Model Designing and Acoustic Analysis of Muffler with Baffles for Four Stroke Diesel Engine

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Abstract: ***A multi-chamber muffler with selective sound-absorbing material like, E – Glass Epoxy and rock wool is designed, modelled with baffles. Acoustic analysis is performed in Ansys Fluent to compare sound level of the muffler with and without muffler.***

1. Introduction

Exhaust mufflers are designed to reduce sound levels at these frequencies. In general, sound waves propagating along a pipe can be attenuated using either a dissipative or a reactive muffler. A dissipative muffler uses sound absorbing material to take energy out of the acoustic motion in the wave, as it propagates through the muffler. Reactive silencers, which are commonly used in automotive applications, reflect the sound waves back towards the source and prevent sound from being transmitted along the pipe. Reactive silencer design is based either on the principle of a Helmholtz resonator or an expansion chamber, and requires the use of acoustic transmission line theory. In a Helmholtz resonator design a cavity is attached to the exhaust pipe. At a specific frequency the cavity will resonate and the waves in the exhaust pipe are reflected back towards the source.

In all muffler designs the tailpipe length can have an important effect. The tailpipe itself acts as a resonant cavity that couples with the muffler cavity. The attenuation characteristics of a muffler are modified if the design tailpipe is not used. Also, the effect of exhaust gas flow speed has a detrimental effect on the muffler performance. Berane gives examples in which the muffler attenuation is reduced from 35 dB to 6-10dB when the flow speed is increased from zero to 230 ft/sec. In typical industrial or diesel truck engine applications the exhaust flow speed can be 164. The effect of flow is related to the interaction of sound with turbulence and will be dependent on the internal design of the muffler.

2. Proposed Theoretical Computation

The exhaust tones are calculated using the following Formulae:
Cylinder Firing Rate CFR = Engine Speed in RPM/60 …. For a two stroke engine (1)
= Engine Speed in RPM/120 ….For a four-stroke engine (2)
Engine Firing Rate EFR = n X (CFR) (3)
C. Muffler Volume Calculation
Volume Of the muffler (Vm):

$$Vm = Vf \times \left[\frac{\pi}{4}(d2 \times l)\right] \times (\text{No. of Cylindres}/2)$$

D. Internal Configuration And Concept Design Based on the benchmarking transmission loss and target frequencies the designer draws the few concept of the internal configuration. The diameter of the hole to be drilled on the pipe is calculated as;

$$d1 = \frac{1.29}{\sqrt{N}}$$

Transmission loss calculation by mathematical calculations

$$TL = 10\log\left[1 + 0.25\left(m - \frac{1}{m}\right)^2 \left(\frac{\sin\left[\frac{2\Pi L}{\lambda}\right]}{\cos\left[\frac{2\Pi La}{\lambda}\right] \times \cos\left[\frac{2\Pi Lb}{\lambda}\right]}\right)^2\right]$$

3. Choosing Muffler Design Pattern

We know that acoustic power W radiated by a cylindrical jet is proportional to the jet velocity to the 6th – 8th degree (depending on the value of velocity), the square of air density in the jet and the square of jet diameter:

$$W = k(M)\frac{\rho_c^2 U_c^n D^2}{\rho_0 c_0^m},$$

whereρc– is density of jet medium;
Uc– is efflux velocity;
D – is the diameter of exhaust nozzle section;
$\rho 0$ – is density of the environment;
$c0$ – is sound velocity
$k(M)$ - is proportionality factor
n, m – are degree indices depending on efflux velocity

Easy Way To Estimate: Your intake system needs to flow 1.5 CFM per engine horsepower, and your exhaust system needs to flow 2.2 CFM per engine horsepower.

Good Way To Estimate: Take engine RPM x engine displacement, then divide by two. This is the intake volume. Use this same volume of air for the exhaust system, but then correct for thermal expansion (you need to know exhaust temps to figure things out).

