DESIGN AND FABRICATION OF A MULTI - CHAMBER FLOW SPLITTING MUFFLER

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ABSTRACT

We made an attempt to design and fabrication of a multi-chamber flow splitting muffler with different geometric and fluid dynamic options for its design optimization. The entry area ratio of inlet channels is taken as 1.7. With this geometry different combinations of the nozzle, holes are tried based on the given envelope. Through various parametric analytical studies, the observed that the multi-chamber flow splitting muffler with the given area ratio and different combinations of nozzle holes the muffler designer could reduce the sound level of an automotive vehicle on the order of 5 - 7 % compared to the existing Flow-master muffler with the same operating conditions. We comprehended that any exhaust system designer can further achieve a reduction in the sound level through prudent design options, viz., optimized impingement angle, optimized inlets area ratios, and suitable aerodynamic contours.

Keywords—Particle impingement muffler, Flow splitting Muffler, Noise suppression, Silencer.

I. INTRODUCTION

Since the invention of the internal combustion engine in the latter part of the nineteenth century, the noise created by it has been a constant source of trouble to the environment. Significantly, the exhaust noise in terms of pressure is about 10 times all the other noise combine. The design of muffler has been a topic of great interest for many years and hence a great deal of understanding has been gained Hence the good design of muffler should give the best noise reduction and offer optimum back pressure for the engine.

The performance of an exhaust system is assessed by a different factor, the most important factors are backpressure and the insertion loss of the system. High backpressure in an exhaust system affects the performance of the engine, decreasing power, and increasing fuel consumption. Exhaust noise can be classified into two categories pulsating noise from the engine, and flow noise from high-speed exhaust gasses flowing through and exiting the exhaust system. Pulsating noise is generated when exhaust gases at high pressure are released from the engine cylinders through the exhaust valves. Flow noise is created by exhaust gas flow oscillating and impacting inside the exhaust system.

There are five different design criterion of mufflers design, they are the acoustical criterion, aerodynamical criterion, mechanical criterion, geometrical criterion, and economical criterion. The acoustical criterion specifies the minimum noise reduction required from the muffler as a function of frequency. The mechanical criterion specifies the materials from which the muffler is fabricated. So that it is durable and requires less maintenance.

The economic criterion is vital in the market place. A muffler must be inexpensive as possible while designing initial cost as well as operating cost must be considered. The various dimensions of the muffler are varied keeping some dimensions constant and then the effect on Backpressure is observed. It can be seen that the backpressure varies nonlinearly and it cannot be predicted by an equation. It can be concluded that the backpressure value is high for small diameters as compare to bigger diameter holes even if the porosity is double.

Analyzed muffler by changing the length of each expansion chambers to understand the effects to the flow characteristics of a cross-flowed perforated and multi-chamber flow splitting muffler. It is known that an increase in the total muffler axial length results in a better noise attenuation performance. The decrease in the length of the middle chamber prevents the cross flow. Thus, a greater pressure loss occurs in this model.

II. PROPOSED NUMERICAL METHODOLOGY

Numerical simulations have been carried out with the help of a three-dimensional standard k–omega model. This turbulence model is an empirical model based on model transport equations for the turbulence kinetic energy and a specific dissipation rate. This code solves standard k–omega turbulence equations with shear flow corrections, using a coupled second-order-implicit unsteady formulation. In the numerical study, a fully implicit finite volume scheme of the compressible, Reynolds-averaged, Navier–Stokes equations is employed. Compared to other available models, this model could well predict the turbulence transition in duct flows and has been validated through benchmark solutions.

