STUDY OF AUTOMOBILE SILENCER DESIGN TO EVALUATE GENERIC NORMS FOR VIBRATION

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ABSTRACT

In automobiles exhaust system is of great importance and silencer is used to minimize unwanted noise, the exhaust gas of high pressure and high temperature coming out of internal combustion engine leads to undesirable noise is known as noise pollution. Pollution creates more disturbance in the environment. Noise is measured in decibel. Audible waves are of frequency ranges from 20 Hz to 20000 Hz. To minimize sound frequency mufflers are used in silencer assembly. The exhaust gases coming out from engine are at very high speed and temperature. Silencer has to reduce noise, vibrations. While doing so it is subjected to thermal, vibration and fatigue failures which cause cracks. So it is necessary to analyze the .Vibrations which would further help to pursue future projects to minimize cracks, improving life and efficiency of silencer. Many researchers have studied and postulate behavior of silencer under loading and studied modal analysis with context to vibrations. Here we can study the given case and avoid resonance if any and look for safe design of silencer by modal analysis

KEYWORDS: *Finite element method, silencer, muffler, resonance, vibrations, modal analysis, Radioss, Hypermesh*

I. INTRODUCTION

The most important objective of silencer shown in fig.1 is to reduce the vibration and noise coming from engine. When the natural frequency of any object matches to the operating frequency of the same object then resonance, and resonance is necessarily to be avoided. Resonance leads to catastrophic failures. Therefore every machine or equipment should be properly addressed for overcoming vibration problems before installing. It is therefore necessary to study the behavior of silencer by analyzing the vibration modes and the response of vibrations by its sources. 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 which is basically considered up to 70 Hz followed by Frequency response analysis.

Figure 1: Bajaj pulsar silencer actual part

II. LITERATURE REVIEW

The initial study of Automobile silencer was carried out by Xing Sufang & Wang Xianrong and many more scholars around the world. The further study can be done by extracting the concepts put forth and the techniques used in the journals directly or indirectly. All the journal papers mentioned below proved to be prime source of knowledge for research work in vibration norms in automobile silencer.
Dr. S. B. Wadkar et al, discussed on Cooling Gas Compressors Discharge Silencer. Discharge silencer are used with rotary compressors to avoid flow fluctuations of gas. In this paper an industrial problem of discharge silencer is discussed. A discharge silencer connected to a cooling gas compressor developed cracks at various locations on its body and supports. The vibration and noise levels of the system were very high. To find out the root causes of the high level of vibration measured on the discharge silencer, it was decided to carry out a CAE based investigation along with comparative study of the actual vibration on site measurements. Hyper-mesh with shell elements is used for meshing the various design models and modal analysis of the structure is done using Radioss as a solver. The response of the discharge silencer under dynamic loading condition through transient dynamic analysis is done using Ls-Dyna as a solver. Hyper-view is used for post processing of the modal analysis results [1]. Vinay gupta et al, briefed about postulates the first stage in the design of an exhaust system, with the specified properties of the different material, the exhaust system is modeled by solid works. In this paper, the structures are automotive exhaust system and the materiel used for the exhaust system is described. The result are compared the deformation of silencer parts of three specified materials for same exhaust thrust. This paper plays a vital role of deciding the life cycle of silencer [2].

Figure 2: Maffle and baffle

S. Rajadurai et al, summarizes the systematic FEA study of exhaust system for passenger car and explaining about the usage of Altair’s Pre-processing tool HyperMesh, solver RADIOSS and Post-processor tool HyperView for performing different kind of analysis to validate the design.
Today’s exhaust system are developed to deliver minimum noise, emissions, maximum durability, packaging, safety, flow rates, lower system restriction, high temperature compatibility, Corrosion resistance, easy serviceability and cost effectiveness. The exhaust system has various attributes including vibration, acoustics, thermal distribution and durability, flow and power loss in addition to its interface with vehicle.

