Fig.20. Comparison of FEA and experimental results

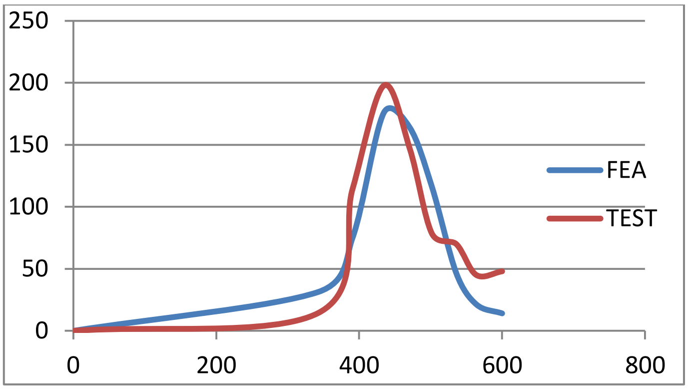


Fig.21. Comparison of experimental and FEA results of modified model.

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:2 Results Of Existing Model

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

Table:3 Results Of modified model

IX. RESULTS AND DISCUSSION

From the given results of model analysis of existing model and modified model of muffler silencer it is clear that the value of natural frequency are differ from existing model of modified silencer, it is clear that by making modification in existing model the natural frequency is more. And it is efficient and good for sustaining the vibration by muffler silencer. The comparison of natural frequency in existing and modified model is shown in given table.

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

Table 2. Comparison of frequency of existing and modified model.

IX. CONCLUSION

In this way we conclude that the natural frequency of existing model is much lower and this model of muffler silencer are unable to sustain the resonance which are formed due to noise and also jerk comes from road and this causes vibration in silencer which is un comfort to ride. But by making modification in muffler silencer the natural frequency at different modes is greater than existing and this frequency is capable to reduce vibration and it provide comfort ride and efficient ride.

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