# Design and Development of Automobile Silencer for Effective Vibration Control

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**Abstract - A Silencer is a part of the exhaust system of an automobile that plays a vital role. It needs to have modes that are located away from the frequencies that the engine operates at, whether the engine be idling or running at the maximum amount of revolutions per second 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 fromnatural frequency and avoid resonating condition.**

**Keyword :Silencer; Modal analysis; Modes, Finite element method; FFT, resonance, Natural frequency**

## I. RELEVANCE

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 and 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- and hence sound.

Silencer has to muffle the vibrations of the exhaust gases, reduce their velocity and thus reduce the amount of noise emitted from the engines. The pulsating low from each cylinder's exhaust process of an automobile petrol or diesel engine sets up pressure waves in the exhaust system-the exhaust port and the manifold having average pressure levels higher than the atmospheric. This varies with the engine speed and load. At higher speeds and loads the exhaust manifold is at pressures substantially above atmospheric pressure. These pressure waves propagate at speed of the sound relative to the moving exhaust gas, which escapes with a high velocity producing an objectionable exhaust boom or noise. A suitably designed exhaust silencer or Silencer accomplishes the muffling of this exhaust noise.

## 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 upto @13.5HP. 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.

*Specifications of silencer:-*

1. Material used:- CRCA (Cold Rolled Close Annealed).
2. Thickness :- 2 mm
3. Weight: - Approx. 19.5 to 20 Kg.

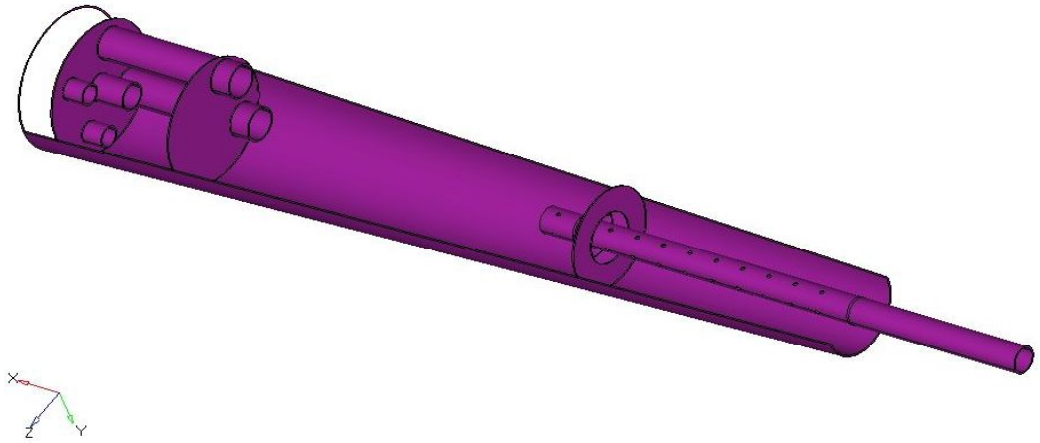


Fig 1. Internal construction of Automotive silencer

*Objective: -*

- Identify and study using software tools (for simulation/ analysis), the nature and characteristics of vibrations
- Evaluate the influence of the vibrations over the design of the silencer
- Review the existing design and consider improvement for negating the harmful influences of the phenomenon