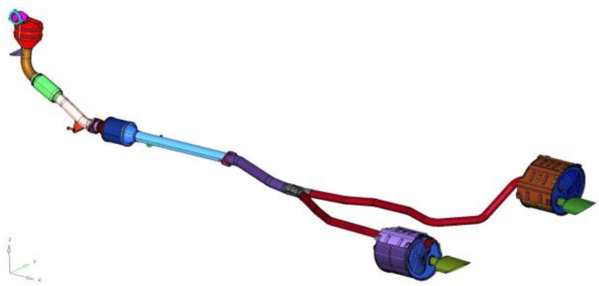


Figure 3: CAD model of Exhaust System

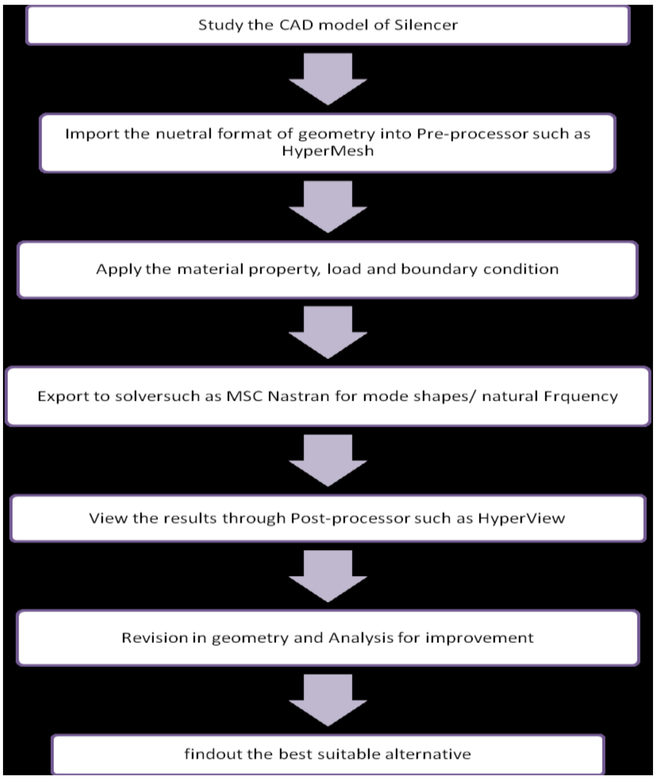
[3]Ying-li Shao, explained conventional muffler of internal combustion engine is mostly constructed as a mixture or combination of perforated ducts, baffle or perforated baffle, expansion chamber, etc., and the noise reduction is limited and backpressure is high hence the fuel efficiency is low. In order to solve the problems of traditional exhaust silencers with poor characteristics of noise reduction in low-frequency range and high exhaust resistance, a new theory of exhaust silencer of diesel engine based

on counter-phase counteract and split-gas rushing has been proposed. Taking the single-cylinder diesel engine CG25 as the experimental engine, the author measured the exhaust noise and its spectra. By comparing the results of the new types of mufflers to those without a muffler and those with the original muffler of the engine, the new theory of muffler has been verified [4] Wang Jie et al, did modal analysis of automotive exhaust muffler In order to improve the design efficiency, resonating of the exhaust muffler should be avoided with its natural frequency. The solid modeling is created by the PRO-E and modal analysis is carried out by ANSYS to study the vibration of the muffler so as to distinguish working frequency from natural frequency and avoid resonating [5] Mr. K.S. Tanpure et al discusses initial primitive stage in the design analysis of a Genset silencer. The geometry of the exhaust system is modeled by using a conventional FEM package after considering specified properties of material, dimensions of silencer. Modal Analysis of the muffler is carried out and the results are compared with the reading taken on FFT analyzer, so as to distinguish working frequency from natural frequency, avoid resonating condition and to find the stress concentration at various regions of silencer.
[6]. BJ Furman, elaborates the use of vibration measuring instruments in actual experimental setup like vibration transducers, accelerometers and vibration measuring instrument.

III. METHODOLOGY

Basically three different methodology are used
1. Computational method,
2. Analytical Method/Numerical Method,
3. Experimental Method Computational Method:

1. Numerical Method: Using mathematical formulae we can find out the natural frequency of the silencer.
2. Experimentation: For experimentation purpose we would use FFT (Fast Fourier Transport) setup to find out the vibrations induced in silencer. Using FFT setup, we would find natural frequency, mode shapes, FRF of silencer in which hammer or shaker would use for excitation purpose.



IV. COMPUTATIONAL OR FEA METHOD

1.FE modeling and meshing technique
2.modal analysis of existing model
3.FRA of existing modal
4.Static strength analysis

Natural frequency and mode shapes that is Eigen value and Eigen vector can be find out by using modal analysis It is force free analysis, that is vibration of system on its own after removal of initial excitation ,modal analysis solve equation that is summation of inertia force plus spring force equal to zero

Need of Modal analysis:
1.To find out natural frequency and mode shape (Eigen value & Eigen vector).
2.To avoid Resonance.
3.To study NVH and acoustics.
4.It's a basic design property.
5.To check meshing connections.

