

Experimental Study of a Exhaust Pipe Using FEM and FFT Analyzer

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ABSTRACT: While designing a new automobile exhaust pipe is to lengthen its 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. Therefore it is necessary to analyze the vibration modes and the response of vibrations. For this purpose, two methods are used, analysis using FEM package and analysis by FFT analyzer.

KEYWORDS:-FEM, Modal analysis, tail pipe, natural frequency, FFT analyzer.

I. INTRODUCTION

The purpose of the exhaust system is simple: to channel the fiercely hot products of fuel combustion away from the engine or generator and the car's occupants out into the atmosphere. The exhaust system has a secondary purpose- to reduce the amount of noise made. The exhaust gases leave the engine at incredibly high speeds. Moreover, with the opening and shutting of the exhaust valves with each cycle of combustion for each cylinder, the gas pressure alternates from high to low causing a vibration. 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.

II. MODAL ANALYSIS

In order to study the structure, modal analysis is used. It gives the natural frequency of the structure to be studied by which we can study the change in behavior of a structure from one phase to other depending upon the application. In this paper, modal analysis is used simply to find the natural frequencies at different modes of bent pipe. 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.[1]

A. Methodology of Finite Element Analysis of Silencer:

- ❖ Material properties were determined and defined with the help of material used.
- ❖ The geometry was created for silencer.
- ❖ Fine and smooth meshing was carried out on the model.
- ❖ The meshed model was solved with constraints and boundary conditions.
- ❖ The results were observed during post-processing.
- ❖ Interpretation over the results for conclusions was done.[2]

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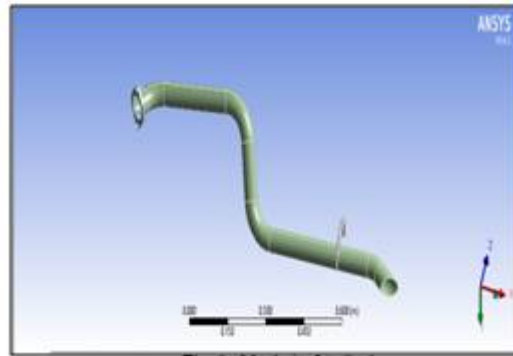


Fig.1. Model of tail pipe

After generating the model of silencer then analysis is done by ANSYS. The material used is steel having density 7850 Kg/m^3 . Further the analysis was done by considering the pipe a cantilever beam. The results obtained by modal analysis for different modes are determined and tabulated as follow:

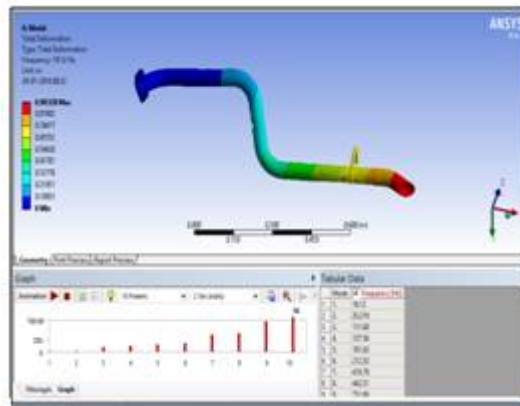


Fig.2. Modal Analysis of tail pipe in ANSYS

Mode No.	1	2	3	4	5
Natural Freq.(Hz)	19.1	20.2	111.6	137.5	181.6

Table 1. Frequency of first five Modes

III. EXPERIMENTAL ANALYSIS

A. FFT Spectrum Analyzer:

The FFT or Fast Fourier Transform spectrum analyzer uses digital signal processing techniques to analyze a waveform with Fourier transforms to provide in depth analysis of signal waveform spectra. It uses digital signal processing techniques to provide in depth waveform analysis with greater flexibility than other methods. The input signal is digitized at a high sampling rate, similar to a digitizing oscilloscope. Nyquist's theorem says that as long as the sampling rate is greater than twice the highest frequency component of the signal, then the sampled data will accurately represent the input signal. In this analyzer, sampling occurs at 256 kHz. [5]

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Figure 3 FFT Analyzer

B. Specifications of the Pipe:

Test Method : IS 1608:2005/ASTM E415:2014/IS 8811:1998.