## III. 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 & 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.

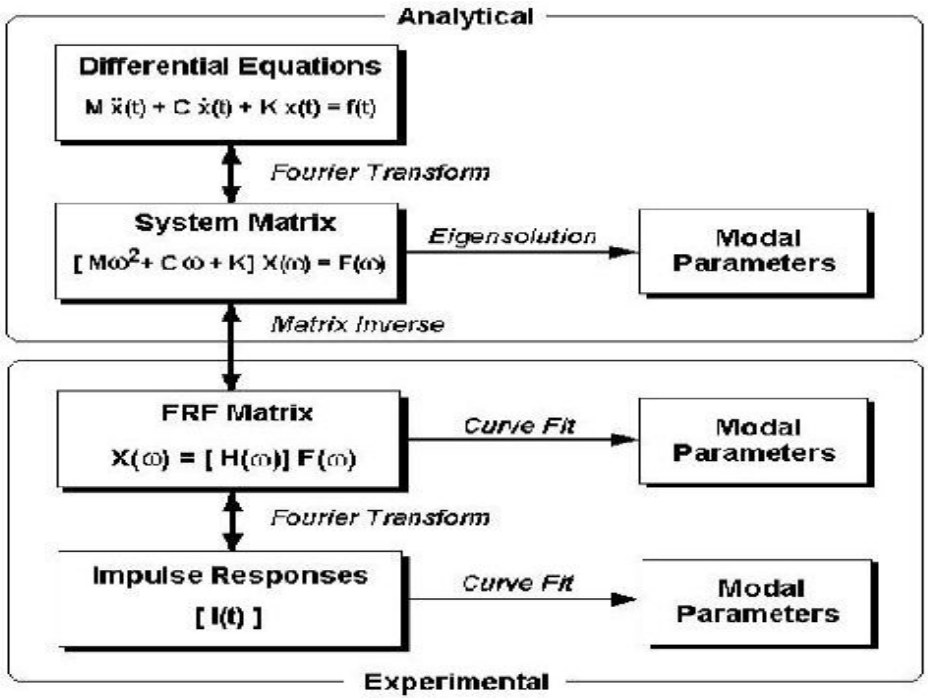



Fig 2. Analytical and Experimental method of frequency detection

## IV. APPROACHES, TECHNIQUES AND METHODOLOGY OF SOLVING PROBLEM

*1) Computational approach*

This presents a computational approach for the lifetime assessment of structures. One of the main features of the work is the search for simplicity and robustness in all steps of the modeling, in order to match the proposed method with industrial constraints. The proposed method is composed of mechanical finite element computation.

Methodology of FINITE ELEMENT ANALYSIS of Silencer

- Creation of Geometry for silencer.
- Importing the geometry for meshing.
- Solving for the meshed model with constraints and boundary conditions.
- Viewing the results during post-processing.
- Interpretation over the results.
- Recommendations.

As for the Design parameters influencing the phenomena, the geometry of the silencer would be modified and the effects would be noted. Typically, the following changes are being considered-

- Increasing mass and dampings on silencer
- Number of perforations and/or size of holes to be modified

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/m3 and the length of silencer is = 700 mm. The following Fig. shows the meshed model of silencer.

