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Modal Analysis of Muffler of an Automobile by Experimental and Numerical Approach

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Abstract: **A pollutant of concern to the mankind is the exhaust sound which should be about 105dB in the internal combustion engine. However this sound can be reduced sufficiently by means of a well-designed silencer. The suitable design and development will improve the sound level, but at the same time the performance of the engine should not be hampered. Muffler design is an important research area for an automotive industry because new regulations and standards for noise emission are formed. To examine the performance of any muffler, certain parameters are used. These parameters are Numerical modal analysis, Experimental modal analysis. In this project both Numerical and Experimental Modal analysis (TATA INDICA car) The experiment conducted on thickness of existing muffler body by FFT analyzer. Also numerous iterations are carried out by changing the thickness of muffler body, perforation of baffle plates. This methodology helps commercial users and OEM (Original Equipment Manufacturers) to design the silencer/muffler accordingly.**

Keywords: **Experimental modal analysis, exhaust muffler, FEM, FFT.**

1. INTRODUCTION

Sound which is unwanted or spoils one's quality of life When there is sound in environment, which is beyond audible range termed as Noise pollution. Maximum pollution is obtained by an automotive, as there are more moving parts in the engine. Noise production is more due to variation of oscillating sound waves coming out from engine of an automobile and friction between the moving parts of the vehicle. In order to control the noise of an automotive a device called Muffler or Silencer is used.

The main function of silencer is to attenuate the high intensity sound waves to low intensity level. This device is designed in such a manner that it must suppress the sound as well as maintain engine efficiency well.

Once ignition takes place, the engine ejects exhaust gases in the form of high pressure vibration through exhaust manifold. This high pressure vibration creates very effective sound. In order to suppress this, a muffler uses some combination of baffles, chamber, perforated tubes, and/or sound attenuating material to achieve the goal. Ideally, well designed muffler will provide a well achieved exhaust tone without creating backpressure. A sound wave coming out from the engine is about 120dB. This wave enters silencer and come out at the range of 90-95dB, which is nearly less than audible.

By FEM analysis Eigen values and Eigen vectors are found by using Software or numerical analysis that is FEM of exhaust muffler. Amongst power train parts in an automobile silencer is the major noise reducing structure.

MUFFLER design is an important research area for automotive industries because of new regulations and standards for noise emission. To examine the performance of any muffler, certain parameters are used. These parameters are transmission loss and back pressure. The transmission loss gives a value in decibel (dB) that corresponds to the ability of the muffler to dampen the noise. New designs to improve the acoustical properties of a muffler cause a resistance against the flow of exhaust gases and this resistance stems the flow. This is called back pressure and it creates an extra pressure inside the engine. [1]

2. LITERATURE SURVEY

1. **Potente, Daniel:** Potente and Daniel discuss the general principle of muffler design and explains the main advantages of various styles of mufflers. When designing muffler for any application there are several functional requirements that should be considered, which include both acoustic and non-acoustical design issues. [2]

2. **M.Rahman, T. Sharmin, A F M E. Hassan, and M. Al Nur:** Explains design and construction of the muffler in order to reduce the noise. They mainly focused on the exhaust noise reduction that is reducing the noise pollution. They manufactured and design muffler for stationary petrol engine. The performance characteristic, that is noise reduction capability of muffler, has been tested and compared with that of the conventional muffler. They found result has been found satisfactory.[3]

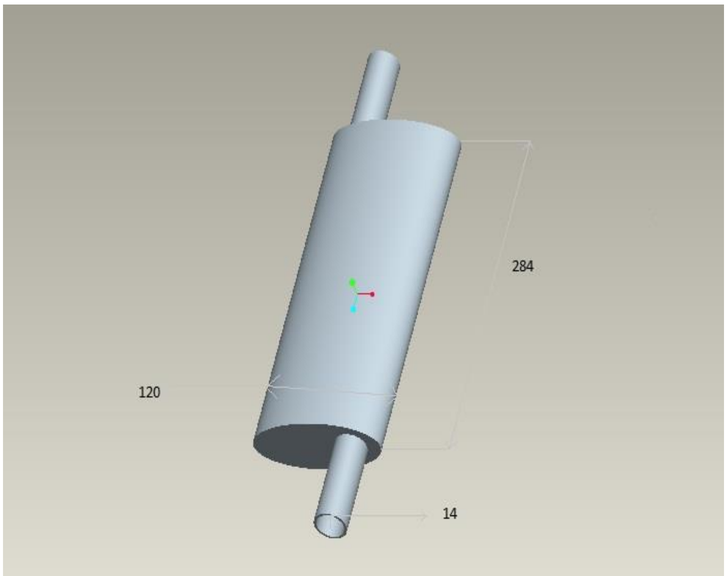
3. **RAHUL D. NAZIRKAR, S.R.MESHRAM, AMOL D. NAMDAS, SURAJ U. NAVAGIRE, SUMIT S. DEVARSHI:** Focused on transmission loss (TL) and natural frequency (NF) of muffler. In this they designed the muffler of single expansion chamber and double expansion chamber. They modaled the solid modal of exhaust muffler by using CATIAV-5 and the modal analysis is carried out by ANSYS to study the vibration and natural frequency of muffler. So as to differentiate between the working frequency from natural frequency and avoid resonating. And they found that double expansion chamber gives better results as compared to single expansion chamber.[4]

