Experimental Modal Analysis of Muffler of Hero Honda Splendor

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ABSTRACT

Automotive exhaust system primarily consists of exhaust system as its main component. Mufflers are used to reduce noise and pass exhaust generated in engine. Mufflers are cantilever structures which forms part of exhaust system. They are subjected to various structural, thermal and vibration loads. Various failures are seen in mufflers due to vibration from engine and road excitations. This vibration failure occurs due to resonant frequencies occurring in defined frequency range. Vertical accelerations are dominant in Mufflers due to road excitations. Design/ CAD modeling of existing muffler will be done using CATIA V5 software by reverse engineering. Meshing (Discretization) of model will be done using Ansys Package. Modal Analysis will be done to find out Natural Frequencies and Modes shapes of Muffler. Impact hammer test will be done to find out mode shapes and Natural frequencies using accelerometer and FFT setup. Existing design will be modified to reduce vertical vibrations by use of stiffener ribs.FEA and Experimental methods will be repeated as above. Comparative analysis will be done with FEA and Experimental results for validation purpose. Conclusion and Future scope will be suggested.

Keywords:- *Muffler,FEA Analysis, ANSYS, Cantilever Structure.*

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1. INTRODUCTION

Internal combustion engines are typically equipped with an exhaust muffler to suppress the acoustic pulse generated by the combustion process. A high intensity pressure wave generated by combustion in the engine cylinder propagates along the exhaust pipe and radiates from the exhaust pipe termination. The pulse repeats at the firing frequency of the engine which is defined by f= (engine rpm x number of cylinders)/120 for a four stroke engine. The frequency content of exhaust noise is dominated by a pulse at the firing frequency, but it also has a broadband component to its spectrum which extends to higher frequencies. Measurements of the exhaust pipe pressure pulse on a Continental O-200 engine show that the majority of the pulse energy lies in the frequency range of 0-600 Hz. Exhaust mufflers are designed to reduce sound levels at these frequencies. In general, sound waves propagating along a pipe can be attenuated using either a dissipative or a reactive muffler. A dissipative muffler uses sound absorbing material to take energy out of the acoustic motion in the wave, as it propagates through the muffler. Reactive silencers, which are commonly used in automotive applications, reflect the sound waves back towards the source and prevent sound from being transmitted along the pipe. Reactive silencer design is based either on the principle of a Helmholtz resonator or an expansion chamber, and requires the use of acoustic transmission line theory.

2. NEED FOR ANALYSIS

The automobile silencer under steady 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, vibration. While doing so it subjected to thermal, vibration and fatigue failures which cause cracks. So it is necessary to analyze the vibration which would further help to pursue future project to minimized crack, improving life and efficiency of silencer.

3. LITERATURE SURVEY

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.[1]

On the basic of vibration analysis of three materials SUS 436J1L have higher deformation then other two material SUS 409L, SUS 436LT and SUS 436LT is the minimum deformation so it is better option for silencer part for manufacturing due to higher life cycle. The value of frequency of materiel SUS 436J1L is the highest at last node of each part of exhaust muffler so it will create more noise so it is not more suitable to reduce the amount of noise emitted by vehicle. [2]

Main drawback of I.C. engines working is that it is a major source of noise pollution. That is why the reduction of exhaust noise generated from engine is in today's world an important issue. Attaching a muffler in the exhaust pipe is the good option for reducing noise. But muffler requires specific design and construction considering various noise parameters produced by the engine. Since early development of mufflers, the main objective of design was attenuation of sound in regular mufflers. This causes a great amount of back pressure at the exhaust port thus losing power, increasing fuel consumption and piston effort to exhale the gases out. For high performance engines the free flow exhaust is made in which the sound level is not important but zero or less back pressure is. There is no intermediate muffler type in between both these, so semi active muffler is an step between these two, in which it attenuates sound when engine is running at low rpm , and converts in free flow when engine at higher revs.[3]