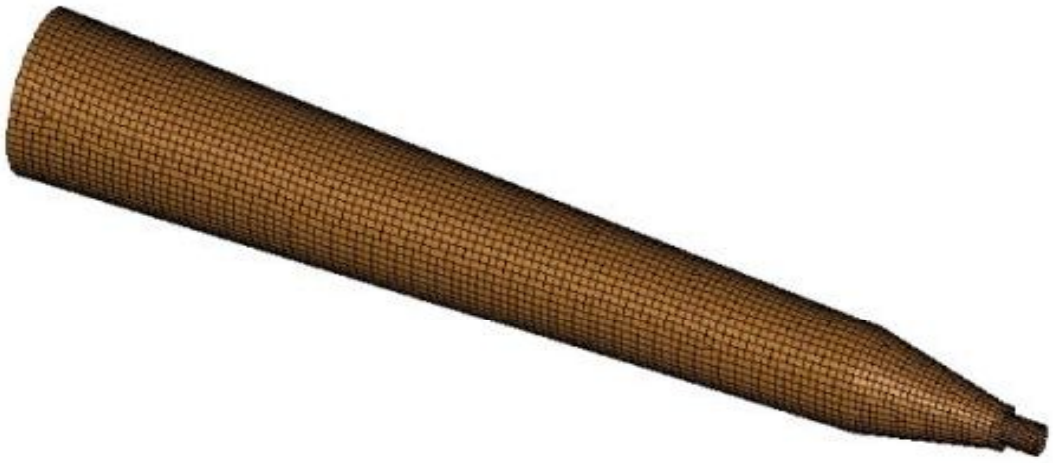
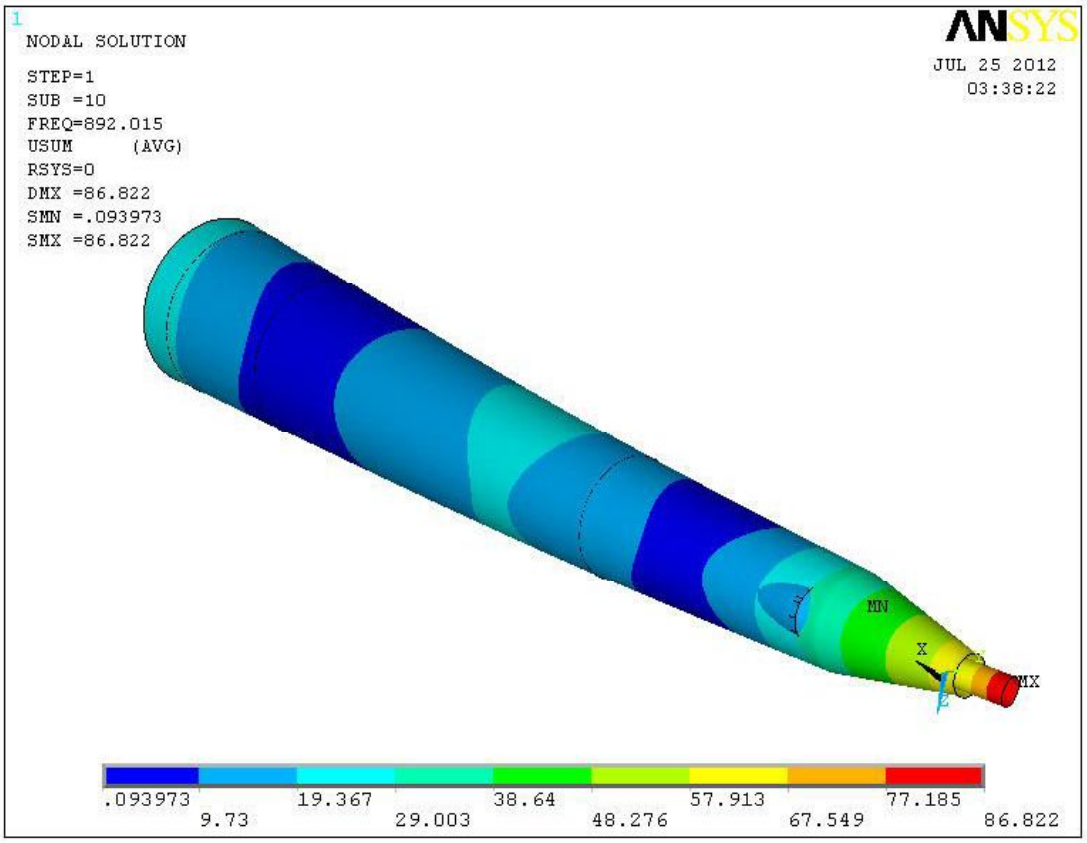


Fig3.Silencer Meshing.