4. **A.K.M. Mohumuddin, MohdRashidinIderes and ShukariMohadHashim:** Presents experimental study of noise and back pressure for silencer design characteristics. The main objective of this study was to find the relationship between the back pressure and the noise level. He concludes that the relationship between the noise and the back pressure is inversely proportional. [5]

5. **Mr. Jigar H. Chaudhri, Prof. Bharat S. Patel, Prof. Satis A. Shah:** Explains different types of mufflers and design of exhaust system belonging engine has been studied. The object of this study is deciding muffler design which one reduces a large amount of noise level and back pressure of engine. In designing, there is different parameter which has to take in to the consideration. These parameters affect the muffler efficiency. And they finally found that combination type of muffler is more efficient than reactive and absorptive mufflers. [6]

3. FEM MODELING AND ANALYSIS OF EXISTING MUFFLER

Modeling: Modeling is compassed with SolidWorks-2013.



Material Property details:- Material: Steel Young's modulus: 210MPa Poisons Ratio: 0.3 Density: 7.89Tonn/mm^3 Card image: MAT1
Type of elements used:- Quad elements: 15657 Tria Elements: 158 Rigid: 4 Total number of elements: 15819 Card image: P-shell

Figure3.1: SolidWork CAD modal

After creating CAD modal, that is after preprocessing we have to proceed for 'Processing'. FEM is one of the powerful tool which helps us to find out solution for the complex problem.

In this analysis complex region are discretized in to small number of elements. Material properties are assigned to these elements and expressed in terms of unknown values at element corners. An assembly process, duly considering the loading and constraints, results in a set of equations. Solution of these equations gives the approximate behavior of the continuum. [7]

In 'processing' Finite element modal is meshed by using linear first order shell elements at mid surface of the muffler. The Structural meshed modal of muffler shown in figure 3.2, Properties of material and Type of elements used in meshing are tabulated in table.

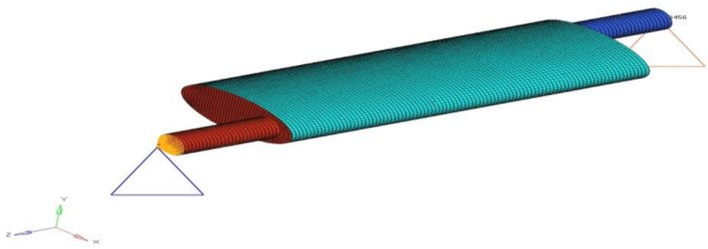
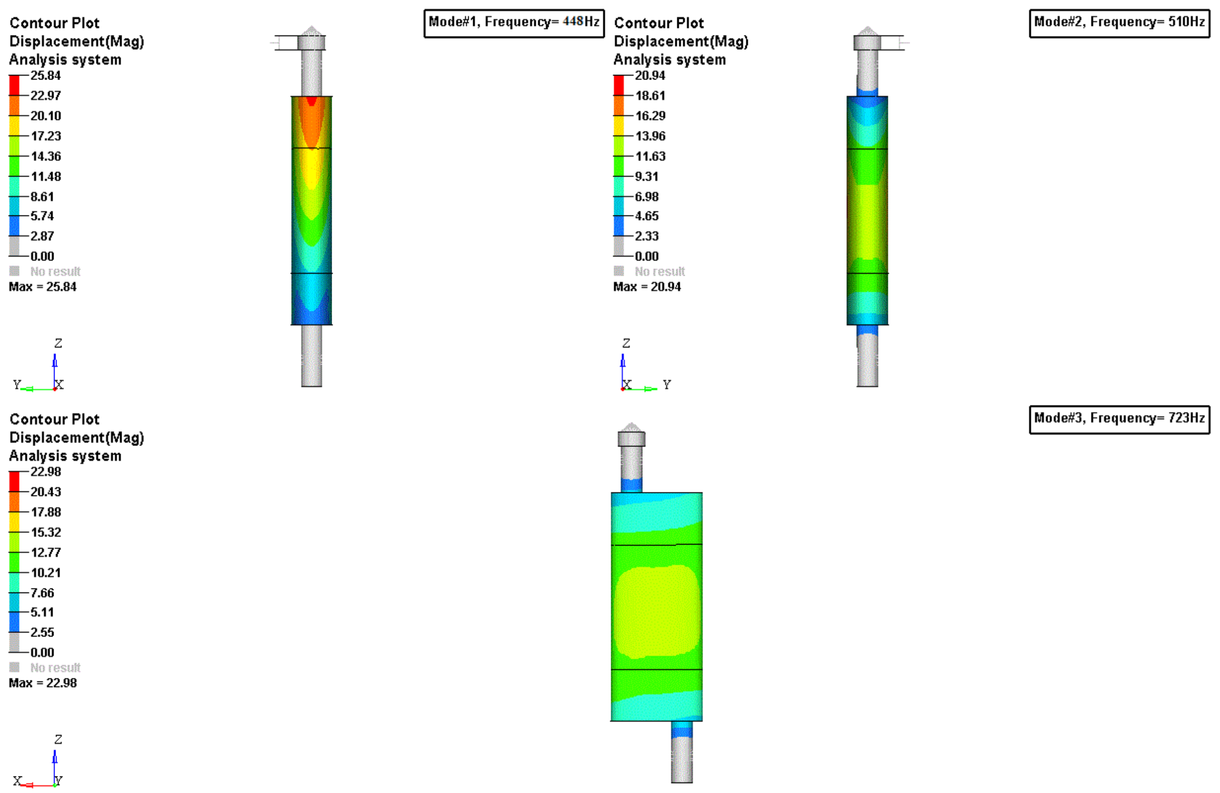


