Thermal Analysis of Compression Ignition Engine Muffler and its Design Modification

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Abstract
Automotive Silencers (or) Mufflers are used to minimize the noise level and vibrations produced in the engine exhaust gas. The Mufflers usually contain complex internal components such as extended inlet and outlet tubes, thin baffles with eccentric holes, internal connecting tubes, perforated tubes, flow plugs, and sound absorbing materials. In this project, thermal analysis is carried out in the existing muffler of C.I. Engine. The various influencing factors of muffler such as thermal concentration, thermal stress and properties of material have been analyzed by the software and the input values for the analysis are measured from the experimental setup. Based on the results of analysis, the optimal modification is to be done in the design in order to improve the life and performance of muffler.

Keywords: Conical Shape, Fins, Heat, Taper, Temperature

1. Introduction
An automotive muffler (or silencer) is a device for reducing the amount of noise emitted by an exhaust gas of engine and the exhaust gas blows out through this device and finally to the atmosphere.

Mufflers are typically installed along the exhaust pipe as part of the exhaust system of an internal combustion engine to reduce its exhaust noise. The muffler accomplishes with a resonating chamber, which is specifically tuned to destructive interference of opposite sound waves that cancel each other, Catalytic converters also often have a muffling effect. The effect is mainly generated largely by restriction, rather than by cancellation.

2. General Information
Types of Muffler
- Baffle.
- Wave cancellation.
- Resonance.
- Absorber.
- Combined Resonance and Absorber.

Factors Affecting Muffler
- Exhaust gas temperature.
- Exhaust gas pressure.
- Back Pressure.
- Vibration.
- Erosion.
- Material failure.
- Crack formation.
- Type of fuel used.

2.1 Problems in Existing Muffler
The smaller holes in the muffler will be enlarged in its diameter due to the exhaust gas comes out with high temperature and thermal expansion in the muffler. This affects more vibration and noise in the muffler

Maximum heat will be occurred at the strikers' which is nearer to exhaust pipe inlet so that striker can be easily damaged because of thermal expansion.

2.2 Solutions for the Problem
To overcome the above problems:
- Design and software analysis is made in the muffler
- Manual analysis is also carried out to check the feasibility

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2.3 Input Data for Analysis in Software

Mild Steel Properties

- Thermal conductivity: 53.6 W/m-k
- Specific heat: 465 J/kg-k
- Density: 7833 kg/m³
- Carbon content: 0.5%
- At Boundary condition: 30 to 300 °C (at no load and normal running condition)

2.4 Outcome of the Analysis

- Found a vigorous HAZ, lead to material failure\(^1\),\(^2\).
- Material failure
- Crack formation
- Corrosion – the reaction between the exhaust gas and the metal surface

2.5 Provisional Solution

To reduce the heat, following design changes are recommended:

- Fins are to be provided in the tubular surface
- Increasing the length of the pipe
- Converting the cylindrical back pressure area into a conical structure (Diverging)

3. Models to be considered for this Analysis

- Model 1: Conical Muffler
- Model 2: Muffler with fins at the tubular surface
- Model 3: Muffler with various diameters of fins
- Model 4: Conical shape muffler with fins
- Model 5: Conical shape muffler with fins at the entire muffler

3.1 Modeling

The modeling of all 5 models is given from Figures 3 to 6.
Figure 5. Conical shape muffler with fins.

Figure 6. Conical shape muffler with fins at the entire muffler.

After modeling all 5 models were analyzed in ANSYS for temperature distribution and post processor output are given from Figures 7 to 11.

Figure 7. Ansys solution for muffler with fins at the tubular surface.

Figure 8. Ansys solution for muffler with varying diameter of fin.

Figure 9. Ansys solution for conical muffler.

Figure 10. Ansys solution for conical muffler with fins.
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4. Checking the Feasibility of Muffler

- At the end of software analysis of these five models, the model 5 shows optimum result in all aspects, in particularly heat dissipation is uniform throughout the muffler areas and its fins\(^2\). The fins are absorbed more amount of heat so that maximum heat flow to the muffler will be restricted. So it is not affected more by thermal expansion because of fins provided at the entire muffler.

- According to the software and experimental analysis, the heat flow in this muffler model 5 was very less\(^{11-13}\). It does not allow the maximum flow through the muffler. Because the fins are absorbed the heat. So the surface does not affect by high temperature of exhaust gas\(^3-5\).

- And another advantage is reduced back pressure because of conical shape of muffler. When exhaust gas comes out, due to the sudden expansion the back pressure created is stopped. This leads to increase the life of muffler\(^6\).

4.1 Engine Specification

Engine type : Single cylinder four stroke Diesel Engine
Name of engine : Kirloskar diesel engine

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<th>S. No.</th>
<th>Current (Amps)</th>
<th>Voltage (Volt)</th>
<th>Brake Power in KW</th>
<th>Muffler Temperature in °C</th>
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Speed : 1500 rpm
Power : 5 hp
Bore : 87.5 mm
Stroke : 110 mm
Piston displacement : 661.5 cc
Compression Ratio : 17.5:1

From the results of software analysis and experimental setup values, the muffler model 5 has been identified as an optimum designed model which shows good result than any other model, hence model 5 (optimum designed model) was fabricated. The thermal analysis was conducted at predetermined points and results were compared with original existing muffler.

Figure 12. Diagrammatic representation of temperatures in existing muffler.

Figure 13. Diagrammatic representation of temperatures in optimal designed muffler.

Figure 14. Temperature $T_1$ distribution in original and optimum designed muffler.

Figure 15. Temperature $T_2$ distribution in original and optimum designed muffler.

Figure 16. Temperature $T_3$ distribution in original and optimum designed muffler.

Figure 17. Temperature $T_4$ distribution in original and optimum designed muffler.

Figure 18. Temperature $T_5$ distribution in original and optimum designed muffler.
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5. Conclusion

The following conclusions were made based on the results obtained from the experimental investigations on both the original muffler and model 5 muffler of a single cylinder diesel engine.

• The model 5 muffler can be replaced by the original muffler. Hence, it has been identified as optimal designed muffler.
• The heat dissipation is quicker than the original muffler. Its value decreases about 20°C.
• The thermal stress and thermal expansion developed on the model 5 muffler material may be less than the original muffler. This is due to uniform distribution of heat by the fins.
• The muffler failures such as outlet hole expansion and cracks are reduced in the optimum designed muffler.
• The backpressure developed inside the muffler has reduced due to decrease of the exhaust gas velocity.

In general model 5 muffler i.e., optimum design muffler improves the performance and life with a significant reduction in muffler failures.

6. References