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TRANSMISSION LOSS AND PERFORMANCE TEST OF A TWO CYLINDER FOUR STROKE DIESEL ENGINE

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Abstract

A pollutant of concern to the mankind is the exhaust noise in the internal combustion engine. However this noise can be reduced sufficiently by means of a well designed muffler. The suitable design and development help to reduce the noise level, however, the performance of the engine should not be hampered by the back pressure caused by the muffler. In the current work, a reactive muffler was designed and fabricated and the transmission loss of the developed muffler was calculated at 1200 rpm. In addition, the current results were compared with the conventional muffler in term of brake thermal efficiency and brake specific fuel consumptions and drop of pressure is also measured.

Keywords: Reactive muffler, Transmission loss, Engine performance.

1. Introduction

There are five different design criteria in mufflers design [1-4]. These are acoustical, aerodynamical, mechanical, geometrical and economical criteria. The acoustical criterion specifies the minimum noise reduction [5-7] required from the muffler as a function of frequency. Aerodynamical criterion specifies the maximum acceptable pressure drop through the muffler at given temperature and mass flow. The mechanical criterion specifies the materials from which the muffler is fabricated or designed. So that it is durable and requires less maintenance. This is especially important in case of involving high temperature exhaust or corrosive gases or the gaseous flow is carrying solid particles in suspension that might be deposited on the inner surface of the wall of the muffler and reduces the muffler effectiveness. Geometrical criterion [8-11] specifies the

Nomenclatures

BP	Brake power, kW
BSFC	Brake specific fuel consumption, kg/BP-hr
c	Speed of sound, m/s
p	Pressure, mm water
S_i, S_o	Inlet and outlet tube areas, mm^2
TL	Transmission loss, db
x_1, x_2	Locations at the muffler inlet, mm

maximum allowable value and restriction on shape. The economical criterion is vital in the market place. A muffler must be inexpensive as possible while designing [12-14], initial cost as well as operating cost must be considered. This thought has inspired the authors to design and fabricate a reactive muffler and calculate the transmission loss and performance test of the engine [15-16].

2. Three-point Method

In a three-point method, transmission loss [14, 10] is evaluated from the field pressures measured at three points inside the muffler. Among the three points, two of them (points 1 and 2) are located in the inlet pipe and one (point 3) in the outlet pipe (Fig. 1).

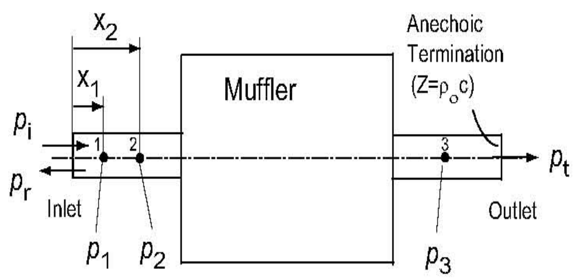


Fig. 1. Three Point Method [3].

The two field points in the inlet pipe are used to extract the incoming wave pressure p_i. The field point pressure at point 3 is the same as the transmitted wave pressure p_t in the outlet pipe, that is, $p_3 = p_t$. This is due to the specification of anechoic termination at the outlet, which by definition does not reflect waves back into the outlet pipe. Due to the discontinuity in the impedance from the inlet pipe to the expansion chamber of the muffler, a portion of the incoming wave is reflected back to the source. Hence, pressures measured at points 1 and 2 in the inlet pipe are resultant of both the incoming (p_i) and reflected (p_r) waves and are given by [3],

$$p_1 = p_i e^{ikx_1} + p_r e^{ikx_1} \quad (1)$$

$$p_2 = p_i e^{ikx_2} + p_r e^{ikx_2} \quad (2)$$

where p_1 and p_2 are the pressure values, x_1 and x_2 are the locations of point 1 and point 2 respectively; and $i = \sqrt{-1}$.