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 follows

| 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 vvibration



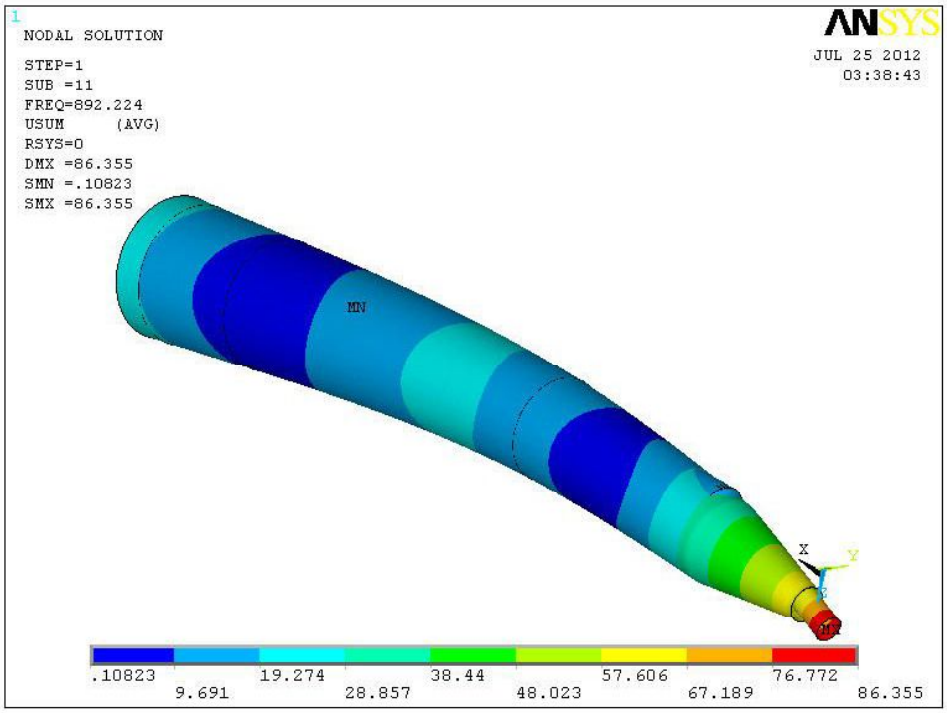
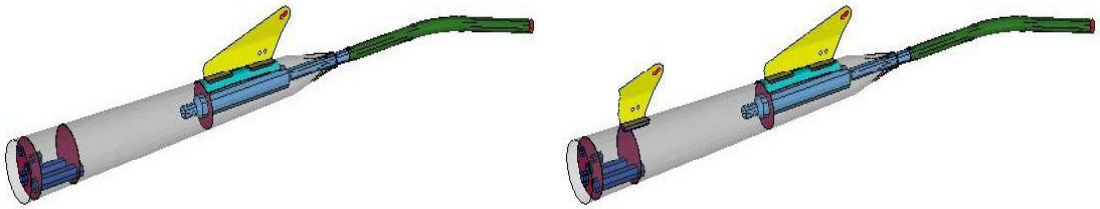




Fig.4 Different mode shape of silencer



Existing Modified

All degrees of freedom are constrained

Fig5.Increasing mass on silencer

| MODE NO. | Existing CYCLES | Modified CYCLES |
|---|---|---|
| 1.00 | 24.86102 | 58.43685 |
| 2.00 | 68.94444 | 163.7082 |
| 3.00 | 145.9364 | 247.435 |
| 4.00 | 210.095 | 378.1995 |
| 5.00 | 431.5399 | 480.3657 |
| 6.00 | 559.6359 | 607.3478 |
| 7.00 | 660.2426 | 740.456 |
| 8.00 | 742.6959 | 823.9265 |
| 9.00 | 938.5655 | 940.2526 |
| 10.00 | 998.2773 | 1007.161 |
| 11.00 | 1082.859 | 1084.075 |
| 12.00 | 1141.638 | 1142.664 |

## V. EXPERIMENTAL SET-UP AND MEASUREMENTS

*Experimental set up*

With the use of experimental set-up, the noise and vibrations of silencer is analyzed.
In lab the silencer would be tested to give results required. Of above approaches computational approach will give results more close to practical values through simulation/ analyses.
The use of software like ANSYS for analysis has a following objectives:

- Static analysis of silencer design for the same repeated cycles.
- Develop design alternatives and analysis of same using above tool.

With help of softwares like FFT Analyzer/Labview or other equivalent , the silencer can be tested for vibration and other related terms. The standard or reference data available for the past design/ validation as standards or reference or standards followed by automotive manufacturers normally proves to be very useful while considering experimentation. The trials are conducted in a very controlled environment with focus on the variables influencing the generation of vibration. A 1:1 working existing silencer would be deployed for the experimental work. Experimentation would be performed through physical tests over the full-scale working model. The validation would be carried out on two wheeler silencer of Hero Honda Splendor and obtained experimental results will be compared with software results.
Experiment would be performed on a `live' two-wheeler for the given model/ variant of the silencer. The Engine would be keptrunning on three levels -
Level1-Idling(1000~1500RPM)
Level2- 2000~3000RPM
Level3- 3500~4500RPM
The frequency reading would be recorded as displayed over the FFT analyzer connected to the head/ tail end of the silencer.

