International Engineering Research Journal

Performance Analysis of Reactive Muffler Using CFD

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***Abstract*—A muffler is important part of the engine system used in exhaust system to reduce noise level. The objective of this study is to reduce exhaust gas noise level. The performance of the muffler is assessed by analyzing pressure variation, exhaust gas flow pattern, length of expansion chamber, transmission loss. The RANS method is used to obtain transmission loss, mach number and pressure distribution by inputting sinusoidal nature of pressure wave. The modeling of muffler is done by using modeling software and performance parameters are estimated using Star CCM+ software. This study helps to improve reduce environmental noise pollution. The numerical results obtained from software are compared with analytical results.**

Key words- Muffler, CFD, Expansion Chamber, Transmission loss, Pressure distribution.

I. INTRODUCTION

Muffler is an important part of the engine system used in exhaust gas system to reduce exhaust gas noise level. The sole purpose of an automotive muffler is to reduce enginenoise.Soundisapressurewaveformedfrom pulsesofalternating highand lowpressureair.Inan automotiveengine,pressure waves are generated when the exhaust valve repeatedlyopens andhigh-pressuregas entersinto theexhaustsystem. Allnoiseemittedbyan automobiledoesnotcomefrom the exhaustsystem. Othercontributorstovehiclenoiseemission includeintakenoise,mechanicalnoise andvibrationinduced noise fromtheengine body andtransmission.

To examine the performance of any muffler, transmission loss and backpressure parameters are used. The transmission loss gives a value in decibel (dB) that corresponds to the ability of the muffler to dampen the noise. Transmission loss is independent from the noise source, thus this property of muffler does not vary with respect to noise source. In this study, acoustic and flow characteristic of a perforated reactive muffler were analyzed.

Muffler is one of the major exhaust system components and it is mainly classified into two types dependingon its operating mechanism are reactive muffler and absorptive muffler. The reactive muffler use the phenomenon of destructive interference to reduce the noise. Theyare designed so that the sound waves produced by an engine partially cancel themselves out in the muffler. Reflections occur when there is a change in geometry or an area discontinuity.Absorptive silencers contain either fibrous or porous material, and depending upon their absorptive properties they reduce thenoise levels. Sound energy is reduced and convertedinto heat in their absorptive material. It is based on the use offlow resistive materials, again normally in the form of porous acoustic linings.

II. LITERATURE REVIEW

Potente et al has studied on principal of muffler design and advantages of various types of muffler has discussed for designing purpose [1]. K. Suganeswaran et al has done work on design and modification of muffler is important to achieve back pressure and attenuation. Target value which is compromise between transmission loss and backpressure, is set for initial stage and to achieve target value internal structure is modified [2]. M. Rahman et al makes muffler for stationary engine has been designed and manufactured. The performance characteristics, i.e. noise reduction capability of the muffler, has been tested and compared with that of the conventional muffler [3].

Z. Tao and A. F. Seybert discussed the current techniques of measuring transmission loss.The most common approach for measuring thetransmission loss of a muffler is to determine the incidentpower by decomposition theory and the transmitted powerby the plane wave approximation assuming an anechoictermination. But it is difficult to built anechoic termination. Alternative to it there are two methods mostly used are two load method and two source method[4]. Shitalkumar Ramesh Shah et al has modern CAE tools to optimize overall system design balancing parameters like noise and transmission loss [5].Pradyumna Saripalli and K. Sankaranarayana has studied the CFD analysis on flow through muffler to obtain the effect of pressure and velocity inlet input. To simulate the fieldby numerical method with Cosmos Flow and analyses the effect which the internal flow field has on the performance of themuffler found out[6].

III.METHODOLOGY

. Details of all models are shown in following table.