Solving the Eqs. (1) and (2) for p_i , Eq. (3) is obtained

$$p_i = -\frac{p_1 e^{ikx_2} + p_2 e^{ikx_1}}{2i \sin k\left(x_2 - x_1\right)} \tag{3}$$

where sin $k(x_2\text{-}x_1) \neq 0$ or $k(x_2\text{-}x_1) \neq n\pi$, n = 0, 1, 2, 3, …Note that the spacing between the points 1 and 2 should be carefully chosen to satisfy this condition at all frequencies.

The transmission loss for a muffler could be evaluated from the incoming pressure p_i and the transmitted $p_3 = p_t$ wave pressures [3],

$$TL = 20 \log_{10} \frac{p_i}{p_3} + 10 \log_{10} \frac{S_i}{S_o} \tag{4}$$

where S_i and S_o are inlet and outlet tube areas respectively.

We used to compute field point pressures at the three field points at point 1, p_1, point 2, p_2, and the point 3, p_3. The field point 1 is arbitrary selected to be 1.524 cm away from the inlet (that is, x_1=1.524), point 2 is 11.684 cm away from the inlet (x_2=1.684), and point 3 is at a distance of 1.524 cm from the outlet. The incoming wave pressure, p_i, and the transmitted wave pressure, p_3 are used to evaluate transmission loss.

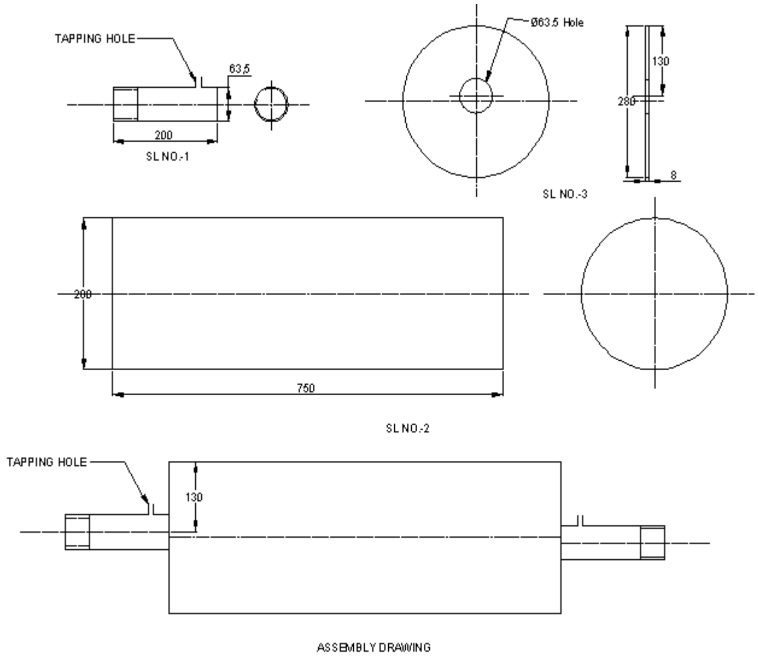
3. Design and Fabrication of Reactive Muffler

Figure 2 shows the details and assembly drawing of the reactive muffler. Component 1 is a M.S. pipe of 63.5 mm diameter and 200 mm length. The wall thickness of the inlet pipe is about 2 mm. Component 2 is the hollow cylinder of 200 mm diameter and 750 mm length. The hollow cylinder was prepared by cutting M.S. plate of 3 mm thickness as per given dimensions. The plate was bent to the truly cylindrical shape with the help of solid cylinder of 200 mm diameter and 750 mm length. The edge of the plate was welded by electric arc welding, which consists of welding tool, design for manual manipulation by the user and an electric power unit. Component 3 is the cover plate. The two side cover plates were welded to the hollow cylinder, inlet and outlet pipes are welded to the cover plates as shown in the figure. Thus assembly of the reactive muffler was carried out as shown in the assembly drawing.

4. Experimental Procedure

The experimental setup is shown in Figs. 3 and 4. The block diagram of the experimental setup is shown in Fig. 5. The setup is self explanatory.

