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Vibrational Analysis of Automotive Exhaust Silencer Based on FEM and FFT Analyzer

V.P. Patekar* and R.B. Patil**

Department of Mechanical Engineering,
**Pad, Dr. Vitthalrao Vikhe Patil College of Engineering, Ahmednagar, (M.S.)*
***Jawaharlal Nehru College of Engineering, Aurangabad, (M.S.)*

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ABSTRACT : 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.

Keyword : Silencer; Modal analysis; Finite element method; FFT.

I. INTRODUCTION

One of the objectives when designing a new automobile exhaust pipe is to lengthen it's durability period, which can be measured. in terms of its life span and mileage. The exhaust pipe is subjected to several stresses, most of which are due to vibration. Particular attention should be given to gas forces which will induce vibration. These vibrations will then induce a fatigue life to the system. It is therefore necessary to study the fatigue behavior of the exhaust pipe by analyzing the vibration modes and the response of vibrations by its sources [3].

II. NEED FOR ANALYSIS

The Automobile silencer under study belongs to a popular 2-Wheeler manufacturer in India with the rated HP of the engine up to @7.69HP. 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.[1]

III. INDUSTRIAL RELEVANCE

Every exhaust system of an industrial or automobile system where hot gases discharge from the combustion chamber into the surrounding atmosphere at relatively high velocities has a silencer as an integral part of the system. The Automotive silencer attempts to reduce the audible noise levels in the proximity of the system to acceptable limits for human comfort. While doing so, it has to withstand stresses induced due to heat and other factors such as vibration, fatigue etc.

As such, any improvement made to the silencer would directly enhance the function of silencer with marked improvement in its effective life-span.

IV. PRESENT THEORIES AND PRACTICES

Modal analysis is method to describe a structure in terms of its natural characteristics which are frequency, damping and Modal shapes and its dynamics properties.

Modal analysis involves process of determining the modal parameters of a structure to construct a modal model of the response. Theoretical [Finite Element Analysis (FEA)] and Experimental Modal Analysis (EMA) have been very separate engineering technologies aimed for solving noise and vibration problems. The modal parameters may be determined by analytical means, such as finite element analysis and one of the common reasons for experimental modal analysis is the verification/correction of the results of the analytical approach (model updating). Experimental modal analysis is used to explain a dynamics problem, vibration or acoustic [5].

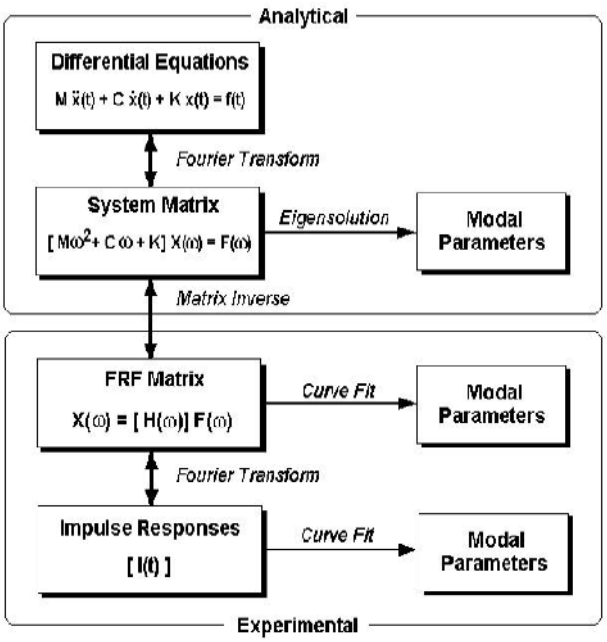


Fig 1. Analytical and Experimental method of frequency detection.

V. MODEL AND MESHING OF SILENCER

The different material properties selected for silencer are as: Young's modulus of Elasticity E = 2e ^ 5 Mpa, Poissons ratio = 0.3, material density is = 7850 kg/m^3 and the length of silencer is = 700 mm. The following Fig. shows the meshed model of silencer.