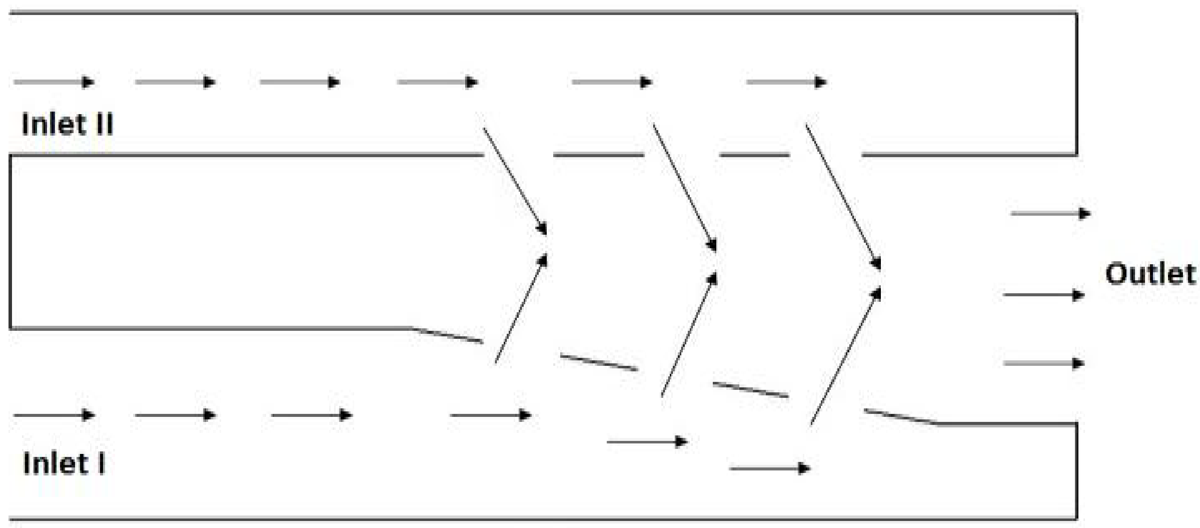

Fig. 1 The idealized physical model (upper half) of a multi-chamber flow splitting Muffler

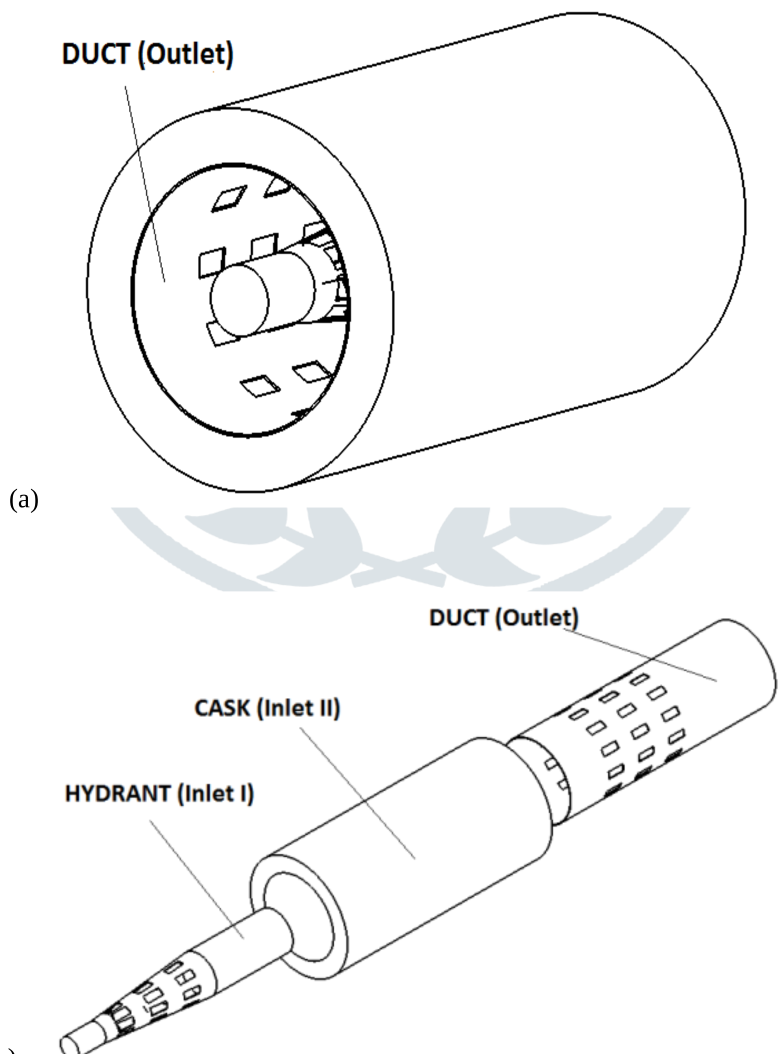

Fig. 2(a-b) show assembled and exploded view of the multi chamber flow splitting muffler.