Figure 3.2: Meshed modal of muffler

After 'Preprocessing' Analysis of muffler has to be done, this work is processed in NASTRAN. Results obtained are tabulate below for 2mm existing thickness.

Mode shapes	Frequency (Hz)
1	**448**
2	**510**
3	**723**

Different mode shapes are shown in below figure



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4. EXPERIMENTAL MODAL ANALYSIS

Experimentally modal analysis is done with FFT analyser. Impulse hammer is used to exite the system. Vibrations coming out from speciman are sensed from the tiny piezoelectric sensor. These signals are sent to DSP where actually converts digital signals to human readable form. Those results are sent to computer system. By help of MEscope software we are going to get following results.

Table 4.1 shows experimental values for 2mm existing thickness.

Table 4.1 Experimental values

Mode shapes	Frequency (Hz)
1	419
2	539
3	674

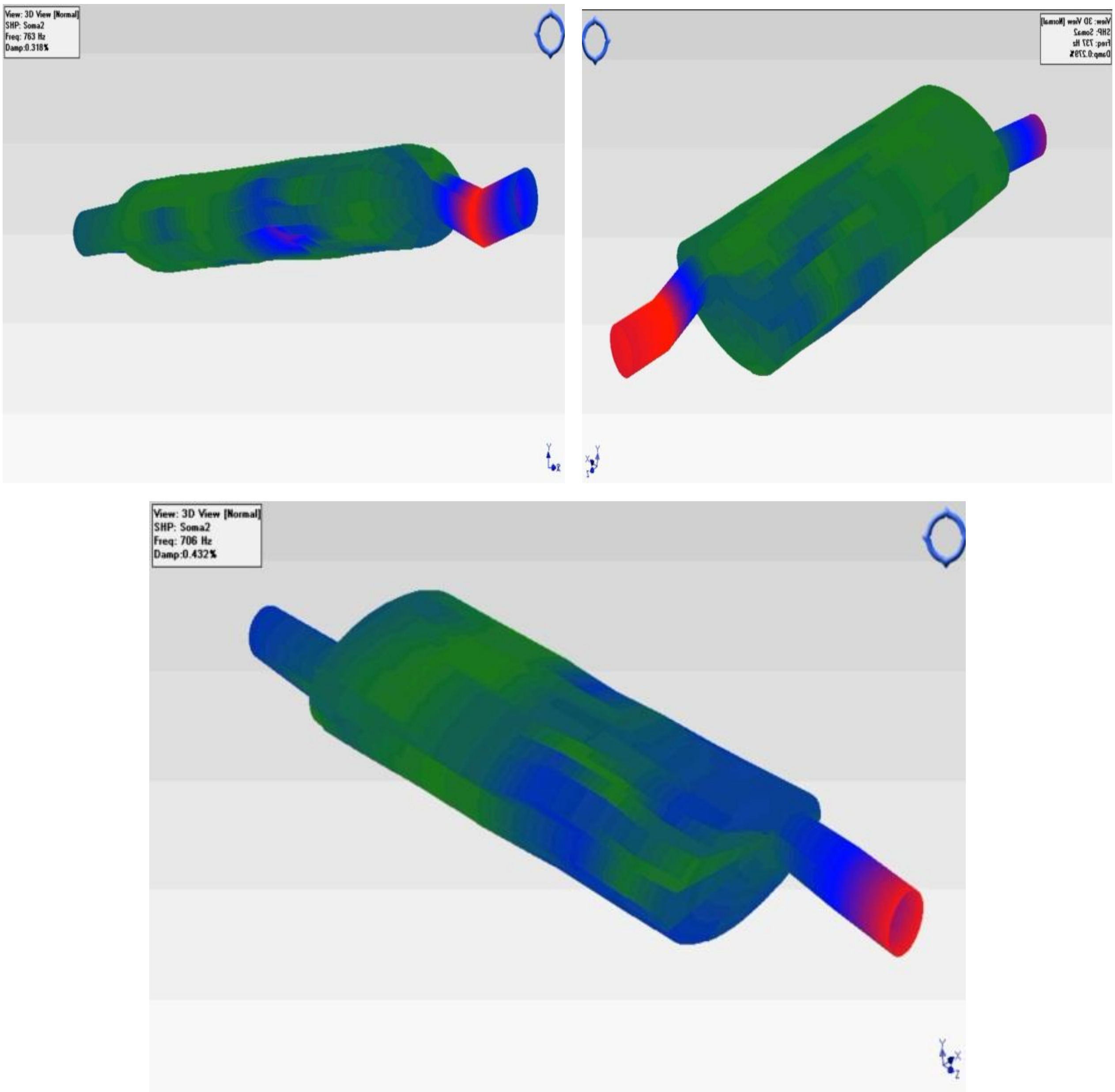

Figure 4.1 Mode shapes obtained Experimentally

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5. OPTIMIZING THE MUFFLER

Also here an effort is made in which four iterations have been done for muffler analysis by varying the thickness of the muffler cover by 1.5mm, 2.5mm, 3mm and 4 mm. The results are plotted as shown below.

For 1.5mm thickness:

Mode	Frequency, Hz
1	425.9
2	540
3	723.7
4	915.3

For 2.5mm thickness

Mode	Frequency, Hz
1	413.3
2	442.9
3	513.1
4	924.0

For 3mm Thickness

Mode	Frequency, Hz
1	402.5
2	415.2
3	491.8
4	903.0

For 4mm Thickness:

Mode	Frequency, Hz
1	372.3
2	382.8
3	455.2
4	859.9

6. RESULTS AND DISCUSSION

6.1 Validation of Experimental Modal analysis and Numerical Modal analysis for 2mm thick:

