"ANALYZING MUFFLER PERFORMANCE USING THE TRANSFER MATRIX METHOD"

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Abstract—*Most recently, automotive engineers have been experimenting with electronic noise suppression muffler. A sound pressure wave, 180o out of phase, is generated by an electronic device to cancel out a similar sound wave generated by the engine. It is an effective way of cancelling noise without restricting the flow. Unfortunately, it is too costly and currently impractical for most of today's engines. However, out of phase sound wave cancellation is the best technology so far to control engine noise. Now-a-days, this 180o phase sound is created within the engine muffler by reflecting the out-going sound waves. This reflected sound is used to attenuate the main noise. This procedure is called reflective noise cancellation system. Using a resonator sometimes does this.*

Keywords— Automotive; Muffler; Analyzing; Transfer; Matrix etc.,

1. INTRODUCTION

Internal combustion engine is a major source of noise pollution. These engines are used for various purposes such as, in power plants, automobiles, locomotives, and in various manufacturing machineries. Noise pollution created by engines becomes a vital concern when used in residential areas or areas where noise creates hazard. Generally, noise level of more than 80 dB is injurious for human being. 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. The exhaust noise is the most dominant. To reduce this noise, various kinds of mufflers are usually used. The level of exhaust noise Reduction depends upon the construction and the working procedure of mufflers. Engine makers have been making mufflers for more than 100 years. As the name implies, the primary purpose of the muffler is to reduce or muffle the noise emitted by the internal combustion engine. Muffler technology has not changed very much over the past 100 years. The exhaust is passed through a series of chambers in reactive type mufflers or straight through a perforated pipe wrapped with sound deadening material in an absorptive type muffler. Both types have strengths and weaknesses. The reactive type muffler is usually restrictive and prevents even the good engine sounds from coming through, but does a good job of reducing noise. On the other hand, most absorptive type mufflers are less restrictive, but allow too much engine noise to come through. Regardless of the packing material, absorptive type mufflers tend to get noisier with age. (19). Most recently, automotive engineers have been experimenting with electronic noise suppression muffler. A sound pressure wave, 180o out of phase, is generated by an electronic device to cancel out a similar sound wave generated by the engine. It is an effective way of cancelling noise without restricting the flow. Unfortunately, it is too costly and currently impractical for most of today's engines. However, out of phase sound wave cancellation is the best technology so far to control engine noise. Now-a-days, this 180o phase sound is created within the engine muffler by reflecting the out-going sound waves. This reflected

2. LITERATURE REVIEW

A number of researchers have worked on design, analysis and experimental investigations of mufflers since the I.C. engine came into existence.Masson et al. [7], worked on optimize the acoustic performance of low cost, simple geometry mufflers by using micro-perforated panels (MPP) in their expansion chambers. The Transmission Loss (TL) given by a computational model is compared with laboratory measurements, both for the mufflers containing the micro-perforated panels and without them. The optimization calculation is based on the easy computing transfer matrix approach. Then, they used the Boundary Element Method (BEM) in order to compare the evaluation of the TL. Different configurations have been tested to detect the real effect of resonator absorbers based on micro-perforated panels in the expansion chambers. It is shown that their presence increases the TL at certain frequencies if their parameters are well chosen, but their dissipative effect is negligible when occurs at a reactive effect resonance.

The acoustic behaviour of perforated dissipative circular mufflers with empty extended inlet/outlet is investigated in detail by means of a two-dimensional (2D) axisymmetrical analytical approach that matches the acoustic pressure and velocity across the geometrical discontinuities, and the finite element method(FEM) presented by Denia et al. [6]. The complex characteristic impedance, wave number, and perforation impedance are taken into account to evaluate the axial wave number in the fibrous material and the central perforated pipe. Two different analytical procedures are presented that allow the computation of the modal wave coefficients for the muffler sections. Benchmarking against FE calculations exhibited an excellent agreement. Both approaches are also compared with experimental work for further validation.