4.1Meshing guidelines

Type of meshing preferred is shell meshing, Type of element 4 noded Quad element and 3 noded Tri and RBE2 (rigid beam element 2), subtype of meshing used is Tetra meshing, Type of element – 10 noded tetra element, Shell meshing is done on mid surface while thickness is assigned to every mid surface. Connections are given by weld element, rigid and 1d beam element.

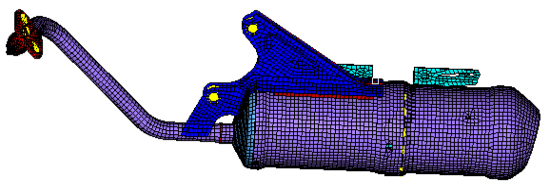


Figure 5. Meshed Silencer

Silencer is constrained at exhaust connected to the engine and brackets are also constrained on the silencer

4.2 Modal analysis

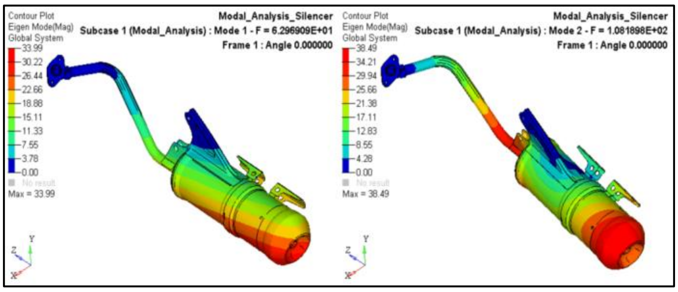


Figure 6. 1^{st} and 2^{nd} mode shapes

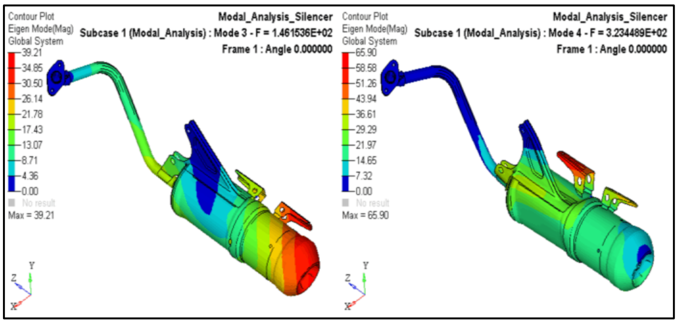


Figure 7. 3^{rd} and 4^{th} mode shapes

In general 4 modes shapes are enough to observe frequency change pattern and study maximum stress involved at a particular frequency.

Observation from modal analysis

1. First mode is at 62.9 (63) Hz that is fundamental frequency
2. We got first 2 mode shapes having frequency upto 108 Hz
3. Engine operating range is 0 to 108 Hz, which is nothing but the excitation range
4. Finally we can conclude that, from modal analysis first 2 modes are critical as they fall in the engine excitation frequency range so chances may be there for resonance while resonance may occur when natural frequency matched with the excitation frequency. So it is necessary to perform frequency response analysis for the system.

4.3 Frequency Response Analysis (FRA)

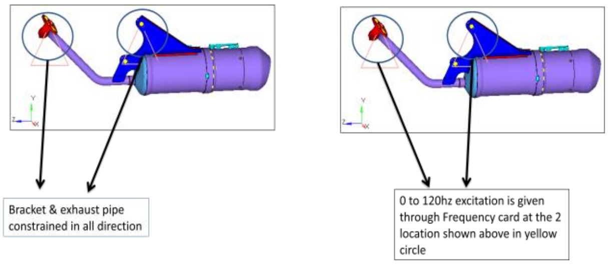


Figure 8. silencer constrained

We have selected some points in the model at which we will extract response of the system. These points are selected based on the maximum deflection in the mode shape from modal analysis

