Improved Version of Exhaust Car Muffler through Modal and Harmonic Analysis

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Abstract - *Automotive exhaust system primarily consists of exhaust system as its main component. Mufflers are used to reduce noise and pass exhaust generated in engine. Mufflers are cantilever structures which forms part of exhaust system. They are subjected to various structural, thermal and vibration loads. Various failures are seen in mufflers due to vibration from engine and road excitations. This vibration failure occurs due to resonant frequencies occurring in defined frequency range. Vertical accelerations are dominant in Mufflers due to road excitations Design/ CAD modeling of existing muffler is done using CATIA V.5 software by reverse engineering. Meshing (Discretization) of model is done using Ansys Package. The objective of this paper is to determine the frequencies that appear at the Modes, which have the more adverse effect during the operation of the automobile and to develop improved version. Existing design will be modified to reduce vertical vibrations by use of stiffener, ribs. The mode shapes and frequencies are found for both without and with modification and the results are compared with each other. The main motivation behind the work is to go for a complete FEA of muffler rather than empirical formulae and iterative procedures.*

***Key Words*: Muffler, Modal Analysis, improved version, Cantilever Structure**.

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 Let's 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 analysed 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 HYUNDAI i10.the modelling using CATIA V.5and the analysis is done using ANSYS R18.1. 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.

II. LITERATURE REVIEW

2.1 Vibration 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 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. Athree-dimensional finite element approach for predicting the transmission loss in Mufflers and silencers with no mean flow.

2.3 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.

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.

V. METHODOLOGY:

5.1 Modeling:

The modeling of the exhaust muffler was done using **CATIA V5**. The fig.1 shows imported model of exhaust muffler in ANSYS.

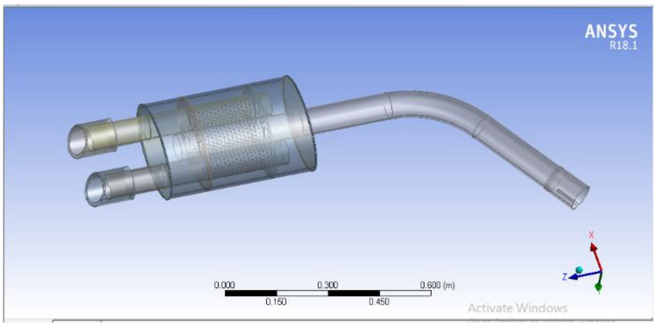

Fig -1: Imported Model of Exhaust Muffler in ANSYS.

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 muffler 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 muffler.

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 **ANSYS18.1** after importing the model from **CATIAV5.** Then mesh the given model.

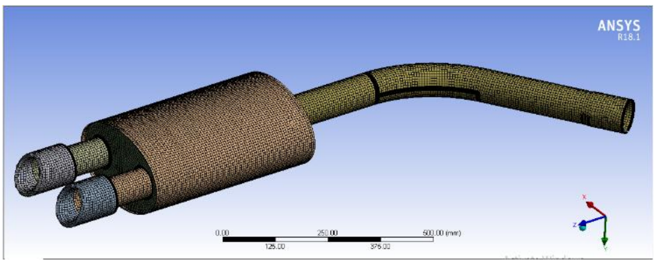

Fig-2: Mesh model of Muffler

Table -1: Material properties of structural steel

Properties	Value
Young's modulus	2×105 Mpa
Poisons ratio	0.3
Density	7890 kg/m3
Yield Strength	340 Mpa

5.4 Boundary Condition

Boundary condition for given muffler which is existing now is as shown in below figure [3]which shows that it is fixed at two outer strip.

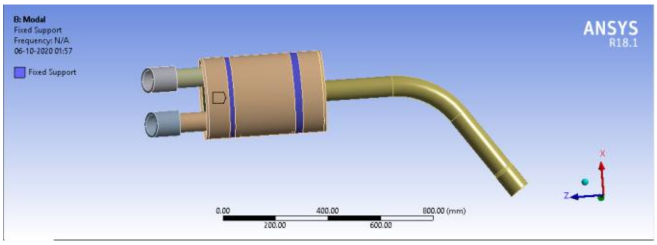

Fig-3: Boundary Condition Apply For Existing Model of Muffler

VI. RESULTS OF EXISTING MODEL:

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

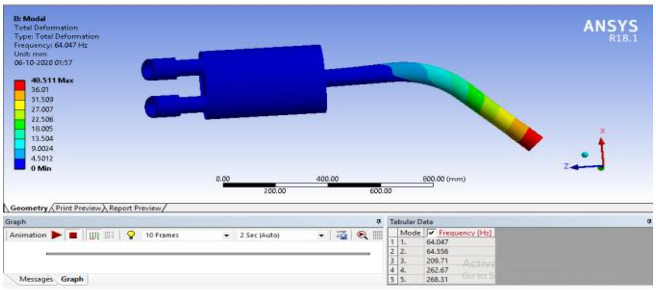

Fig-4: Frequency at Mode 1(64.047 Hz)