Double expansion chamber gives better results as compared to single expansion chamber. Transmission loss of double expansion chamber is 42.48 which is more than requirement and satisfactory. Also Natural frequency of double expansion chamber is within range of 583.62 to 1001.1 Hz resulting in no resonance. By fixing the muffler at first and double expansion chamber we can increase the frequency and avoid the resonance. Transmission loss of the muffler can be increased by adding protrusion pipe at inlet and outlet. It can be seen that the finite element modal analysis has certain significance in the study of vibration characteristics of the muffler. The time required for optimization of muffler using ANSYS and MATLAB is very short and can be repeated simply after changing the input parameters which provides an easy way to find an optimum solution for muffler design.[4]

4. METHODOLOGY

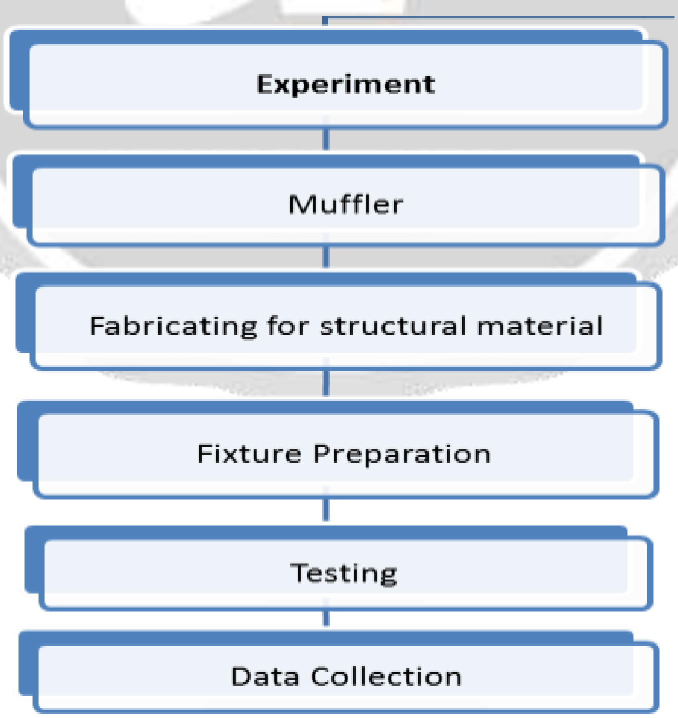

Fig.1 Flowchart of Experimental Methodology

5. EXPERIMENTAL ANALYSIS OF MUFFLER

5.1 Fast Fourier Transform

FFTs were first discussed by Cooley and Tukey (1965), although Gauss had actually described the critical factorization step as early as 1805 (Bergland 1969, Strang 1993). A discrete Fourier transform can be computed using an FFT by means of the Danielson-Lanczos lemma if the number of points N is a power of two. If the number of points N is not a power of two, a transform can be performed on sets of points corresponding to the prime factors of N which is slightly degraded in speed. An efficient real Fourier transform algorithm or a fast Hartley transform (Bracewell 1999) gives a further increase in speed by approximately a factor of two. Base-4 and base-8 fast Fourier transforms use optimized code, and can be 20-30% faster than base-2 fast Fourier transforms. Prime factorization is slow when the factors are large, but discrete Fourier transforms can be made fast for $N = 2$, 3, 4, 5, 7, 8, 11, 13, and 16 using the Winograd transform algorithm.

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.

5.2 Impact Hammer Test

Impact excitation is one of the most common methods used for experimental modal testing. Hammer impacts produce a broad banded excitation signal ideal for modal testing with a minimal amount of equipment and set up. Furthermore, it is versatile, mobile and produces reliable results. Although it has limitations with respect to precise positioning and force level control, overall its advantages greatly outweigh its disadvantages making it extremely attractive and effective for many modal testing situations.

The use of impulse testing with FFT signal processing methods presents data acquisition conditions which must be considered to ensure that accurate spectral functions are estimated. Problems stem from the availability of only a finite duration sample of the input and output signals. When a structure is lightly damped the response to the hammer impact may be sufficiently long that it is impractical to capture the entire signal. The truncation effect manifests itself in terms of a spectral bias error having the potential to adversely affect the estimated spectra. The signal truncation problem is further compounded in practice by the computational and hardware constraints of the FFT processing equipment. Typically the equipment has a limited number of data capture lengths or frequency ranges which are available for an operator to select. Normally a user is more concerned with useable analysis frequencies and less with the data capture length. Therefore, it is conceivable that an inappropriate data capture duration could be used which truncates the vibration signal and introduces errors in the estimated spectra. To suppress the truncation a common practice is to artificially force: it to decay within the data capture window [1,2,3]. This artificial reduction is obtained by multiplying the slowly decaying vibration signal by an exponential function. However, the application of the exponential window must be considered carefully since it may also adversely affect the estimated spectra.