The physical model of the multi-chamber flow splitting muffler is shown in Fig.1. Figures 2(a) & (b) show assembled and exploded view of the multi chamber flow splitting muffler.

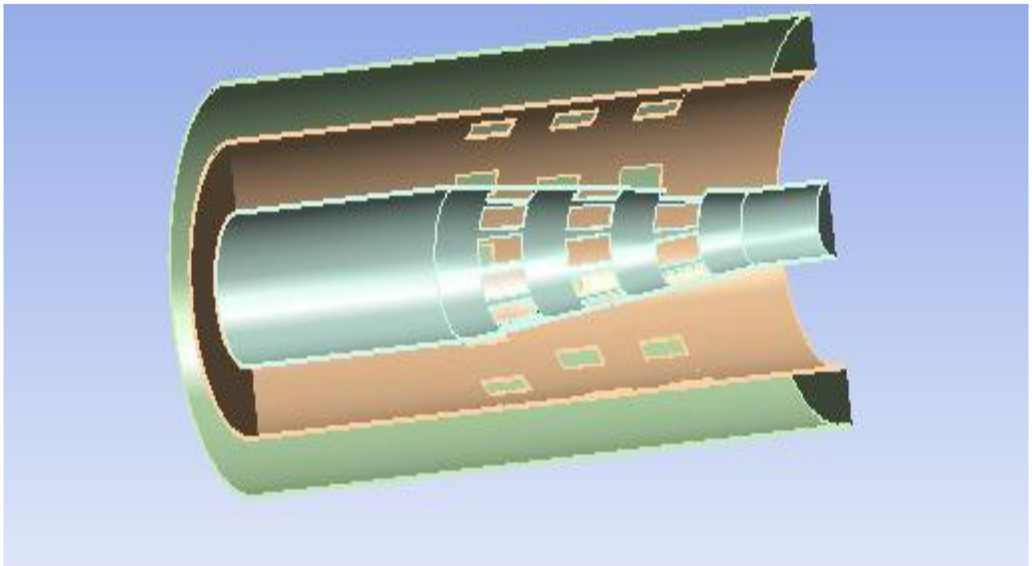

Fig. 3 Cut section view of the multi chamber flow splitting muffler.