The experiments were conducted on a I.C. Engine Laboratory of College of Engineering and Management Kolaghat, Purba Midnapore. All acoustic measurements were taken on relative basis instead of absolute basis. The background noise was measured before starting the experiments. All engines and other machines in the laboratory were shut down during testing of mufflers and also while measuring background noise. This is to avoid local disturbances.



SL. No.	Name	Quantity	Weight (kg)	Thickness (mm)
1	Inlet pipe	1	0.5	2
2	Cylindrical drum	1	3.4	3
3	Side wall of drum	2	2.2	3
4	Exhaust pipe(same as inlet pipe)	1	0.5	2

Fig. 2. Drawing of Developed Reactive Muffler.

Fig. 3. Experimental Setup.

The sound level meter was used for measuring sound pressure level and it was positioned at a distance of one meter away from the outlet of muffler and at an angle of 45°. The meter was positioned at the same level that of flow of exhaust gas so that the noise level can be recorded effectively.

Fig. 4. Developed Reactive Muffler.

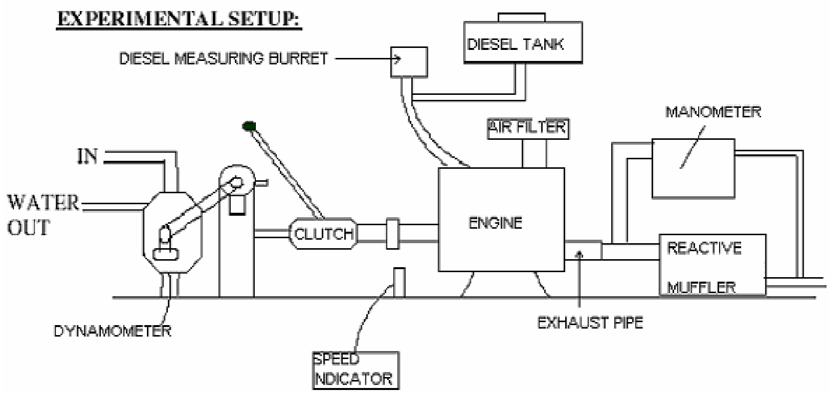


Fig. 5. Schematic Diagram of Experimental Setup.

The 4-stroke diesel engine was started. The readings were observed at 1200 rpm, as reactive muffler is most effective at low frequencies and different torque (loads); no load, 50 Nm, 100 Nm, 150 Nm, 200 Nm. The engine was operated at different load sand fixed speed. The measurement of fuel supply is recorded, i.e., time was recorded for consumption of 50 ml of fuel from calibrated burette. The rate of fuel consumptions in kg/hr was calculated. This data further helped in calculating BP and BSFC.

The sound pressure level was recorded before starting of engine or pump or dynamometer and keeping all the machines and engines of the laboratory in the shut off position. The background noise level was recorded. Room temperature was also recorded. Then sound pressure level was observed at above mentioned speeds and loads. This will help in getting the signatures of the exhaust noise through the muffler at different speeds and different loads.

The metallic bulb of thermocouple was inserted in the outlet pipe of the muffler and exhaust gas temperature was recorded. The sound pressure level also depends on exhaust gas temperature.

The tube of water filled manometer was attached to inlet pipe and outlet pipe of the muffler. The drop of pressure across the muffler was recorded in mm in water. This data will help in calculating the amount of back pressure exerted on the engine. The experiment was repeated for all types of muffler, i.e., reactive, existing and without muffler.

5. Results and Discussion

Figure 6 represents the plot of BP (kW) as a function of Transmission Loss (db) for developed muffler at 1200 rpm. Here it can be seen that transmission loss increases after certain BP (kW). This is due to higher pressure drop.

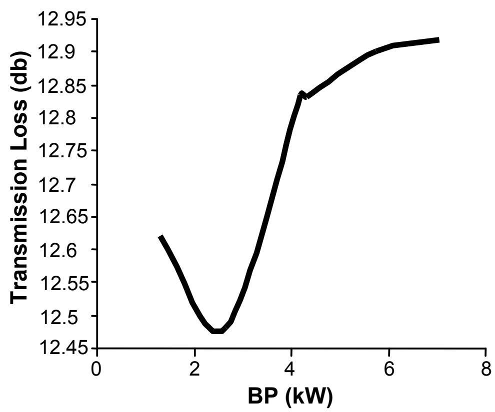


Fig. 6. Variation of Transmission Loss with Brake Power for Developed Muffler at 1200 rpm.