TABLE I

Sr. No.	No. of holes on baffle	Number of pipes in third chamber	Dia. of pipes (mm)	Dia. of perforations (mm)
1	4	4	25	2.5
2	2	4	29	3
3	4	2	29	3
4	4	2	20	2

IV. MODEL BUILDING

The performance parameters of the muffler is estimated by considering transmission loss, flow pattern, velocity contours, pressure distribution. The 3D model has been created using CATIA modelling software. To estimate the performance parameters of the muffler analysis is done by using Star CCM+ software.

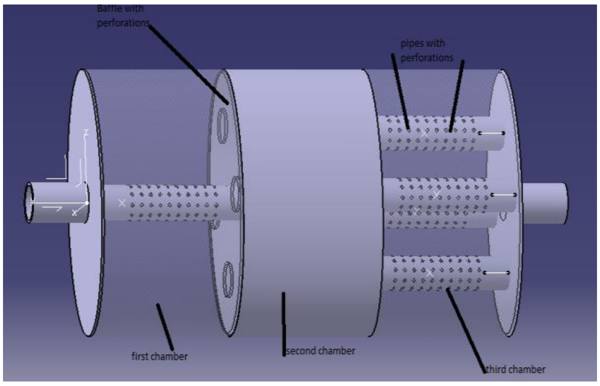

Fig.1- Geometric model of reactive muffler in 3D

Total length of muffler model is 360 mm.The entire model is divided into three chambers of same length (of 120 mm)and each chamber has different construction. First chamber of muffler has perforated inlet pipe extended upto second chamber which discharge gas into second chamber.There are perforations on pipes to allow the exhaust gas percolates The second baffle of muffler has four holes on it to pass the spread exhaust gas into second chamber. Third chamber of muffler has four perforated pipes which spread exhaust gas into third chamber and destructive interference cancellation of waves occurs causes in noise reduction. When spread waves of same amplitude collide with each other they create destructive interference causes cancellation of wave and thus noise gets reduced. Model of muffler has four baffles arrangement.

*A)*Computational Meshing

Geometry of muffler is divided into number of parts for meshto obtain better mesh quality. Hexagonal volume mesh type of meshing is used for analysis because it provides better analysis results by comparing to otherand reduced number of elements. Reduction in number of meshing elements causes reduction in analysis time of software. Total number of elements in volume mesh are 449990 and meshing size is 5 mm are used. .

*B)*Turbulent Model

There are many turbulent model used in CFD k-epsilon, k-omega, Shear stress transport depends on their applicability for specificwork. K- epsilon turbulent model is selectedfor analysing in Star CCM+ software which is mostly validated

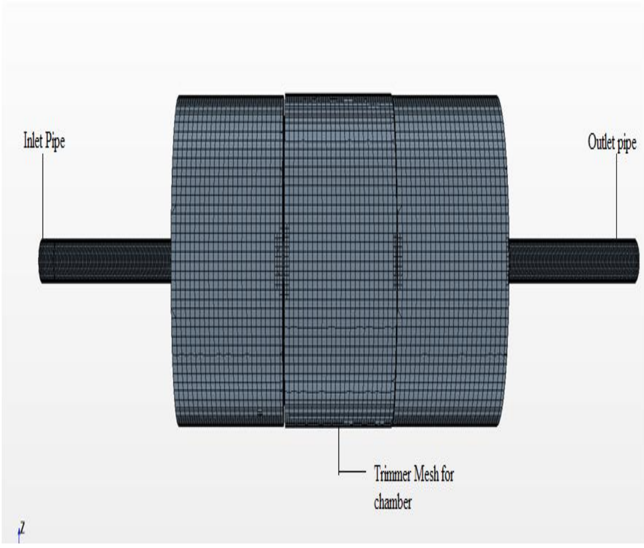

Fig.2- Mesh model

for automobile muffler work.In K epsilon model, kinetic energy gets dissipated in flow. There is formation of small and large eddies in which kinetic energy gets transferred from large eddies to small eddies and dissipates it.