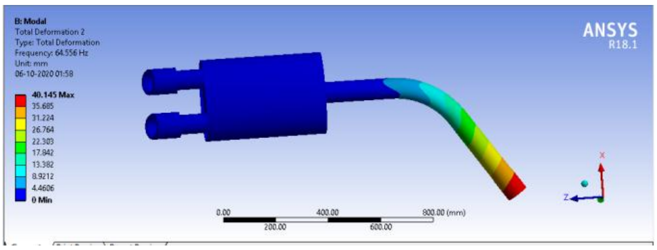

Fig-5: Frequency at Mode 2, (64.556Hz)

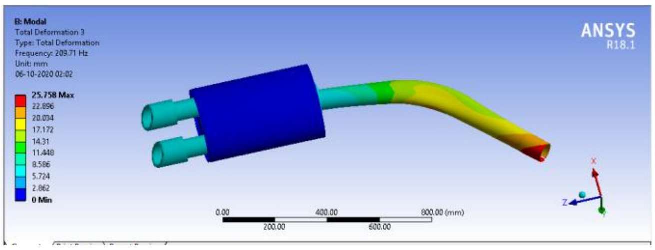

Fig-6: Frequency at Mode 3, (209.71Hz)

6.1 Harmonic Response of Existing Silencer:

After this harmonic response of given model at 0 Hz is determined. For this model having acceleration 9810 mm/s2 and components are 0, 9810, 0 mm/s2 are shown in below figure [7].

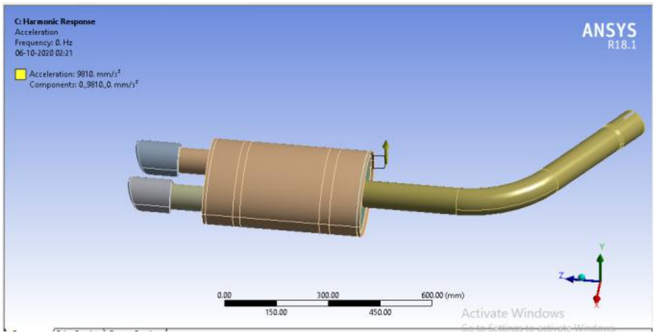

Fig-7: Acceleration for Harmonic Response.

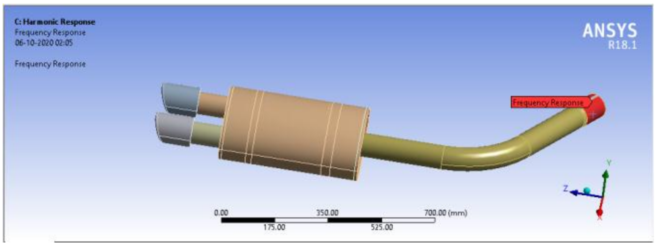

Fig-8: Point at Which Harmonic Response Derived.

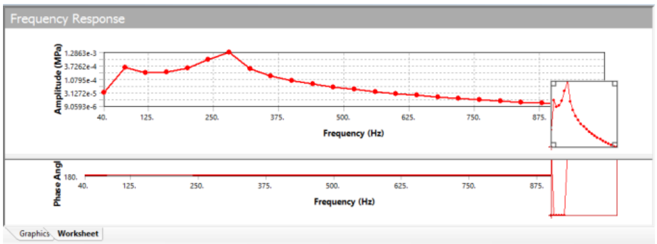

Fig-9: Frequency Response of existing model.

In given graph of frequency response of existing muffler silencer is shown in above figure [9] where the amplitude is maximum at frequency near about 270 Hz.

VII. RESULTS OF MODIFIED MODEL OF MUFFLER SILENCER:

After model analysis of existing model the natural frequency is 64.047 Hz is obtained at first mode and, at third mode natural frequency is 209.71Hz is obtained. For increasing the natural frequency of muffler silencer modification in existing model has been made and for getting maximum natural frequency, two additional strips on the periphery of silencer has been added and increase outlet pipe thickness as shown in below figure [10]

7.1 Boundary Condition for Modified Model:

In the modified model of muffler silencer the boundary conditions applied area model is fixed at two ends of strips and middle two strips as shown in below figure [10]

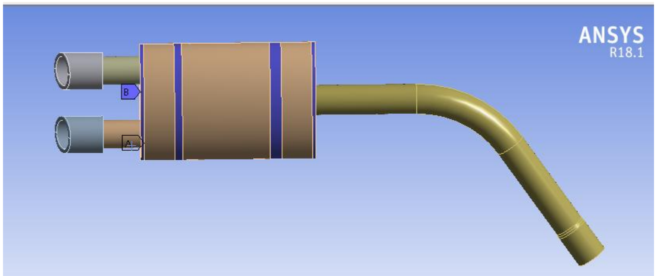

Fig-10: Boundary condition applied for modified model of muffler (4 strips).