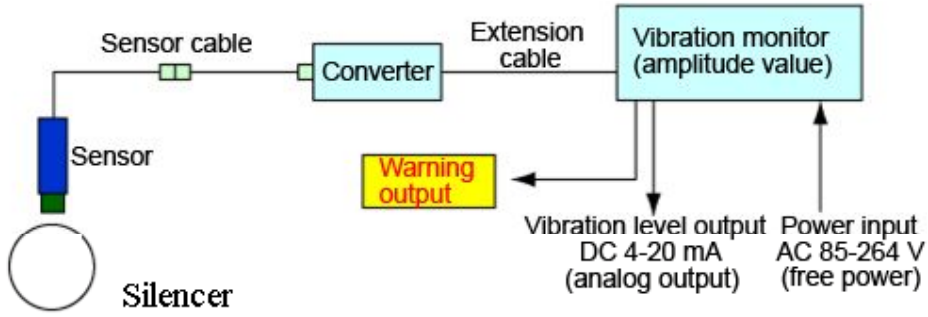



Fig 3: Experimental set up for Vibration Test

*5.1Vibration Measuring instrumentation:*

The FFT spectrum analyzer is an invaluable tool for mechanical engineers in today's world of measurement and analysis ofmechanical systems. FFT analyzers are an essential tool in such fields as vibration and shock data analysis, machinery monitoring and analysis of complex waveforms. Use of the FFTanalyzer is required in many industries, including military, transportation, aerospace, manufacturing and consumer products. Many mechanical engineers today make careers in the fields of vibration and machinery analysis; the knowledge ofprinciples and applications of the FFT analyzer is essential for these disciplines.

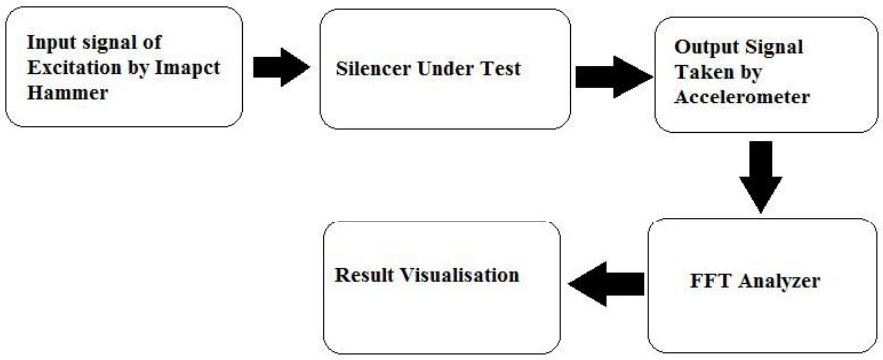




Fig 4: FFT Analyzer Experiment Schematic

## VI. VALIDATION

The validation of the silencer is done by physical prototype development. While the Silencer is made available in the physical form, the trials and testing would address the phase of validation. The correlation between the experimental and theoretical results will be analyzed and recommendations can be made for future scope of work.

Considering the use of softwares like FFT/ Lab view or equivalent towards the measurement of vibration. The values obtained by from the test bench would be evaluated for arriving at an appropriate design with a development of a full-scale working prototype which would be typically produced by modifying the existing component in the physical form (silencer). The same would be used for validation further. The FFT analysis or Vibration Test is carried out on existing two wheeler Automotive Silencer. Basedon the measurement obtained during test, the results will be adopted for modification of existing silencer.

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.
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| Mode Order | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Frequency (Hz) | 97.20 | 564.4 | 772.75 | 850.5 | 1040 | 1080 |

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

Frequency response function of the exhaust system is shown in Fig. 5 for different modes.

