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Experimental Study of Exhaust Configurations on the Diesel Engine Performance

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Abstract: The overall diesel engine performance is very much dependent upon the design and operation parameters of the inlet and exhaust system. This study was undertaken to provide knowledge for improving the diesel engine performance through modification of the exhaust middle pipe configuration. This study presents the results of an experimental study of the exhaust middle pipe on diesel engine performance in terms of torque produced, brake horsepower, Brake Mean Effective Pressure and the specific fuel consumption. Experimental study is adopted in this study based on two conditions, at 50% throttle opening and 100% throttle opening conditions. The experiment was conducted on a four stroke, four cylinders, in-line OHC and indirect injection diesel engine with different exhaust middle pipe configuration attached. The results of the physical testing shows the differences in engine performance for different exhaust middle pipe configurations especially at the engine speed greater than 2000 rpm.

Key words: Diesel engine performance, exhaust, middle pipe configuration, experimental analysis

INTRODUCTION

The overall internal combustion engine performance is very much dependent upon the design and the operation parameters of the inlet and exhaust system. The inlet and exhaust are used to deliver clean air to the engine and dispose the exhaust gas quietly with minimum loss of performance. The parameters considered for properly designing the exhaust pipe system of internal combustion engines are diameter and length of pipe, material, thickness and insulation of exhaust pipe system, geometry of pipe connection (junctions) and the position of the necessary elements of the exhaust system. Numerous studies have been done to investigate the influence of inlet and exhaust manifold design on the engine operational characteristics in transient and steady state mode, the engine performance and engine emission (Kesgin, 2005; Galindo *et al*., 2004; Seenikannan *et al*., 2008a).

Length and diameter are two important parameters in the exhaust system designs that influence the effectiveness and efficiency of the gas flow. Various modeling and experimental studies have been also carried out to investigate the fluid dynamic characteristics in the exhaust pipe and its influence on the diesel engine performance (Graff and de Weck, 2006; Sekavcnik *et al*., 2006; Seenikannan *et al*., 2008b; Bell, 1997). The viscous compressible fluid within the straight circular pipe was excited by an impulse disturbance at the inlet of the pipe, and the dynamic response was analyzed. The dynamic behaviors of the fluid are influenced by the variation of the pipe lengths. Other research works relate the cross-section of the pipe with the power produced and investigate how the length of the pipe influences of the behaviors of the fluid (Kesgin, 2005).

Backpressure exists in the exhaust system and a properly tuned exhaust system can improve the engine performance by reducing the backpressure (Bell, 1997). The study also showed that a free flowing exhaust system will provide about 10 hp useful powers due to less amount of pumping loss.

Since most of the studies focuses on the exhaust manifold, the objective of the present work is to experimentally study the diesel engine performance for different exhaust middle pipe configurations. The experiment is conducted using a diesel engine test bed fuelled by pure diesel fuel. The throttle opening is set at two positions i.e., 50% and 100% throttle openings. The parameters to be studied are torque, brake horsepower, Brake Mean Effective Pressure and specific fuel consumption.

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MATERIALS AND METHODS

The experiments were conducted at the Universiti Teknologi Petronas Centre of Automotive Research using Diesel Engine Test Bed which is equipped with a cubic capacity of 1753 cc 4 cylinder engine as shown in Fig. 1. The engine is fuelled using pure diesel and the exhaust system consists of a catalytic converter, muffler and 60 mm diameter exhaust pipe. The overall length of the exhaust assembly is 12.8 m. The specification of the engine test bed is tabulated in Table 1.

The experiment was carried out to observe the relationship between exhaust pipe configurations to the engine performance. The experiment has been conducted by using three different configurations of the exhaust pipe. The first experiment was initially done using the original exhaust pipe configuration with total length of 12.8 m long with three bends. Then, the experiment is repeated using 5.67 m with one bend and 8.24 m long with two bends. Fig. 2a, b and c below show the schematic diagram of the variation of the exhausts pipe configuration used for this study. The red circle indicated the joint of the pipe which can be unfastening to change the configuration of the exhaust pipe.