*C)*Pressure Distribution

The pressure distribution in muffler shows the values of pressure at particular region. Figure 3 shows that, in first chamber there is more pressure observed as compare to other chambers. Pressure inside the muffler varies from -3000 Pa to 3000 Pa.

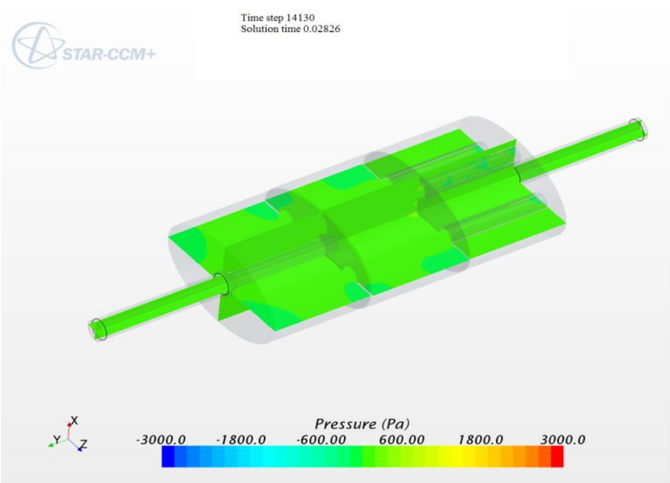

Fig.3- Pressure distribution of muffler

D) Velocity Streamlines and Velocity vectors

Fig 4 and fig 5 shows the velocity streamlines and velocity contours. Central chamber shows greater turbulence as compared to other than two chambers. Streamlines confirms variation in velocity between 5 to 32 m/s. Velocity contours shows the nature of flow of exhaust gas. In first chamber perforated pipe there is maximum velocity for contours about 32 m/s due small diameter of holes. As diameter of holes increased velocity of contours decreased.

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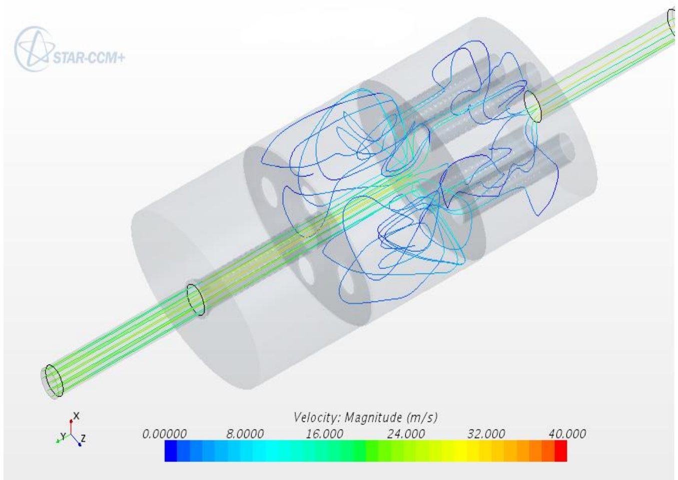

Fig 4- Velocity Streamlines

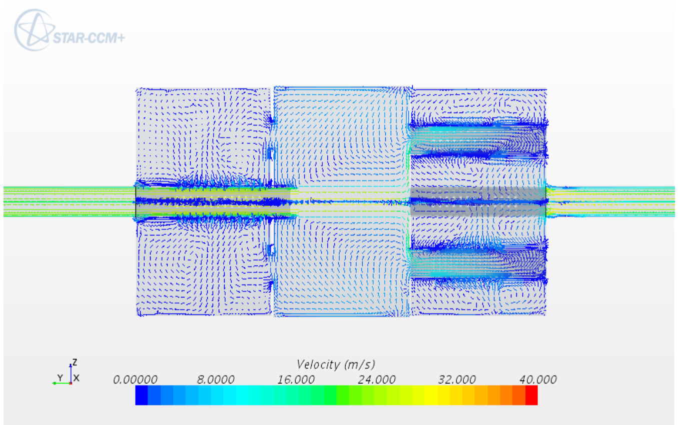

Fig 5- Velocity Contours

E) Transmission Loss

Transmission loss is a characteristic parameter which shows the performance of muffler. Transmission loss is thedifference between the sound level at inlet and outlet. selection of suitable muffler is based ontransmission loss and backpressure but because transmission loss does not depend on the source of noise. Figure 6 shows graph of frequency verses transmission loss.