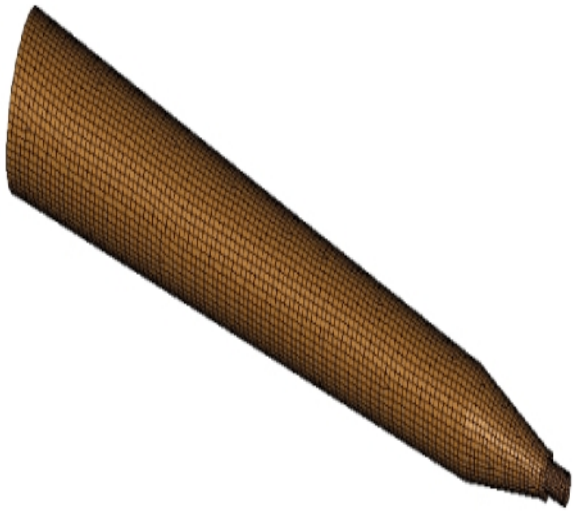


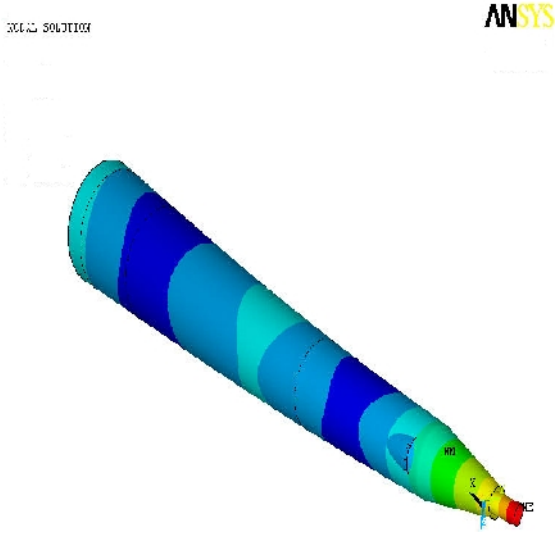
Fig 2. Silencer Meshing.

After generating the model of silencer then analysis is done by ANSYS. The result obtained by modal analysis for first six natural frequencies are determined and tabulated as follow :

Mode Order	1	2	3	4	5	6
Frequency (Hz)	90.508	570.81	892.01	892.22	1036.3	1037.3

Table 1: First six modal frequency of vibration.

The different mode shapes are shown in Fig. below :



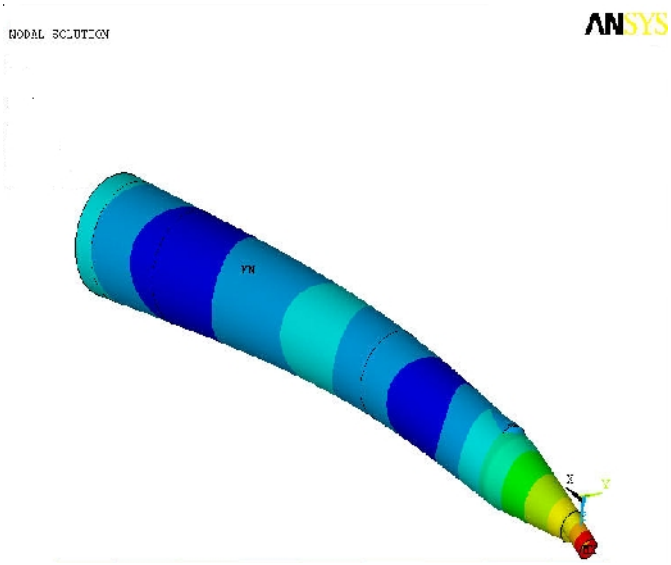


Fig 3. Different mode shape of silencer.

VI. EXPERIMENTAL VALIDATION

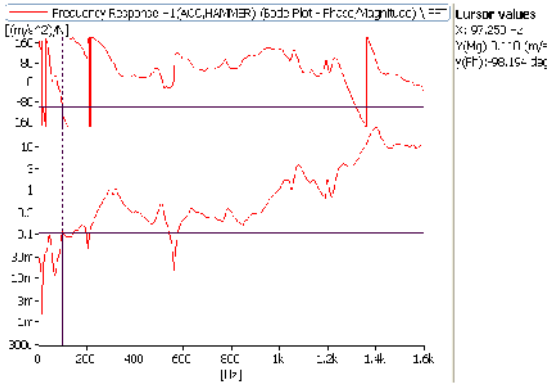
The experimental validation is done by using FFT (Fast Fourier Transform) analyzer. The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. The advantage of this technique is its speed. Because FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analog spectrum analyzers.