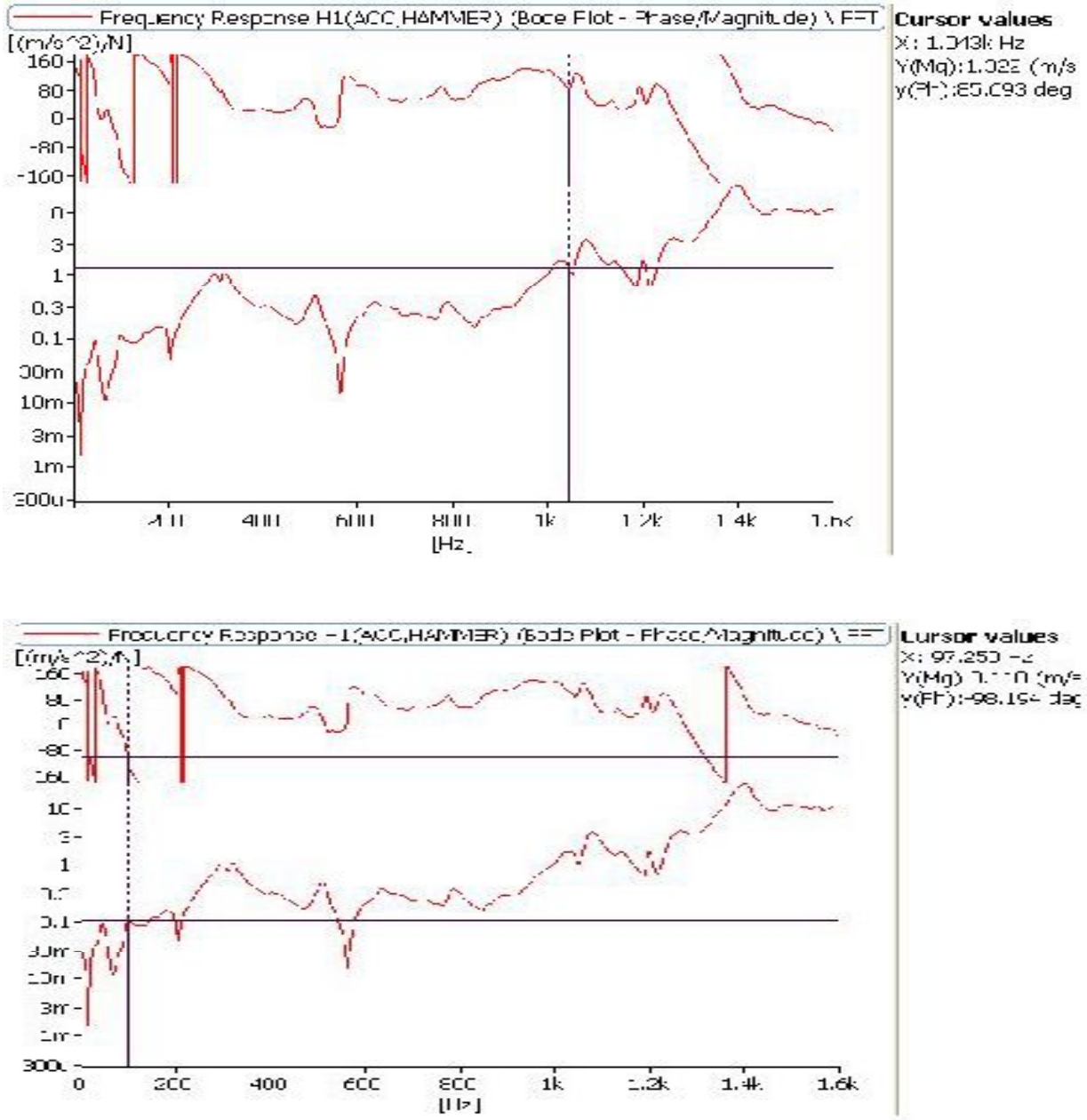


Fig.5 Frequency response function of the exhaust system at different modes

## VII. RESULT

The following table shows the comparison for the firstsix 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.

| ***Sr. No*** | ***Freq. by FEM in Hz*** | ***Freq. by FFT in Hz*** | ***Engine Idling speed*** |
|---|---|---|---|
| 1 | 90.58 | 97.20 | 1200 |
| 2 | 570.81 | 564.4 | 1200 |
| 3 | 892.01 | 772.75 | 2500 |
| 4 | 892.22 | 850.5 | 2500 |
| 5 | 1036.3 | 1040 | 4000 |
| 6 | 1037.3 | 1080 | 4000 |

## 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 mass of silencer.

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