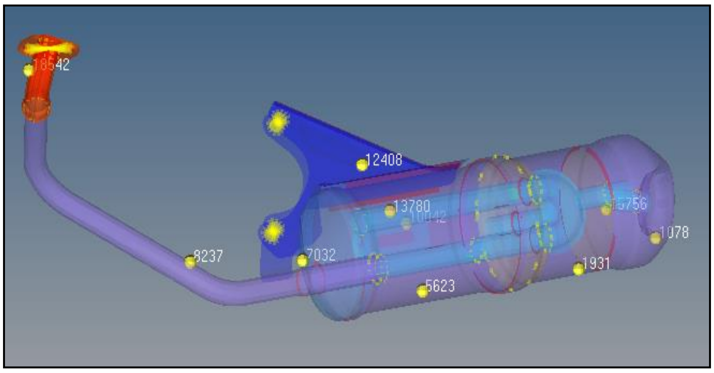


Figure 9. nodes at silencer

Frequency response graphs for few selected node

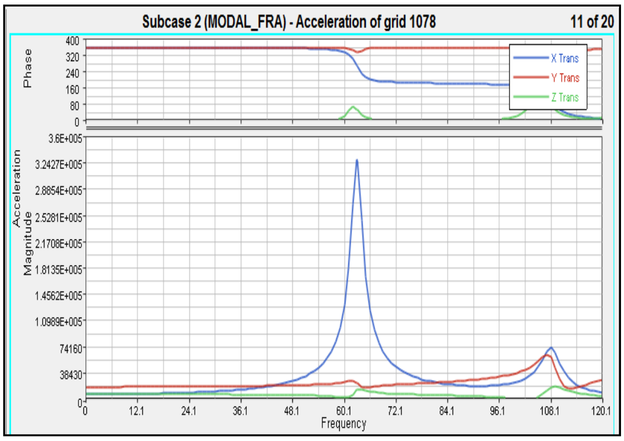


Figure 10. frequency vs Acceleration graph for node 1078

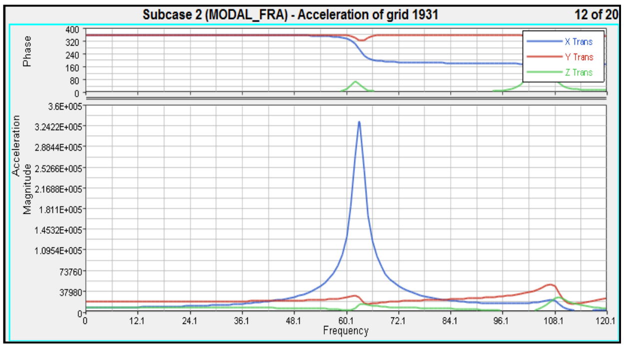


Figure 11 frequency vs Acceleration graph for node 1931

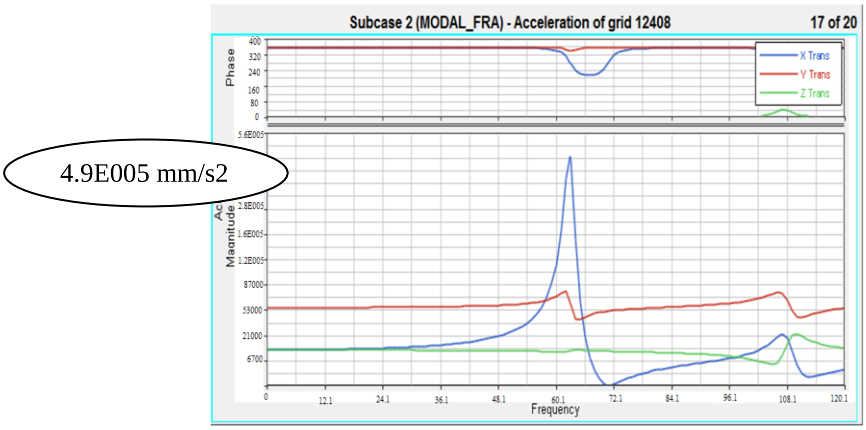


Figure 12 frequency vs Acceleration graph for node 12408

Silencer System respond more at 63Hz in X direction .So it is necessary to find out the stresses at 63Hzfor that we can take stress contour for 63Hz

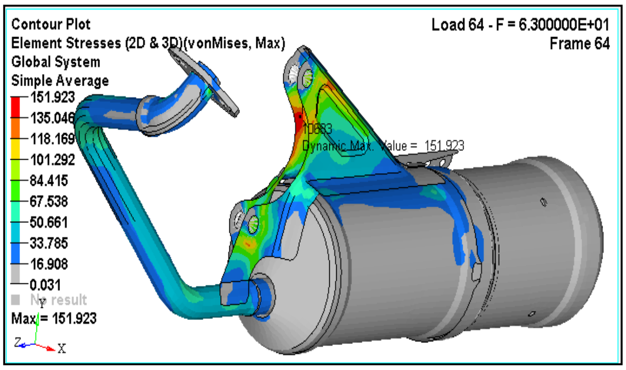


Figure 13. contour plot for frequency at 63 Hz

Observations after FRA

A).Silencer System respond more at 63 Hz in X direction. B).Stresses found maximum in bracket & are within yield limit.