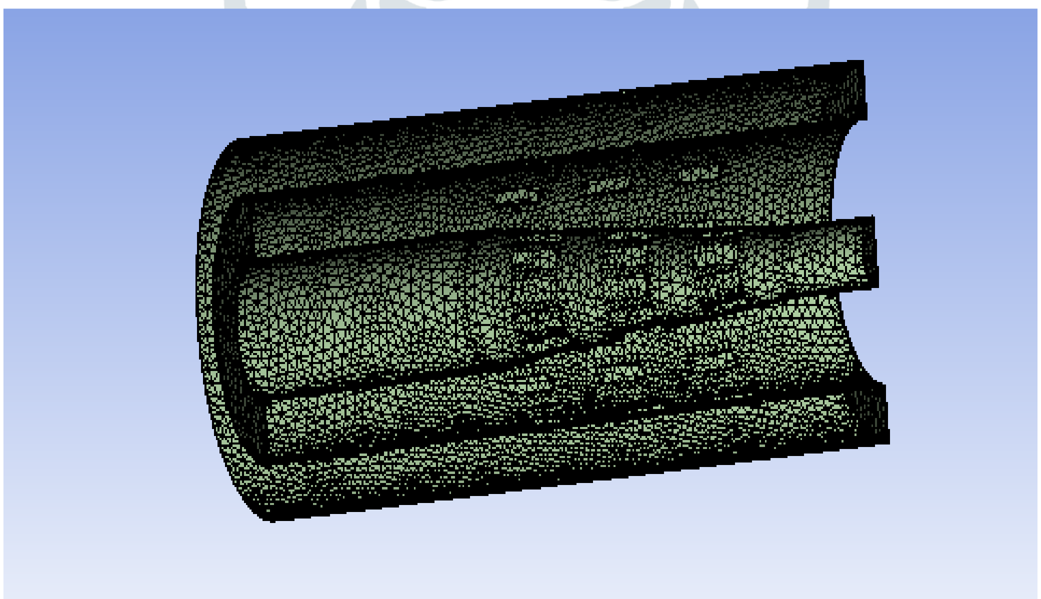

Fig. 4 Typical 3D grid system in the computational domain

As a first step, the authors made an attempt to compare the acoustic level of 2D and 3D model for the proposed and *existing cases. We have found that it is varying marginally at the outlet. Therefore, we have taken the 2D model of* the proposed muffler for comparison with the existing model. This is done for reducing the computational time. However, we have generated 3D results for the proposed model, as well. Figure 3 shows the cut session view of the multi-chamber flow splitting muffler. Typical 3D grid system in the computational domain is shown in Fig. 4. The grids are clustered near the solid walls using suitable stretching functions. At the solid walls, a no-slip boundary condition is imposed. The Courant–Friedrichs–Lewy number is suitably chosen an ideal gas is selected as the working fluid. The muffler geometric variables and material properties are known a priori. In this paper, the authors further made attempts for the geometrical as well as fluid dynamic optimization of the multi-chamber muffler, by varying the length to diameter ratio. This is done for facilitating different angles of jet impingement to achieve best results.

III. RESULTS AND DISCUSSION

The job description of a muffler is simple, viz., noise reduction; but its design optimization is a challenging task. Once internal combustion takes place, the engine expels exhaust gasses in the form of high-pressure pulses. These high-pressure pulses create very powerful sound waves, and the muffler is tasked with reducing this powerful sound to a tolerable level. While the job description is simple, the way in which a muffler performs its main task is more varied and complicated. Ideally, an aftermarket muffler will provide a good performance exhaust tone without creating too much power-stealing backpressure.

Depending on the style, a muffler uses some combination of baffles, chambers, perforated tubes, and/or sound deadening material to achieve this goal. In this paper, the authors essentially focused on the geometrical as well as the fluid dynamic aspect of noise suppression. Accordingly, design optimization has been carried out using a three-dimensional k-omega model. The entry area ratio of inlet channels (A hydrant inlet/Acask inlet) is taken as With this geometry different combinations of the nozzle, holes are tried, based on the given envelope. For demonstrating the merits of this invention, the inventors have conducted a case study using a computational fluid dynamics model and compared the sound level with one of the typical Flow-master mufflers. Figures 5 and 6, shows the acoustic level comparison of both existing, and the proposed mufflers. Figure 7 shows a graph comparing the acoustic levels of both existing and proposed muffler. The line of reference is shown. A steep rise is noticed in the acoustic levels due to the recirculation of the flow. It is evident from Figs. 5-7 that the proposed multi-chamber flow splitting muffler is superior to the existing muffler. Therefore, the authors made an attempt for the hot internal flow simulation of multi-chamber flow splitting muffler using the 3D turbulence model.