Below tabulation shows the Experimental modal analysis and numerical modal analysis. It can be seen that the results obtained through finite element modal analysis are in agreement with the experimental approach Results. This is for TATA INDICA car. This is of thickness 2mm.

Table 6.1: Validation of Numerical and Experimental Modal analysis

Mode shapes Experimental	Frequency (Hz)	Mode shapes Numerical	Frequency (Hz)	% of Error
1	419	1	448	5.8
2	539	2	510	5.3
3	674	3	723	6.6

6.2 Comparison of natural frequency for different thickness of the muffler cover.

	Natural frequency				
Mode	T=1.5mm/Mass=6Kg	T=2mm/mass=6.9Kg	T=2.5mm/mass=7.8Kg	T=3mm/mass=8.7Kg	T=4mm/mass=10Kg
1	425.9	448	413.3	402.5	372.3
2	540	510	442.9	415.2	382.8
3	723.7	723	513.1	491.8	455.2
4	915.3	-	924.0	903.0	859.9

By observing the table of comparison of different thickness, all the modals are meeting the performance criteria and first four natural frequencies of the all modals shows the same characteristics in terms of natural frequency. However 1.5mm thick modal giving a better results where in weight also reduced compare to other modals. So we can confer modal 1 is most idealistic.

7. CONCLUSION

- Modal analysis of muffler is carried out numerically under free condition using MSC NASTRAN, and experimentally by impulse hammer testing machine. Frequency range lay between 410 to 730Hz, these frequencies are Natural frequency. Frequency obtained from both the methods is agreeing and are useful for designing the muffler.
- By observing the table of comparison of different thickness all the modals are meeting the performance criteria and first natural frequency of the all modals shows the same characteristics in terms of natural frequency. However 1.5mm thick modal giving a better results where in weight also reduced compare to other modals. So we can confer modal 1 is most idealistic.

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