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Exhaust Pipe Size Estimate: A good section of straight pipe will flow about 115 CFM per square inch of area. Here's a quick table that shows how many CFM each common pipe size will flow, as well as the estimated max horsepower for each pipe size:

Table 1

Pipe Diameter (inches)	Pipe Area (in2)	Total CFM (est.)	Max HP Per Pipe	Max HP For A Dual Pipe System
1 1/2	1.48	171	78	155
1 5/8	1.77	203	92	185
1 3/4	2.07	239	108	217
2	2.76	318	144	289
2 1/4	3.55	408	185	371
2 1/2	4.43	509	232	463
2 3/4	5.41	622	283	566
3	6.49	747	339	679
3 1/4	7.67	882	401	802
3 1/2	8.95	1029	468	935

4. Objective of the Project

Boundary Conditions

The material properties are specified in the below table which are taken from website www.matweb.com

Material	Density (kg/m3)	Young's modulus (GPa)	Poisson's ratio
ROCKWOOL	100	12.6	0.27
E-GLASS EPOXY	1900	179	0.36

Modeling of muffler for four stroke diesel engine

Original model

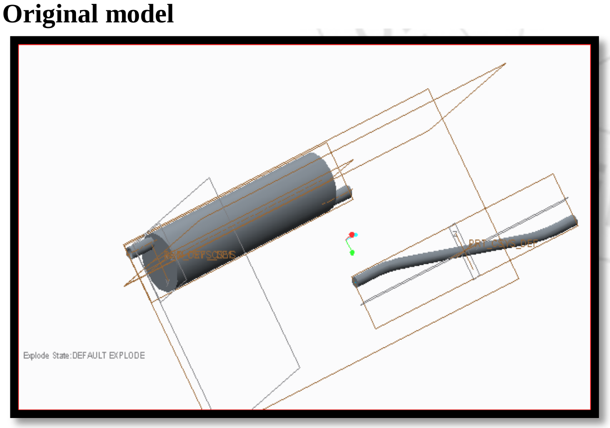

Figure 1: Exploded view of Assembly

Modified Model of Muffler with Baffles