Experimental methodology: The experiments were conducted using pure diesel fuel and carried out in two phases based on 50 and 100% throttle opening conditions. In 100% throttle opening, the throttle was set to a maximum level while the 50% throttle opening can be considered as driving in normal condition or daily driving.

Table 1: Specifications of the diesel engine test bed

Make and Model	Power Products, XLD 418
Engine Type	Diesel, 4 cylinder, in-line OHC , Indirect Injection
Bore x Stroke	82.5 mm x 82 mm
Cubic Capacity	1753 cc
Compression Ratio	21.5 : 1
Power Output	44 kW at 4800 rpm
Torque	110 Nm at 2500 rpm

Fig. 1: Diesel engine test bed

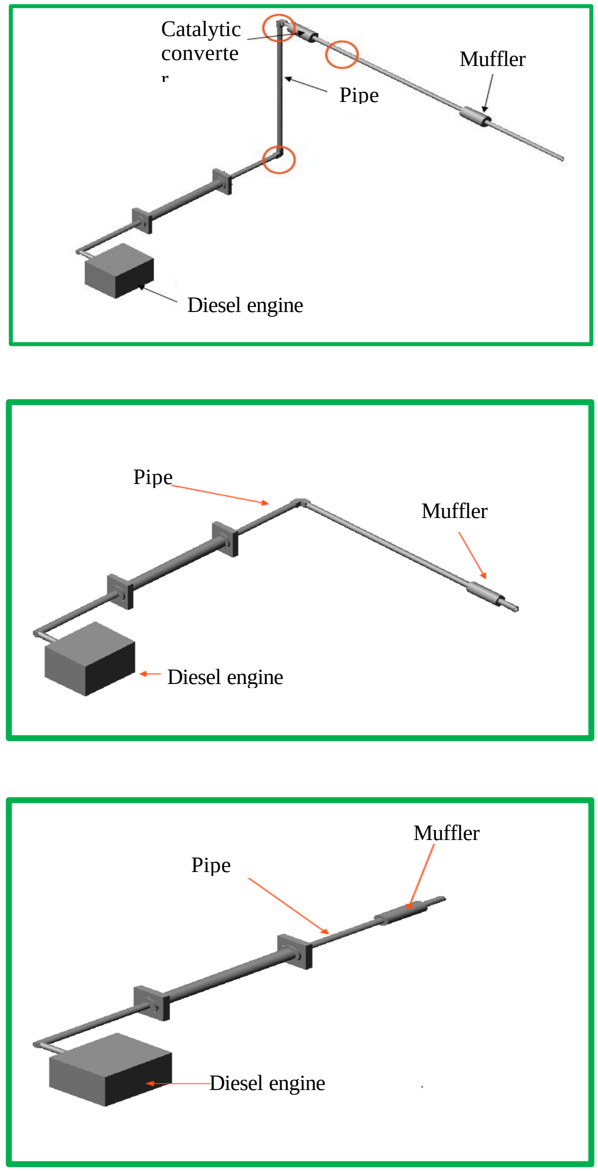

Fig. 2: (A-c) Variation of the exhausts pipe configuration for the experimental study

Fig. 3: Typical display of the engine test bed panel

The data recorded in the experiment were the Brake Horsepower, torque, Brake Mean Effective Pressure and specific fuel consumption. The readings were taken from the engine test bed panel which is shown in Fig. 3 below.

RESULTS AND DISCUSSION

Torque: Figure 4 and 5 are the variation of engine torque with respect to the engine speed for three different middle pipe lengths for the case of 50% and 100% throttle opening as measured in the experiments. At 50% throttle opening condition, the engine is producing 68 Nm torque at 2000 rpm engine speed. When the speed increases to 3000 rpm, the torque value reduces to 46 Nm and decreases further as the speed increases. At 100% throttle opening, the maximum torque is 88 Nm at 3000 rpm and reduces to 80 Nm at 4000 rpm as shown in Fig. 5.

The pattern of the torque are similar for different length of the exhaust pipe where the torque increases with the engine speed until reaching the maximum value and then the torque decreases as the speed increases. These findings agree with the theory as every engine cycle results in thrust caused by the combustion. The faster the engine cycles, the more thrust will be produced until reaching a point where the inefficiencies of the higher engine speed outweighs the benefits of the higher speed itself.