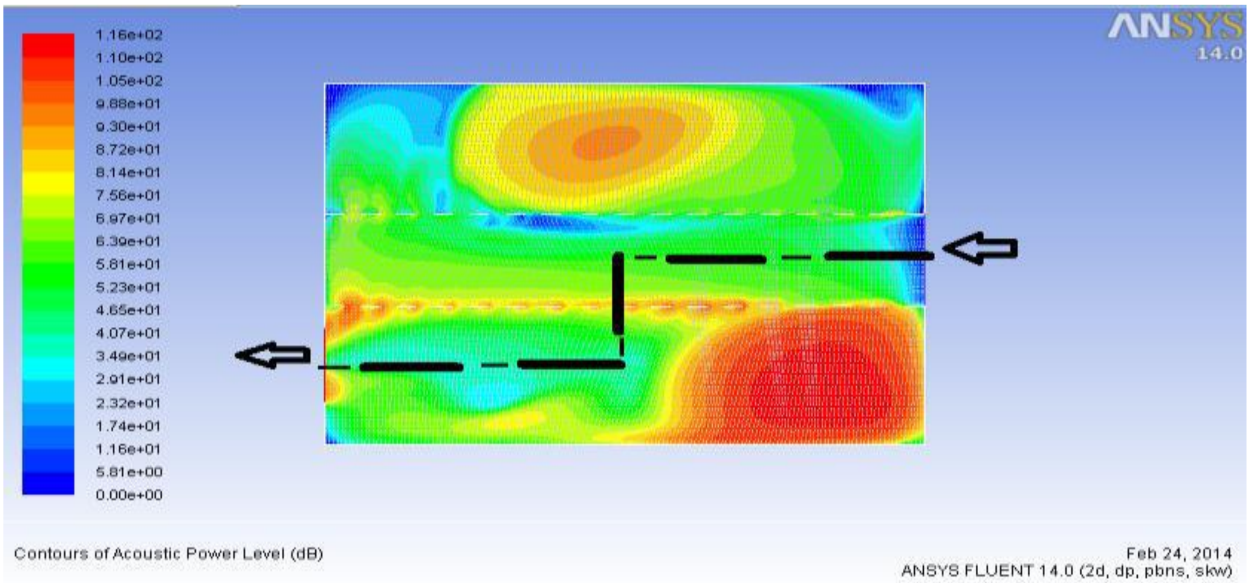

Fig. 5 Demonstrating the acoustic level of 2d existing case (FLOWMASTER)