7. EXPERIMENTAL TESTING

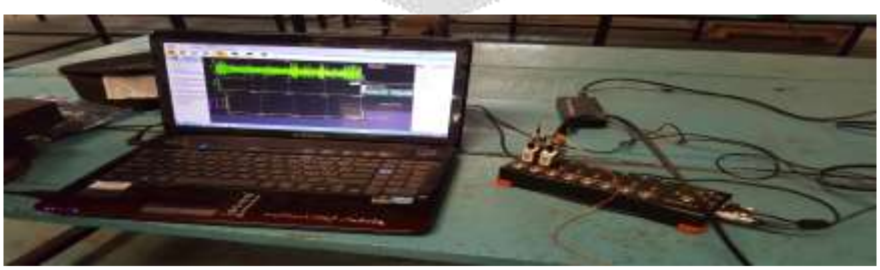

Fig 2 FFT Setup

Fig 3 Impact Hammer

Fig 4 Modified Muffler with Stiffener

8. RESULTS AND DISCUSSION

8.1 Mode Shape Results Obtained from Testing:

- Mode Shapes of Muffler

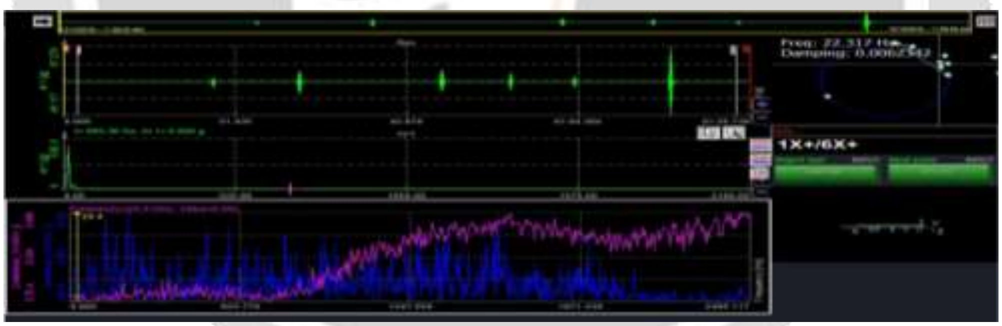

Fig 5 Mode no 1 of Muffler is 22.317 Hz

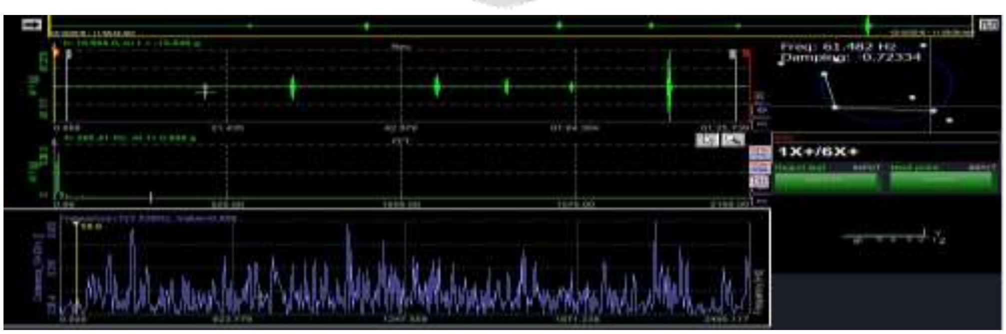

Fig 6 Mode no 2 of Muffler is 61.482 Hz

- Mode Shapes of Muffler with stiffener

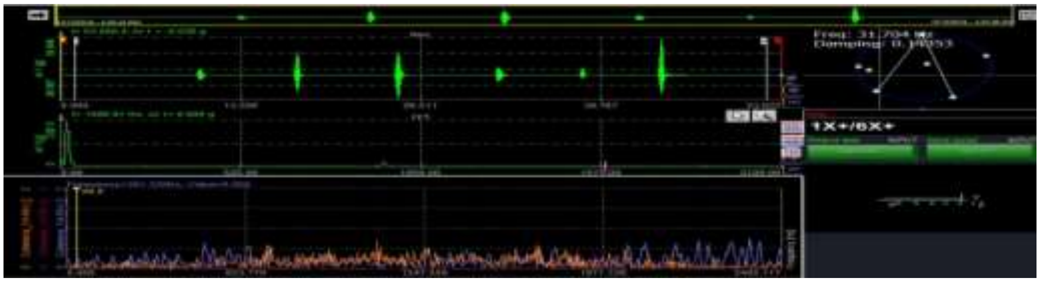

Fig 7 Mode no 1 of Muffler with stiffener is 31.704 Hz

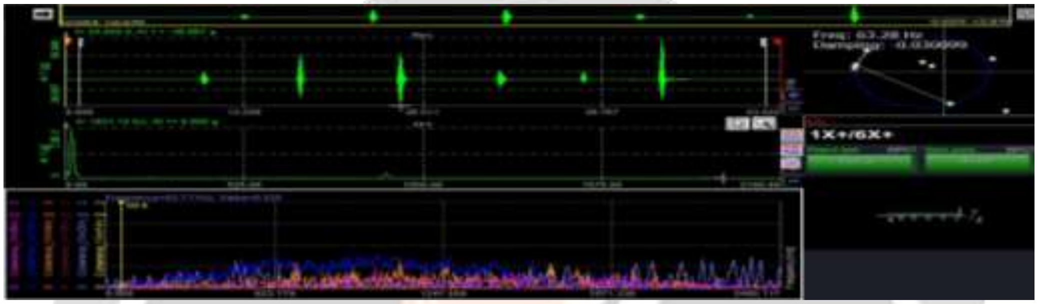

Fig 8 Mode no 2 of Muffler with stiffener is 63.28 Hz

8.2 Comparison between FEA and Testing Results

- **Existing Muffler**

Fig 9 Comparison between FEA and Testing Results of Muffler

- **Muffler With Stiffener**

Fig 10 Comparison between FEA and Testing Results of Muffler with Stiffener

9. CONCULSION

1. By Comparing first five natural frequencies of vibration of exhaust muffler by FEA package and FFT analyzer. The natural frequencies obtained from both the methods are agreeing with each other.

2. Harmonic Analysis was done for both models using FEA. Vertical vibration of base model is reduced by adding stiffener in second model.

3. Vertical vibration at 2nd mode i.e., vertical mode (dominant) reduced from 680.28 m/sec^2 to 67.866 m/sec^2 by adding stiffeners.

