Abstract

Intake and exhaust system noise makes a huge contribution to the interior and exterior noise of automobiles. The automotive industry is vibrant and fast-changing. Accurate prediction and control of noise from automobiles is of significant importance in automotive exhaust system design.

The present work discusses and validates, through measurements conversion of a geometrical model of an exhaust muffler to an acoustic model. When it comes to acoustic performance there are several parameters that describe the performance of a muffler, the Transmission Loss (TL) being the most popular one for validating an analytical model. The current work involves use of side outlet muffler and derivation of generalised TL formula for side outlet muffler. Analytical models are generally limited to simple shapes and can not handle more complex contours as the geometry evolves during the design process. Numerical models based on Finite Element Method (FEM) and Boundary Element Method (BEM) require expert knowledge and are more suited to handle complex muffler configurations in the latter part of the design phase. Though acoustic theory using the finite element method and boundary element method is effective, it requires enormous computational resources.

3-D analysis of geometrically difficult mufflers is carried out using ANSYS and COMSOL (FEM software) for investigating various shapes of mufflers along with effects of expansion ratio, length of chamber, extended inlet and outlet mufflers with various positions and angles of side outlet tubes and multiple chamber mufflers and silencers. Effects of inlet and outlet extensions are also seen to curtail the effect of certain higher order modes and enhance the muffler performance. The effects of important design parameters are studied to provide design guidelines. Further study is carried out with perforated mufflers. The influence of the internal geometry modifications of reactive mufflers, dissipative silencers, such as baffles and extended inlet/outlet, hybrid silencers and the impact of connecting duct length between a pair of silencers, are investigated using FEM. These theories and methods though reliable for the analysis, do not predict optimized configuration.

Today’s global market demands quicker, cheaper, and better product designs for silencer manufacturing industries. Hence, efficient design methods which require less effort and cost are needed for systematic design of muffler for noise reduction. Hence the in-
interest in maximal sound transmission loss (STL) of muffler under given space constraints becomes important.

So further analysis is carried out for optimal length of extended inlet and outlet for single and double chamber mufflers considering their end corrections using optimization technique such as grid search method for entire frequency range or specific frequency range of interest.

Further the thesis proposes an optimal design scheme to improve the muffler’s capability of noise reduction of the exhaust system by using Taguchi and fractional factorial design. In order to perform better analysis pilot experiments were carried out first. From the pilot experiment $L_9$ tables were prepared. From $L_9$ tables signal to noise ratio charts were prepared with Minitab software and optimised models were predicted. From analysis of variance (ANOVA), F tests were carried out and were shown that F values were more than F criterion (F ratio from the tables) for required confidence level (90% confidence).

Acoustic characteristics of silencers filled with fibrous material (hence dissipative) are also investigated. Following a theoretical and numerical analysis of a dual chamber muffler with extended inlet outlet and with side outlet, the study is extended to a hybrid silencer designed by combining reactive and dissipative components.

The results obtained from analytical model and numerical model are compared with experimental results. Zero flow measurements of these properties were carried out for mufflers ranging from simple expansion chambers to complex geometry using two load method. The predicted results agreed reasonably well with the experimental results.

The present work has thus led to development of a simple technique of designing a complex effective optimized hybrid muffler/silencer using reactive as well as absorptive elements; of different shapes and sizes making use of grid search optimization technique, Taguchi method, ANOVA method and validation of the design by experiments.