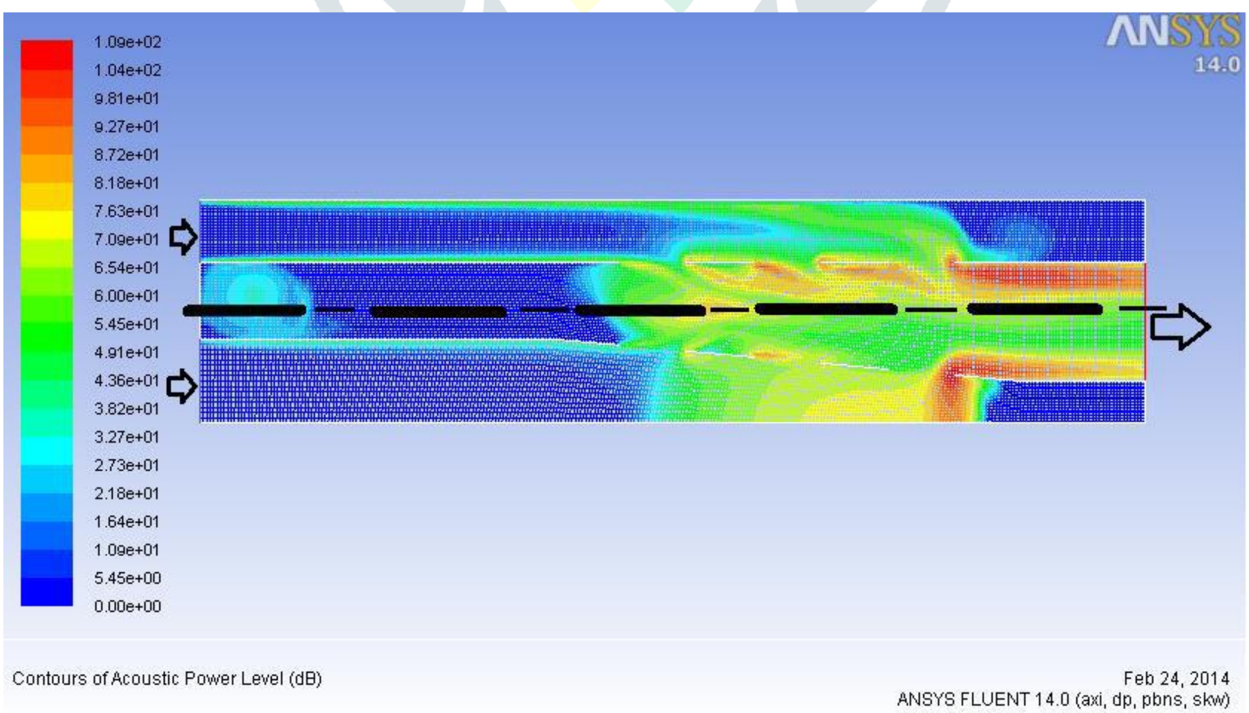

Fig. 6 Demonstrating the acoustic level at various inner locations of the proposed multi-chamber flow splitting muffler unit.

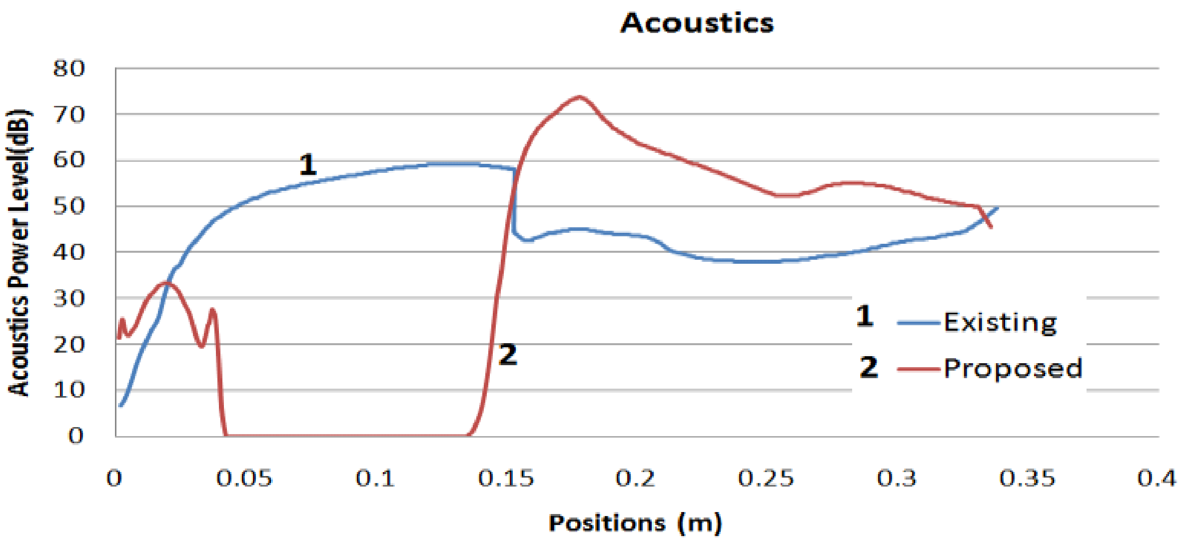

Fig. 7 Comparison of the acoustics levels of the existing and the proposed multi-chamber flow splitting muffler, corresponding to the line of reference shown in Figures 5 & 6.

IV. CONCLSION

The multi-chamber flow splitting muffler is more efficient and lucrative than the existing mufflers, owing to the fact that the present system is entirely utilizing the particle impingement theory for self-noise suppression. With the given inlet channel area ratio and 36 numbers of nozzles in the outlet, we could reduce the sound level on the order of 5-7 % compared to the existing Flow-master muffler with the same operating conditions. Additionally, one could reduce the total weight of the unit by 50 % leading to the reduction of the total material cost. Through various parametric analytical studies, the authors observed that the multi-chamber flow splitting muffler with the given area ratio and different combinations of nozzle holes any automotive vehicle could reduce the sound level on the order of 5-7 % compared to the existing Flow-master muffler with the same operating conditions. Authors comprehended that any automotive muffler designer or industrial exhaust system designer can further achieve a reduction in the sound level, through prudent design options, viz., optimized impingement angle, optimized inlets area ratios, and suitable aerodynamic contours.

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