Brake horse power: Figure 6 and 7 show the variation of the bhp value with respect to the engine speed for three different middle pipe lengths for the case of 50% and 100% throttle opening as measured in the experiment. The graph of bhp vs. engine speed shows that the brake horsepower (bhp) is proportional to the engine speed. It is observed that for the 50% throttle opening condition, the bhp value increases with the increase of the engine speed and reaches the maximum value at 3000 rpm. However, the bhp value reduces as the engine speed reaches 4000 rpm. The trends of the bhp values are the same for different length of the pipe. The result for the exhaust pipe length of 5.67 m and 8.24 m is almost the same but for the 12.8 m exhaust pipe, the bhp value

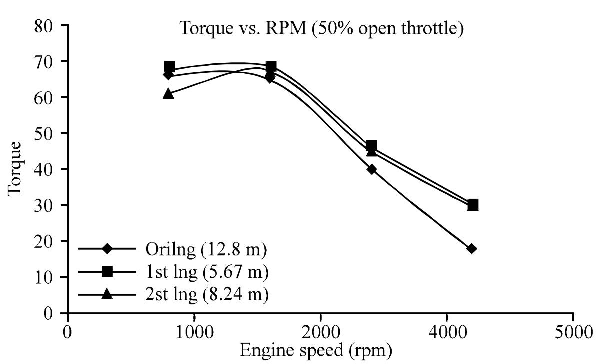

Fig. 4: Graph of Torque vs. engine speed (RPM) at 50% throttle

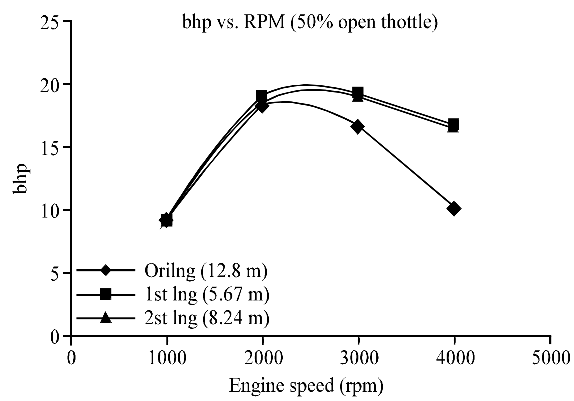

Fig. 6: Graph of bhp vs. engine speed at 50% throttle

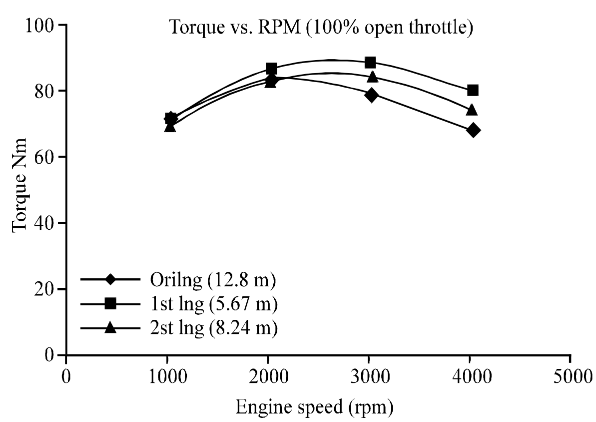

Fig. 5: Graph of Torque vs. engine speed at 100% throttle

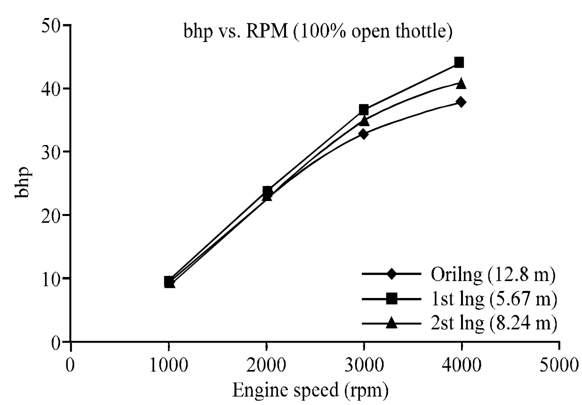

Fig. 7: Graph of bhp vs. engine speed at 100% throttle

drops by about 40% at 10.2 hp for the 4000 rpm engine speed as dipict in Fig. 6. For the 100% throttle opening, the results for all three different exhaust pipe lengths are almost the same except those at 4000 rpm engine speed. Although there is no significant difference of bhp values for all three different exhaust pipe configurations when the engine is running at 2000 rpm, the differences grow wider when the engine speed exceeds 2000 rpm and 3000 rpm for the 50% and 100% throttle opening conditions respectively.