4. Durability of stiffened model is more than, that of base model.

10. FUTURE SCOPE

We can change the material of the Muffler. Also we cn perform CFD analysis, Thermal Analysis for the same.

12. ACKNOWLEDGMENT

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13. REFERENCES

[1]. Vinay Gupta, Dhananjay Kr. Singh, Dhirendra kr. Singh, Madan Mohan Mishra, Satish Kumar Dwivedi, Ajay Yadav, “Vibrational analysis of exhaust muffler”.
[2]. Potente, Daniel, “Vibrational analysis of exhaust muffler”.
[3]. V.P. Patekarand R.B. Patil, “Vibrational Analysis of Automotive Exhaust Silencer Based on FEM and FFT Analyzer”
[4]. Rahul d. Nazirkar, s.r.meshram, amol d. Namdas, suraj u. Navagire,sumit s. Devarshi, “Design & optimization of exhaust muffler & design validation”
[5]. M.P.Tambe 1, SaifaliSanadi 2, ChaitanyaGongale 3, SurajPatil 4, SurajkumarNikam“Analysis of Exhaust System- ‘Semi ActiveMuffler”
[6]. Amanda Frederick, Sarah Brady "Design project on vibration analysis on automobile muffler" April 23, 2003, EGR 315, Mechanical Vibrations, Dr.Amit Shukla, pp.1-15
[7]. Shi Ying Wang Liang ," The muffler suspension parts forepart fatigue damage problem study and improvement design, 2nd international Conference on Education

BIOGRAPHIES

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