C).No failure observed in silencer system

V. EXPERIMENTAL METHOD

For experimentation purpose we would use FFT (Fast Fourier Transport) setup to find out the vibrations induced in silencer. Using FFT setup, we would find natural frequency of silencer, in which hammer or shaker would be used for excitation purpose.

5.1 Experimental setup

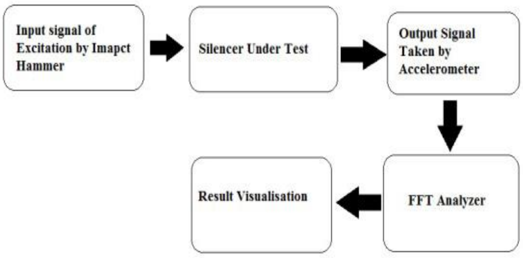


Figure 14. Block diagram of experimental setup

5.2 Components used in setup

1. vibration measuring instrument

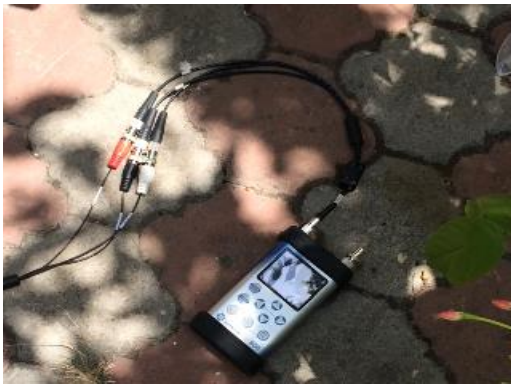


Figure 15. vibration measuring instrument (SVAN 958)

Instrument is of svanteck digitals which has FFT analyzer inbuilt which can perform 1/1 and 1/8 octave band analysis with frequency working range 0.5 Hz to 20 kHZ

2. Accelerometer

Figure 16. Accelerometer put on silencer

Accelerometer are available to detect magnitude and direction of the proper acceleration that could be in either of X Y Z direction (or g-force), as a vector quantity, and can be used to sense orientation (because direction of weight changes), coordinate acceleration (so long as it produces g-force or a change in g-force), vibration, shock, and falling in a resistive medium (a case where the proper acceleration changes, since it starts at zero, then increases).

5.3 Experimental procedure

Simple Connections are made from vibration measuring instrument to accelerometer mounted on target position on silencer that is near to bracket at silencer sensor sensitivity is set in X Y Z directions

Experimentation was carried to find out stress developed at silencer bracket as FRA result shows stresses were found more at silencer bracket so accelerometer was put on silencer nearer to bracket

5.4 Experimental results/graphs

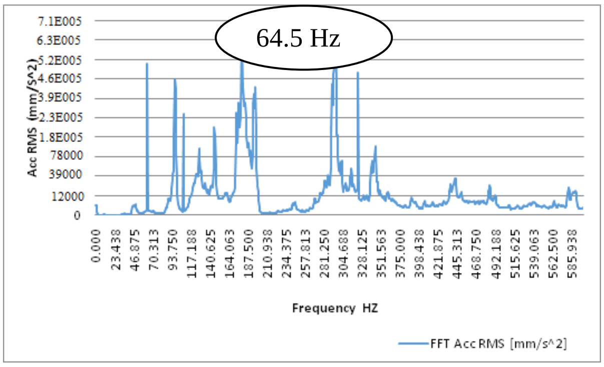


Figure 17. plot of frequency vs acceleration

Experimental conclusions

Experimental results shown by plot of frequency vs acceleration Graph reads value 64.5 Hz for the position mentioned at silencer nearer to bracket that is silencer respond more at 64.5 Hz more at bracket of silencer

VI. Validation of Computational vs Experimental Values

Table 1. Validation

Reading by FEA	Reading by Experimentation	% variation in Results
63	64.5	2.23

VII. Conclusion

The given specimen silencer was found safe and without failure within excited range with 2.23% variation in computational and experimental result values that is no occurrence of resonance hence no vibration and shock effects so silencer is safe

VIII. Future Scope

Vibration being a non-saturating subject and that to automotive components, hence there is always scope for improvement in the particular project silencer properties could be changed to observe change in performance and aesthetics like silencer material could be changed, its mechanical properties could be changed cad modeling could be somewhat different for aesthetics with combination of such changes performance may vary.

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