Specific Fuel Consumption (SFC): Figures 8 and 9 show a variation of SFC with respect to the engine speed for three different exhaust middle pipe configurations for the case of 50% and 100% throttle opening as measured in the experiment. The graphs show the fuel consumption by the shorter exhaust pipe configuration is less than the fuel consumption by the original exhaust pipe system. The SFC decreases as the engine speed reaching 2000 rpm after which the SFC increases with the engine speed. The

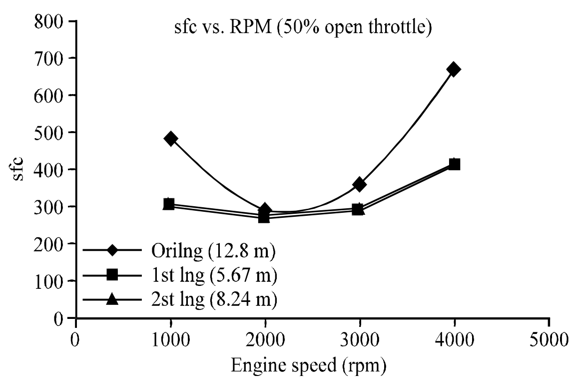

Fig. 8: Graph of specific fuel consumption vs. engine speed (50% open throttle)

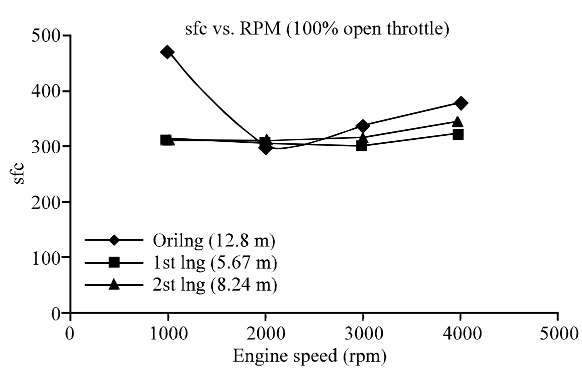

Fig. 9: Graph of specific fuel consumption vs. engine speed (100% open throttle)

higher SFC might be due to the warming up session required by the engine where much fuel is required to put the engine from cold state to its normal operational condition.

The SFC is higher at 1000 rpm particularly for the longest configuration whereas it should be similar for all configurations because at that engine speed, the engine is at idle state and no work is done yet. The discrepancy in initial SFC because the first experiment was started with the original exhaust system at cold engine condition while the second and third experiments were carried out after the engine is already in suitable temperature to operate. The SFC is lowest at >middle = rpm that is at 2000 rpm because the engine is tuned to develop best cylinder filling at middle revs; the engine's breathing is at highest efficiency at these speeds. At higher engine speeds, the frictional loses of the engine rise alarmingly and so the energy of combustion is again being wasted, this time in heating the oil. Low value of SFC is desirable as it use less fuel to produce work. SFC is lower when the engine is in high volumetric efficiency. Nevertheless, the exhaust pipe configuration does play an important role in the engine efficiency as it was related to the power required to push the gases along the pipe as shown by the variation of the SFC for different exhaust pipe configurations.