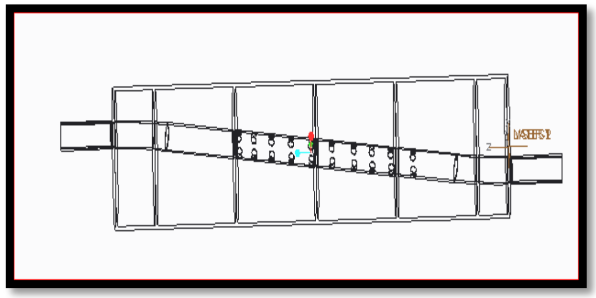

Figure 2: Assembly of modified model

Acoustic Analysis of Modified Model In CFD Fluent

Material – E – Glass Epoxy

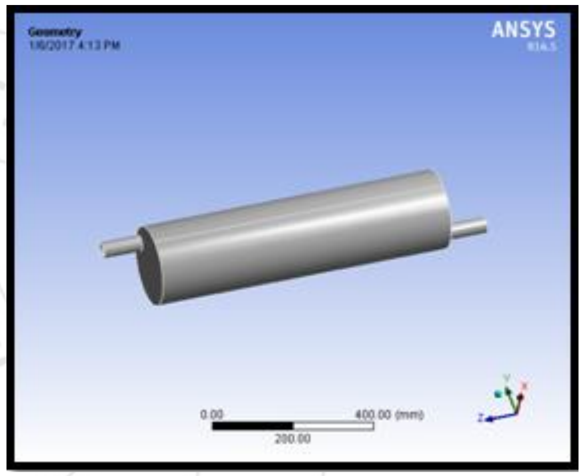

Figure 3: Imported

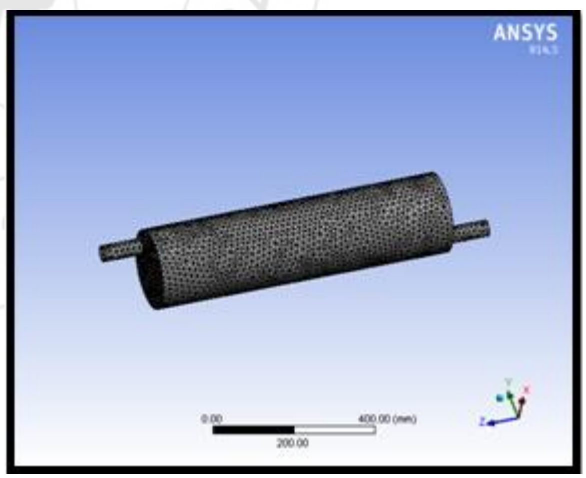

Figure 4: Meshed model

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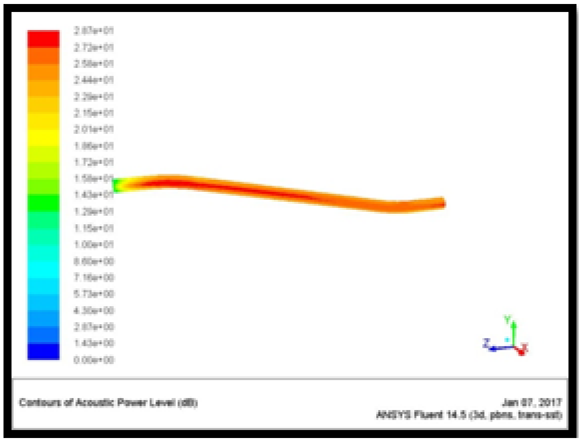


Figure 5: Acousting power level (dB)

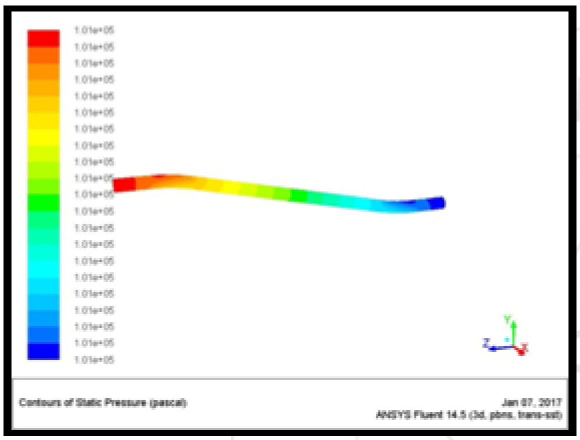


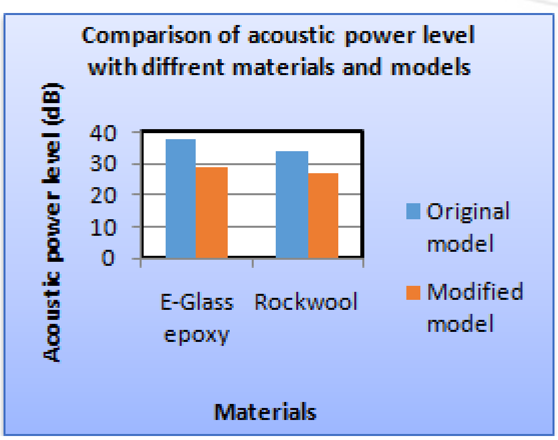
Figure 6: Acoustic power level (dB)

5. CFD Acoustic Analysis

Table 2: CFD analysis results of original model

Materials	Original Model Acoustic power level(dB)	Modified Model Acoustic power level(dB)
E-Glass epoxy	37.5	28.7
Rockwool	33.6	26.9

6. Comparison Graphs



7. Conclusion

The following conclusions can be made from the analyses results: The acoustic power level is decreasing for the modified model than original model. So the sound level from the engine is less when modified model is used. When the material Rockwool is used, the sound level is lesser.

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