The result obtained by FFT analyzer for first six natural frequencies are determined and tabulated as follow.

Table 2 : First six modal frequency of vibration by FFT analyzer.

Mode Order	1	2	3	4	5	6
Frequency (Hz)	97.25	564.5	773.75	848.5	1039	1077

Frequency response function of the exhaust system is shown in Fig. 4 for different modes.



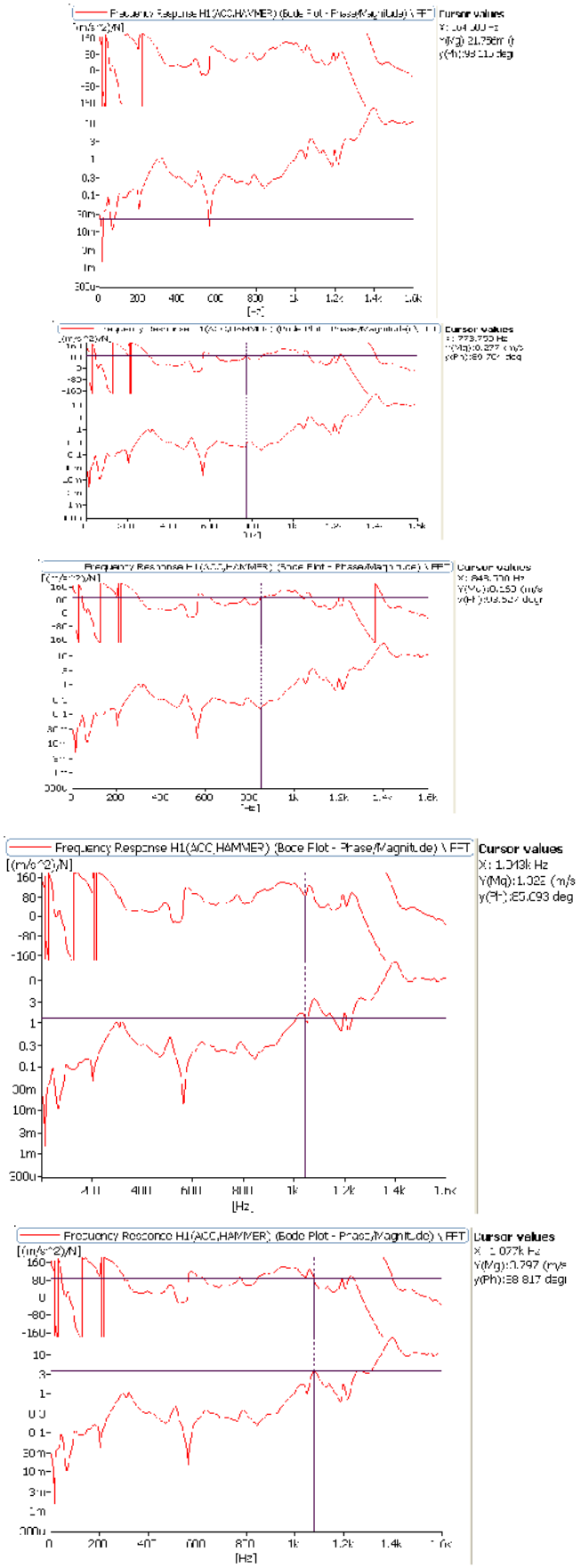


Fig 4. Frequency response showing different mode.

VII. RESULT

The following table shows the comparison for the first six natural frequencies of vibration of silencer by FEM package and FFT analyzer. The comparison shows that the natural frequency by both method is nearly same.

Table 3 : Six modal frequency of vibration.

Sr. No.	*Freq. by FEM in Hz*	*Freq. by FFT in Hz*
1	90.508	97.25
2	570.81	564.500
3	892.01	773.75
4	892.22	848.500
5	1036.3	1039
6	1037.3	1077

VIII. CONCLUSION

The silencer natural frequencies have been calculated by using the ANSYS package and by FFT analyzer. By both the method the natural frequencies are nearly same and that are useful while the design of silencer to avoid the resonance. Though the dynamic performance can be increased by increasing the thickness of different part. Furthermore is to add the support for partition, increase the support etc.

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