3. RESEARCH METHODOLOGY

Mufflers play an important role in reducing the exhaust and intake system noise and as a result, a lot of research is done to designing these systems effectively. The traditional "build & test" procedure, which is time consuming and expensive, can nowadays, be assisted by numerical simulation models, which are able to predict the performance of several different muffling systems in a short time. A number of numerical codes have been developed in the past few decades, based on distinct assumptions.

Considering only one-dimensional models, the two types of simulation models may be distinguished as

I. Linear Acoustic models: This is based on the hypothesis of small pressure perturbations within the ducts, and

II.Non-linear gas dynamics models: This describes the propagation of finite amplitude wave motion in the ducts.

Linear acoustic models are frequency domain techniques, which for instance use the four-pole transfer matrix method to calculate the transmission loss of mufflers. This approach is very fast but the predicted results may be unreliable because the propagating pressure perturbations generally have finite amplitude in an exhaust system. On the other hand, non-linear gas dynamic models are able to simulate the full wave motion in the whole engine intake and exhaust system and are based on time domain techniques. This simulation follow the gas flow from valves to open terminations and so is suited to deal with finite amplitude wave propagation in high velocity unsteady flows. The excitation source can be modelled by means of appropriate boundary conditions for the flow in these simulations. The exhaust systems of internal combustion engines generate noise with a wide frequency range, including particularly strong low frequency components. In such applications, silencers can be designed to work at low frequencies by reactive acoustic elements such as Helmholtz or quarter wave resonators.

There are a number of methods currently used to model and investigate the performance of mufflers. They Include:

4. ANALYTICAL METHOD

Analytical methods are well suited for determining the acoustic response of different configurations of simple expansion chamber mufflers but not for mufflers with complex geometries.

Following empirical formula is used to find out the transmission loss of single chamber muffler.

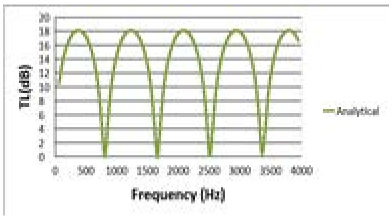
$$TL = 10\log_{10}\left[1+\frac{1}{4}\left[(M)-\left(\frac{1}{M}\right)\right]^2 \sin^2(KL)\right]$$

An expansion chamber has a predictable transmission loss curve having maxima at,

$$f = \frac{nc}{4L} \quad (4.2)$$

5. EXPERIMENTAL METHOD

Experimental method requires set-up of an experiment and manufacturing a prototype muffler. As shown in fig.4.3.1 and fig.4.3.2 two microphones were connected upstream while two were connected downstream. The Microphones are used to convert acoustic signal into electrical signal [12]. The microphone output is given to "Data Acquisition System" which processes it and gives it to computer. At downstream end of muffler, the noise signal is terminated anechoically so that no reflection of pressure wave takes place. The output of data acquisition system is given to computer, which gives Transmission loss for various frequencies.



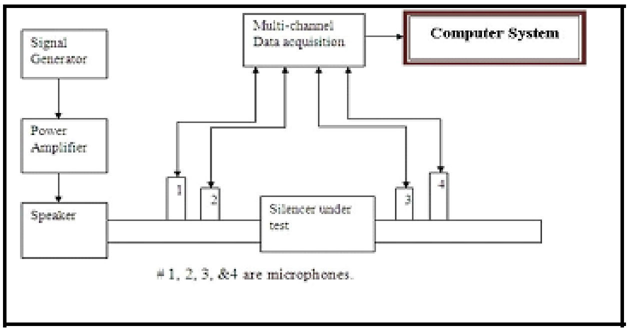


Fig. 4.3-1 Experimental Setup line diagram for Transmission Loss Evaluation

6. FEM COMPARED TO BEM

To be objective, the features of the BE methods should be compared to its main rival, the FE method. Its advantages and disadvantages can be summarized as follows.

