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Effect of Extended Inlet and Outlet Lengths on Transmission Loss of Double Expansion Chamber Reactive Muffler

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ABSTRACT:

Internal combustion engines are one of the major causes of noise emissions. As in different industrial equipment, locomotives, and vehicles, the engines have a wide application base. Exhaust noise and noise that is created due to friction of different parts share the extreme input to noise pollution. A muffler is a means used by the exhaust system to reduce noise. For the reduction of noise, it is placed alongside the exhaust pipe. The decrease in the exhaust noise level is controlled by muffler construction and operating techniques. Therefore, the muffler configuration plays an important role. In this research work, an effort has been made to study the effect of parameters like different lengths of Extended Outlet (EO) for constant lengths of Extended Inlet (EI) elements in both chambers of Double Expansion Chamber (DEC) reactive muffler with an external connecting tube on transmission loss. It is observed that, as the length of EO is increased from L/5 to L/3 keeping EI constant, the average transmission Loss for the models decreases. The acoustic performance of the muffler is assessed by using COMSOL Multi-Physics and experimental validation.

KEYWORDS:

Transmission loss; Double expansion chamber muffler; Numerical method; Experimental method

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1. Introduction

Engine exhaust noise pollution is a key concern for residential areas. For a normal human being, 80 dB noise is harmful. The mufflers of numerous types are used to reduce this noise. Many parameters, such as Insertion Loss (IL), Transmission Loss (TL), characterize the exhaust muffler. TL classifies the output of the muffler using the physical parameters defined. Theoretical, computational, and experimental approaches are the means of achieving the transmission loss. The combined algebra of analytical methods is complicated, so it is often impossible to solve such problems by this method [1-2]. The cost of the numerical process is lower than that of the experimental process. The full design method is available in the book by Munjal [1]. The results obtained by analytical and numerical methods are verified by experimental methods. The overall performance of the model can be analysed by using these methods [2].

2. Modelling and simulation

Finite element method is used for evaluation of muffler transmission loss. COMSOL Multi-physics software is used for the analysis. Fig. 1 shows the double expansion chamber model used for the analysis. In this model, the Extended Inlet (EI) is positioned in both chambers of muffler. The length of EI is taken as (L/2) of the chamber length. The length of Extended Outlet (EO) is varied. The lengths of inlet and outlet tubes (L) are 95 mm each and diameter is 44 mm. The length of expansion chambers 1 and 2 is 270mm. The length of external connecting tube is 110mm. Fig. 2 shows the muffler internal configuration and Fig. 3 shows meshed model. The EI length is set as constant to L/2. The EO lengths is varied to L/3, L/4 and L/5 respectively referred as model-1, model-2 and model-3 hereafter. COMSOL Multi-physics software is used for numerical analysis. In the analysis, muffler mean flow is neglected. Tetrahedral elements are used for meshing [5-6].

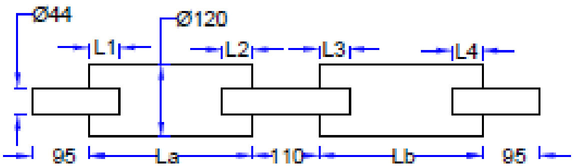

Fig. 1: Muffler model

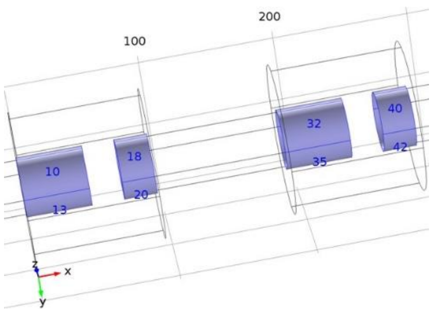

Fig. 2: Muffler internal configuration

$$D_{23} = \frac{B_{34}(H_{31a} - H_{31b}) - A_{12}(H_{32b} - H_{32a})}{B_{12}\Delta_{34}(H_{34b} - H_{34a})}$$

The four poles for elements 3-4 are deduced using,

$$\begin{bmatrix} A_{34} & B_{34} \\ C_{34} & D_{34} \end{bmatrix} = \begin{bmatrix} coskl_{34} & j\rho c\ sinkl_{34} \\ \frac{j\ sinkl_{34}}{\rho c} & coskl_{34} \end{bmatrix} \quad (8)$$

The transfer function between P_i & P_j is $H_{ij} = P_j / P_i$. The final transfer matrix is stated as follows,

$$\begin{pmatrix} A_{14} & B_{14} \\ C_{14} & D_{14} \end{pmatrix} = \begin{pmatrix} A_{12} & B_{12} \\ C_{12} & D_{12} \end{pmatrix} \begin{pmatrix} A_{23} & B_{23} \\ C_{23} & D_{23} \end{pmatrix} \begin{pmatrix} A_{34} & B_{34} \\ C_{34} & D_{34} \end{pmatrix} \quad (9)$$

The experimental TL is given by,

$$TL = 20\ log_{10}\left[\frac{1}{2}\left(\left|A_{14} + \frac{B_{14}}{\rho c} + \rho c C_{14} + D_{14}\right|\right)\right] \quad (10)$$

The range of frequency considered for the experiment is 1-2000 Hz. In order to obtain the H_{31}, H_{32} and H_{34} transfer function with corresponding positions, test microphone is placed at place 3 and the other is positioned in turn at place 1, 2 and 4. Actual experimental set up is displayed in Fig. 7. The readings have been taken for no load and with load conditions. The comparison of TL obtained using FEM and experimental analysis for the model-3 is shown in Fig. 8.

Fig. 7: Actual experimental setup

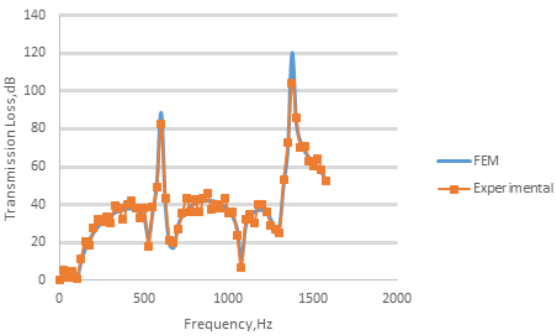

Fig. 8: Comparison of FEM and experimental analysis

The troughs are obtained at 101 Hz, 526 Hz, 676 Hz, 1076 Hz and 1301 Hz. The trough displays the points where minimum TL is attained. The muffler model showing uplifted troughs is considered as good model. The crests are observed at 601 Hz and 1376 Hz. The crest displays the points where maximum TL is attained. The maximum TL indicates that the minimum noise is radiated at the specified frequency. The experimental results and FEM results show good agreement. The small difference in the experimental outcome from that of the FEM result is attributable to the sound leakage from the impedance tube, FFT white noise production issues, impedance tube's surface finish.

4. Conclusion

In this research, three models with different EO lengths and constant EI length are analysed using COMSOL Multi-physics. Out of three models, model-3 with EO length as L/5 (19mm), has provided broadband TL over the frequency range of consideration. This is because it exhibits uplifted troughs as compared to the other EO lengths studied. It is also observed that, as the length of EO is increased from L/5 to L/3 keeping EI length as constant, the average TL decreases. The results of numerical analysis are validated with experimental analysis. The results of numerical and experimental analysis are in good agreement with each other.

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