7.2 Frequency of Modified Muffler Silencer:

The natural frequency of modified muffler silencer at different modes is shown in below figure [11].

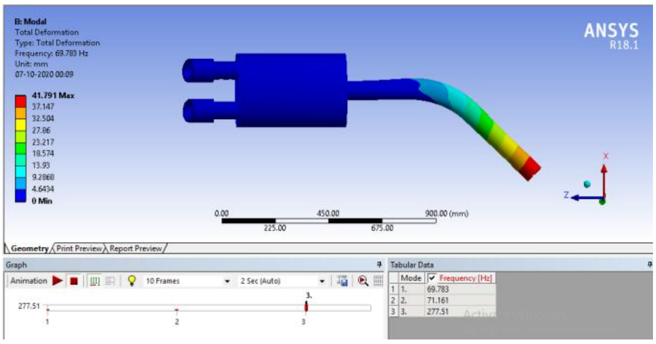

Fig-11: Frequency of modified model at Mode1, (69.783Hz)

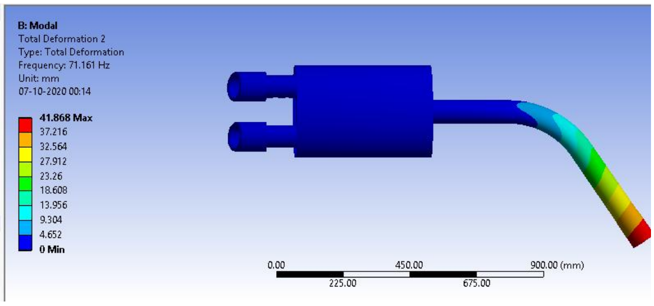

Fig-12: Frequency of modified model at Mode2, (71.161Hz).

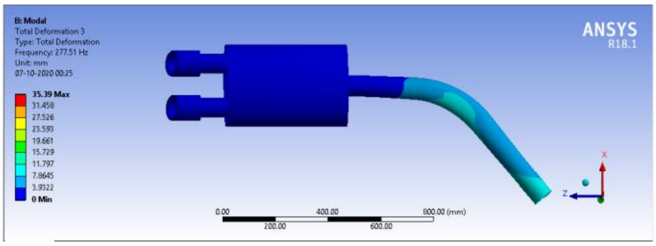

Fig-13: Frequency of modified model at Mode 3, (277.51Hz).

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/s2 and components are 0. 9810, 0. Mm/s2 is shown in above figure [7].

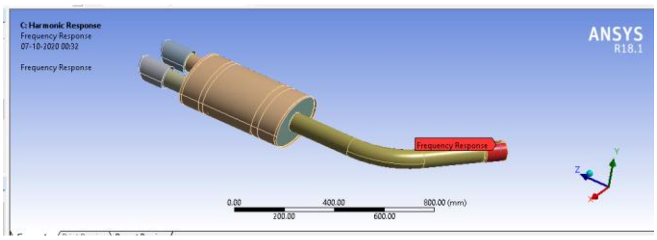

Fig-14: Point at Which Harmonic Response Derived

After this a graph is obtained which is shown in below figure [15].A frequency response of existing muffler silencer is shown where the amplitude is maximum at frequency between 200 Hz to 300 Hz approximately.

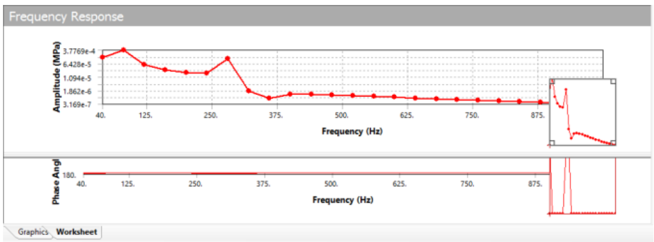

Fig-15: Frequency Response of modified model.

VIII. RESULTS AND DISCUSSION:

The results obtained by modal analysis of existing model and modified model of muffler silencer shows that the value of natural frequency are differ from existing model of modified silencer, it also shows that by making modification in existing model the natural frequency is more which is different for every mode 69.783Hz, 71.16Hz, or 277.51 Hz 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	64.047	69.783
2	64.556	71.161
3	209.71	277.51

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 lower which is different for every mode shapes as 64.04Hz, 64.55Hz, 209.71Hzand 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 which is shown in above table no.2 and this frequency is capable to reduce vibration and it provide comfort ride and efficient ride.

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