F) Comparison of Transmission Loss

Experiment 4 has better transmission loss as compared to other models. Between lower frequencies 400 – 500 Hz model has 35- 40 db transmission loss and between 1000 – 1200 Hz it has 40 -45 db transmission loss.

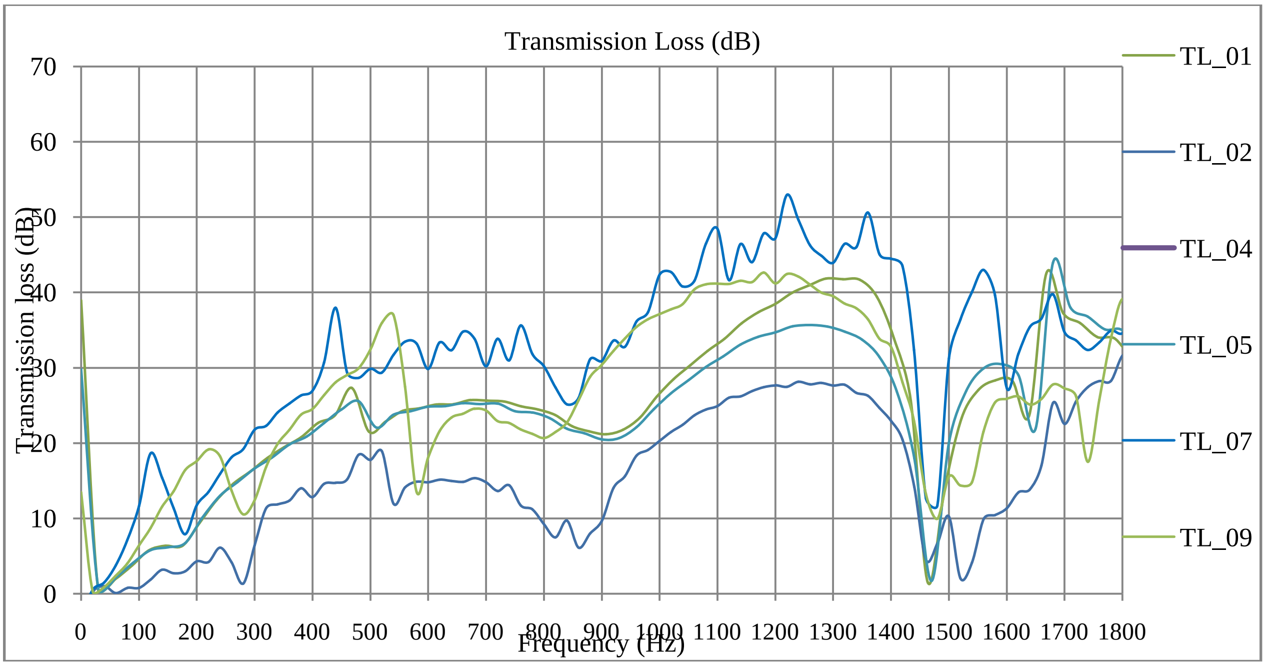

Fig.6- Comparison of Transmission Loss of all models

IV. CONCLUSIONS

Streamlines shows higher turbulence in second chamber as compared to third chamber. Velocity contours shows as diameter of holes increased velocity of vectors decreased, velocity contours and diameter are inversely proportional to each other. Pressure in first chamber is more non uniform than other chamber. Model 4 reveals better transmission loss for the range of 400- 800 Hz frequency is 35- 37 db.

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