7. ADVANTAGES OF THE BEM METHOD

1 Less data preparation time. This is a direct result of the 'surface-only' modelling (i.e. the reduction of dimensionality by one). Thus the analyst's time required for data preparation (and data checking) for a given problem should be greatly reduced. furthermore, subsequent changes in meshes are made easier. This advantage is particularly important in problem where re-meshing is required, such as preliminary design studies, crack propagation and frictional contact problems…

2. High resolution of stresses. Stresses are accurate because no further approximation is imposed on the solution at interior points, i.e. solution is exact (and fully continuous) inside the domain. This makes the BE method very suitable for modelling problems of rapidly changing stress such as stress concentration, contact and fracture problems.

3. Less computer time and storage. For the same level of accuracy, the BE method uses a lesser number of nodes and elements (but a fully populated matrix). Since the level of approximation in the BE solution is confined to the surface, BE meshes should not be compared to FE meshes with the internal points removed. To achieve comparable accuracy in stress values. FE meshes would need more boundary divisions the equivalents BE meshes.

4. Less unwanted information. In most engineering problem, the 'worst 'situation (such as fracture, stress concentration problem and thermal shock) usually occur on the surface. In many design codes and engineering practices, the analyst is usually only concerned with what happens in the worst situation. thus modelling an entire

three-dimensional complex body with finite element and calculating stress at every nodal point is very inefficient because only a few of these value will be incorporated in the design analysis. Therefore, using boundary element is a much more efficient use of computing resources.furthrmore, since internal points in BE solution are option, the user can focus on a particular interior region rather than the whole interior.

5. Easily applicable to incompressible materials. The displacement based plane strain FE formulation fails when poison's ratio equal 0.5 exactly (i.e. the material is incompressible). The BE formulation, however handles these material without any difficulty. Therefore in problems involving rubber-like materials the BE method is much more suitable than the FE method.

8. LIMITATIONS OF FEM AND BEM GEOMETRICAL MODELLING

1. While building the CATIA model joints, screwing, welding, rivets are not considered.
2. In CATIA model, manufacturing variation in the geometry is not captured.

9. DISCRETIZATION

1. Due to small holes, it is not possible to capture the circular shape of hole.
2. Due to large variation in dimension, maintain the aspect ratio becomes difficult.

10. COMPUTATIONAL ANALYSIS

1. To maintain aspect and capture geometry element size (0.1 times λmin) needs to be small resulting into larger FE model. This required high computation power and time.
2. Due to student version of the software package, it could not take more than 25000 nodes while analysis.
3. To achieve better results it requires specific number of (10-14) elements per wavelength, but because of limitation of student version maintains this is difficult and results into lesser accuracy.
4. The limitations due to number of elements restrictions can be removed by reducing element size i.e. by building larger model. This will also ensure the correct representation of geometry.
5. It will require higher data storage space and computational time and power but will leads to better results.

11. RESULTS AND CONCLUSION

Based on work carried out in this project, it can be concluded that: w.

1.The acoustic performance in terms of TL of reactive simple expansion chamber with various lengths of expansion chamber and baffle investigated computationally. The computational (FEM and BEM) result shows good agreement with experimental published results.

2.It shows how the transfer matrix may be extracted using the complex wave amplitudes at two specific points on the inlet side and outlet side, while running only a single simulation at multiple frequencies.

3. The presence of a centered baffle leads to an acoustic attenuation that exhibits pairs of domes. The first dome of each pair is smaller in amplitude and frequency bandwidth than the second one. When the baffle hole diameter is reduced, the amplitude and frequency bandwidth of the second dome of each pair become larger for constant porosity and constant number of holes.

4. No frequency limitations, short setup time, and easy redesign are among the advantages of using 3D pressure acoustic simulation without making prototype model. The FEA has the particular advantage of being able to model any complicated shape to study the muffler performance and effect of higher order modes.

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