Brake Mean Effective Pressure (BMEP): Figure 10 and 11 show a variation of BMEP with respect to the engine speed for three different exhaust pipe configurations for the case of 50% and 100% throttle opening as measured in the experiment. The result for BMEP is quite similar with the result for the torque. The graph shows that the highest BMEP value which is 4.88 at 2000 rpm for 50% throttle opening and 6.29 at 3000 rpm for 100% throttle opening. The highest BMEP value are achieved by the shortest exhaust pipe configuration i.e. 5.67 m long exhaust pipe.

For 50% throttle opening, the BMEP value is reduced from 4.88 to 3.29 at 3000 rpm and 2.16 at 4000 rpm. For 100% throttle opening, the BMEP value only decrease after 3000 rpm. The value increases from 5.06 at 1000 rpm to 6.29 at 3000 rpm and decrease to 5.7 when engine speeds reached 4000 rpm. It makes the result look like parabolic curve. Both of the graph (50% and 100% throttle opening) show that the BMEP decreases with the increasing of pipe length. The longest exhaust pipe has the lowest value of BMEP. The BMEP is higher at 2000 rpm but decrease when the engine speed becomes 4000 rpm especially in 50% throttle opening. BMEP value becomes lower when the engine speed increase because the engine efficiency is lower due to friction and air viscosity. Longer pipe will have more friction and thus,

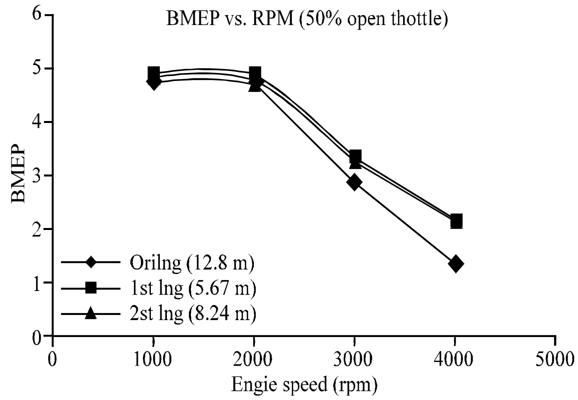

Fig. 10: Graph of BMEP vs. engine speed at (50% open throttle)

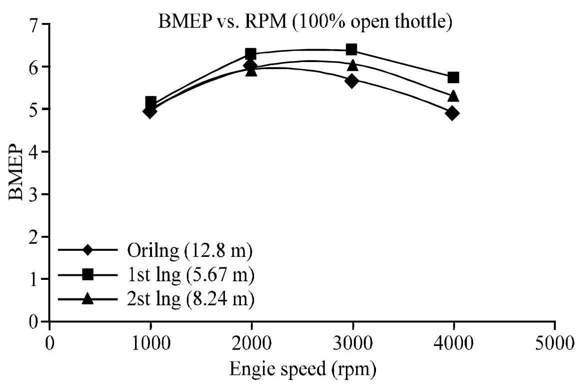

Fig. 11: Graph of BMEP vs. engine speed at (100% open throttle)

the longer pipe has the lowest BMEP value at 4000 rpm. BMEP is simply an effective comparison tool between different engines. It measures the efficiency of the conversion from the indicated mean effective pressure in the cylinder to the output shaft and the level of pressure attained in an engine. Higher value of BMEP would indicate higher performance of the engine. The bend in the pipe also affect the outputs of the engine. In the experimental result, it shown that the result for 5.67 m and 8.24 m pipe is quite similar. There is not much difference in term of value of the engine performance. The graph is almost similar especially in 50% throttle opening. The factor that differentiates their value is the bend. The bend in 8.24 m pipe causes the gas to slow down and hence the engine need more energy to push out the gas resulting in less useful power generated.

CONCLUSION

Both the length of the exhaust middle pipe and number of bends influence the engine performance characteristic. The number of bends gives greater impact to the engine performance as compared to the length of the exhaust pipe. The more bends installed in the exhaust pipe, the lower the engine output produced. The experimental results also confirm that the length of the pipe influences the performance characteristic of the engine. It can be clearly seen that different lengths do give different output value where the shorter exhaust pipe with less bend produces better diesel engine performance. Even though the variation of the length used in this work is consider small, but the differences in flow pattern and engine performance for different exhaust pipe configurations are noticeable especially at the engine speed greater than 2000 rpm.

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