Figure 7 represents the comparison of brake thermal efficiency among existing, developed and without muffler at 1200 rpm. The maximum brake thermal efficiency without muffler, with existing muffler and with developed and fabricated mufflers are 25.84, 23.64, and 24.89, respectively. The brake thermal efficiency with developed muffler is little less than the without muffler, because of the higher pressure drop in case of developed muffler in comparison to without and existing mufflers.

Figure 8 represents the comparison of BSFC among developed, existing and without muffler. Here it can be seen that BSFC is 0.323 when it is without muffler. When the existing muffler is used, BSFC becomes 0.354. For developed and fabricated muffler BSFC is 0.336.

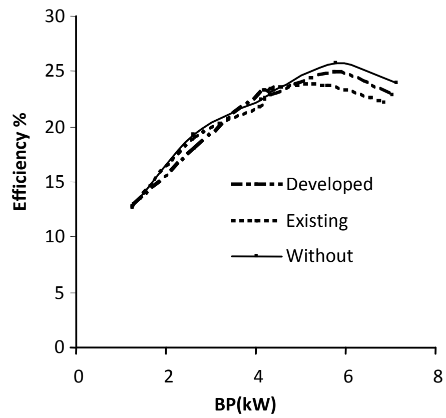


Fig. 7. Comparison of Brake Thermal Efficiency among Developed, Existing and without Muffler at 1200 rpm.

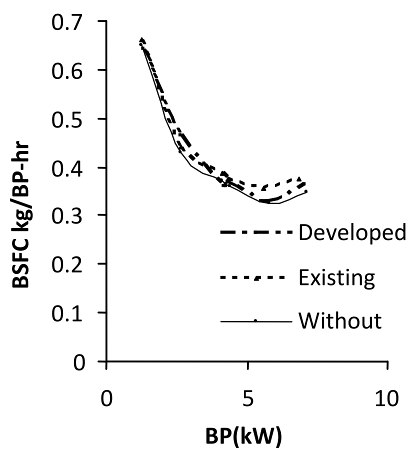


Fig. 8. Comparison of BSFC among Developed, Existing and Without Muffler at 1200 rpm.

Figure 9 represents the drop of pressure at 1200 rpm with developed and existing muffler. It is interesting to note down that the pressure drop for developed fabricated muffler is higher than the existing muffler.

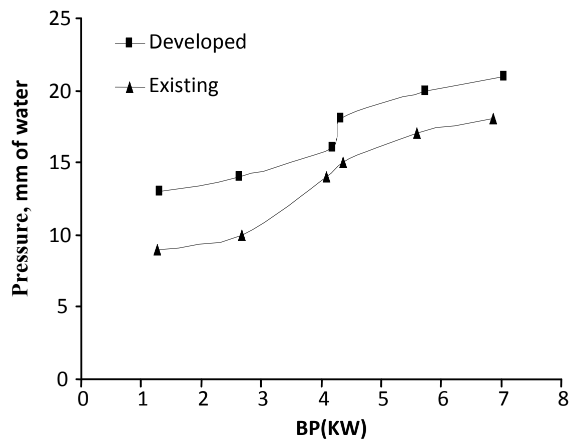


Fig. 9. Drop of Pressure vs. BP(kW) between Developed and Existing Muffler at 1200 rpm.

6. Conclusions

From results and discussions the following conclusions are drawn:

- Maximum transmission loss is approximately 13 db for developed and fabricated muffler.
- The brake thermal efficiency of engine is higher for developed and fabricated muffler as compared to existing muffler.
- The brake specific fuel consumption is low compared to existing muffler.

The fuel consumption is less compared to existing muffler.

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