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Performance evaluation of reactive Silencer

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ABSTRACT

This paper explores the performance of reactive silencer. Noise pollution created by engines becomes a vital concern used in residential areas or area where noise creates a danger. Issues concerning the design and use of large-scale silencers are more prevalent today than ever before. The main sources of noise in an engine are the exhaust noise and the noise produced due to friction of various parts of the engine. Vibration of the engine that affects on the exhaust system and road vibration transferred to the silencer through the vehicle body was measured and analyzed. The dynamics of the exhaust system, which may creates a noise in the passenger compartment using a vibration measurement device and the changes depending on engine rotation speeds, were verified. There are a number of methods currently used to model and investigates the acoustic performance (TL) of mufflers including analytical methods such as the TMM ,computational methods including the use of FEM & BEM & experimental measurement techniques. The use of finite element method (FEM) & the boundary element method (BEM) can aid in the prediction & design. The exhaust pipe is subjected to several stresses most of which are due to vibration Stainless steel is used for variety of automobile components by virtue of its good corrosion resistance and heat resistance. Now a day's SUH 409L, SUS 436J1L, SUS 436L are mainly used as materiel for silencer whose corrosion resistance and thermal resistance is good. The resonance of the muffler was obtained from a frequency response function (FRF) after sine sweep excitation, followed by silencer vibration measurements using the direct body excitation method under simulated road conditions and mode shape analysis for each condition. Through these results, the effects of the vibrations transferred from the road and those created by the engine was verified. The function of silencer is to reducing the noise level to acceptable standards per the norms of regulations towards compliance. From the exhaust system the exhaust gases at a high velocity that tends to undermine the structural strength of the various elements of the silencer. The perforated pipes, body, baffles and the mounting parts tend to vibrate as the excitation frequency of the source (engine). The 'frequency match' could lead to a response detrimental to the life of the structure. *Finite element analysis* (FEA) techniques are used in this work to avoid resonance. Physical experimentation is done by using *fast Fourier transform (FFT)* Analyzer.

***Keywords*— Vibration, Back pressure, Transmission loss, Exhaust manifold, Direct body excitation, Muffler, FFT analysis**

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I INTRODUCTION

A vehicle exhaust system emits exhaust gas generated from a vehicle engine. It also reduces noise generated by the combustion of fuel in the engine. It is installed at the bottom part of a vehicle and consists of pipes extending from the muffler to the outlet. Such a structure is not advantageous in terms of vibration prevention. Its structure should be designed in line with the vehicle bottom layout, which poses challenges when its design needs to be changed. The two major influencing factors for exhaust system vibration are the vibrations transferred from the engine and road excitation. For example, the vibration caused by road irregularities is transferred to the exhaust system through its mounting points. Such vibrations have adverse effects on the ride comfort and the noise generated by buzz, squeak, and rattle (BSR) perceived in the passenger compartment [1].

One of the objectives when 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. 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 [4]. Vibration of the vehicle exhaust system can be reduced by designing the exhaust system resonance frequency to be different from the natural frequencies of other vehicle parts. Another method is reducing the input excitation transferred from the engine by installing bellows or changing the positions of components.

Moreover, the relationship between the frequencies of muffler resonance and cylinder firing, a vibration caused by combustion in a four-stroke engine, is the most important part of an exhaust system design. Such resonance frequencies can be measured using sine sweep excitation or an impact hammering test [1].

The method of direct body excitation, unlike the conventional method for exerting excitation to the wheels was chosen. This method has the advantages of reducing the effects of the suspension system and simplifying the vibration model, thus facilitating the analyses of the behaviors of vehicle parts. The vibration characteristics of a muffler installed in a vehicle using direct body excitation were identified and the effects of the vibration of the muffler tip on the exhaust system using mode shape changes were analyzed [1].

The durability of that part of the system is therefore crucial customer demands for the comfort and long product kind guarantee also for the exhaust system as a whole are additional reasons for the increasing importance for design engineers to be able to predict ,describe and access the dynamics of various system design proposals during product develop[3].

II.PROBLEM STATEMENT

• Investigation of acoustic behavior of reactive silencer.
• Investigation of the effect of backpressure on the engine due to the perforated pipe and baffles in the silencer.
• To find out transmission loss.
• To reduce noise and vibration of reactive silencer.

III.OBJECTIVES

• Determine using FRA (Frequency Response Analysis) the behavior of the existing design.
• Identify the potential levels (modes) that can cause resonance
• Suggest modifications for harmonious alignment with the FRA results.
• Implement change and perform experimentation.
• Compare results with FEA for finalizing proposal.

IV.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.

V.METHODOLOGY

A .Mathematical/ Numerical approach

This is global approach, based on the loading definition, the modeling of the constitutive law and of the damage and a failure criterion. This approach is applied on cylinder heads and on exhaust manifolds submitted to transient thermal loading and permits to predict the cracked area as well as the lifetime. [3]

B. Computational/Analytical 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 a fluid flow, a thermal and a mechanical finite element computation, as well as a final fatigue analysis. The CAE software has intuitive graphical interface with direct access to CAD geometry, advanced meshing, integration with other compatible software for solving. It is optimized for large scale systems, assemblies, dynamics and NVH simulations. It has graphical interface with direct access to CAD geometry, most suitable for fatigue analysis. [3]

C. Experimental set up (Physical Testing)

With the use of experimental set-up we can analyze the fatigue and vibrations for silencer. In lab 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 technique would deploy any of the following software tools: Abacus, Pat ran/ Nast ran, ANSYS, MSC fatigue or any compatible CAE software.