Material : Steel pipe.

Dimensions : 50.8 X 1.2mm

C. Experimental Setup:

A typical measurement setup for experimental modal analysis consists of three parts. The first part is responsible for generating the excitation force and applying it to the test structure, the second part is to measure and acquire the response data and the third part provides the signal processing capacity to derive FRF data from the measured force and response data. For experimental modal analysis of silencer impact hammer is used for giving excitation to the silencer. An accelerometer used has a magnetic base and is located at the end of the silencer. The FFT spectrum analyzer is used to analyze the data.

With the use of the above equipments experimental test setup is prepared. The impact is given at the end of silencer by using impact hammer. Analyzer receives analog voltage signals from the accelerometer. The analyzed signals used to find natural frequencies and mode shapes in graphical form with the use of software installed in the computer. The graph of acceleration verses frequency for impact test is shown in figure.

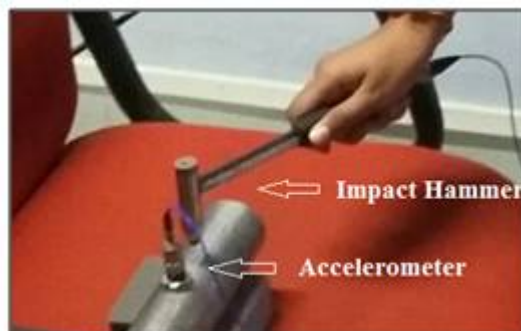


Fig. 5. Impact hammer and accelerometer

A sample of pipe of 1800mm length having diameter and bends is taken whose natural frequency is to be determined. Because of bending, the wall thickness of the pipe is reduced. This pipe was placed on well cushioned surface to avoid unwanted vibration from the surface. Initially, the pipe was marked after every 100mm to check natural frequency of the pipe throughout the length. Then using FFT analyzer, the sensor was placed at each marking and readings were obtained for different sections (markings) of pipe.

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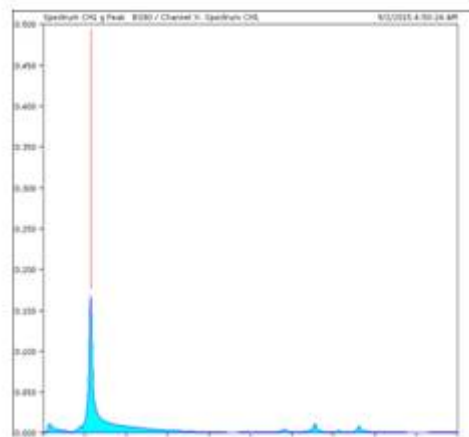


Fig. 6. Frequency response at mode no. 3

Mode No.	1	2	3	4	5
Natural Freq.(Hz)	19.7	21	115	141	187

Table 2. Frequency of first five Modes using FFT Analyzer

IV. RESULT

From the following table, for the first five natural frequencies of vibration of silencer by FEM package and FFT analyzer, natural frequency by both methods is nearly same.

Mode No.	Frequency By FEM	Frequency By FFT	%error
1	19.12 Hz	19.7	2.95
2	20.2 Hz	21	3.8
3	111.6 Hz	115	2.9
4	137.5 Hz	141	3.8
5	181.6 Hz	187	2.88

Table 3. Comparison of Frequency of first five Modes using FEM and FFT Analyzer

V. 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 in the design of silencer to avoid resonance. By using experimental method, we get the actual natural frequency of the silencer.

With the validation of both the methods we can conclude that, the natural frequency is nearly same due to some assumptions in the Numerical method.

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