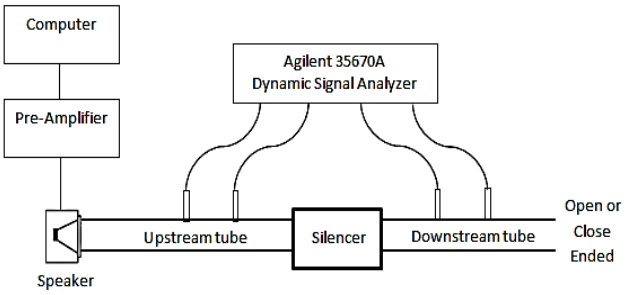

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fig.1. Experimental test setup

VI.STEPS FOR ANALYTICAL METHODOLOGY

3D model for the silencer shall be taken as an input for Finite Element Analysis (FEA). The model is discredited using pre-processor, preferably Hyper Mesh, using suitable element type and size. Modal analysis will be done for existing model on the basis of modal analysis, we can suggest weight optimization if natural frequencies are higher than the engine frequencies which is basically considered up to ~70 Hz followed by Frequency response analysis. If natural frequencies are not within the acceptable limit then we have to shift the natural frequencies out of concerned zone by suggesting some modifications (Change in geometry or mass or boundary conditions) and then frequency response analysis will be done at first resonance frequency to check the stress levels, stress criterion should also satisfy. The Fast Fourier Transform (FFT) is a development of the DFT which removes duplicated terms in the mathematical algorithm to reduce the number of mathematical operations performed. In this way, it is possible to use large numbers of samples without compromising the speed of the transformation. [3]

VII.EXPERIMENTATION AND VALIDATION USING FFT ANALYZER:

An FFT spectrum analyzer works in an entirely different way. The input signal is digitized at a high sampling rate, similar to a digitizing oscilloscope. The resulting digital time record is then mathematically transformed into a frequency spectrum using an algorithm known as the Fast Fourier Transform or FFT. The FFT is simply a clever set of operations which implements Fourier's basic theorem. The resulting spectrum shows the frequency components of the input signal. The advantage of this technique is its speed. The entire spectrum takes only 4 ms to measure.[3] The FFT spectrum analyzer samples the input signal, computes the magnitude of its Sine and cosine components, and display 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. [4]

VIII.FINITE ELEMENT MODELING OF SILENCER

The model in IGES format is imported in the hyper-mesh and meshing is done. The CGC discharge silencer has a single inlet duct and two outlet ducts as shown in Fig 1. The radial outlet duct is in closed position. The discharge silencer is divided into inlet and outlet chamber with the help of partition plate. The inlet and outlet chamber is connected with the help of transfer tubes. The basic idea behind a finite element method or finite element analysis is a building of complicated object with simple blocks or dividing complicated object into small and manageable pieces. [2]

Fig.2. Modeling and Meshing of Silencer ---An Example

Finite element analysis has a great power, but when the analyst using this and similar methods the disadvantages of computer solutions must require to be kept in mind. The computer solutions do not know how the materials properties and geometrical features influence the stresses. Errors in input data by the analyst can produce wildly incorrect results. The meshed model of CGC discharge silencer is shown in the Fig 1. [2].Two types of analysis were carried out for the discharge silencer to see the behavior of the structure under loading condition.

a) Modal analysis

b) Transient analysis.

In order to perform any type of analysis the boundary conditions plays important role. The inaccurate modeling of the loads and restraints on a model is one of the most significant sources of errors in FE modeling. So giving accurate boundary conditions is very much important in any type of analysis. [2]

IX.CONCLUSION

The purpose of analysis was to verify the vibrations experienced in each design were a result of fluid flow inside the silencer. When modal results of the design matched with experimental results in an attempt to correlate the analytical results with experimentally obtained results. Some of the modal frequencies were matching with fluid intake frequency. Hence it was concluded that the vibrations were essentially result of fluid structure interaction. Transient response analysis of this design was carried out and have fair amount of correlation with experimental results.

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. The dynamic performance can increase by increase in the thickness of different part. Furthermore is to add the support for partition, increase the support etc.

In the present study, the changes in vibration depending on road and engine excitations were verified, which are likely to be influenced by a muffler mounted on a vehicle body. Additionally, the effects of actual vibrations on the muffler and body were analyzed.

The silencer natural frequencies have been calculated by using the FEM package and by FFT analyzer. The natural frequencies hence found are nearly same by using both the

methods. This data is valuable for designing of silencer & to avoid the condition of resonance. The dynamic performance can be increased by increasing the thickness of different part or changing the material type or by changing the stiffness. Furthermore is to add the support for partition, increase the support etc.

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