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Original article

Investigation of the Effects of Air Filter Design Changes on Engine Performance and Emissions in Portable Single Cylinder Irrigation Engines

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Abstract

In this study, the effects of changing the design of the air filter of an internal combustion diesel engine on engine performance and harmful exhaust emissions are experimentally investigated. In an internal combustion engine, a sufficient amount of clean air intake must be provided for complete combustion of the fuel. Air filters are used to provide this clean air. Otherwise, the particles in the air entering the cylinder pose a threat to the engine. Filtering unwanted particles in the air entering the combustion chamber is important to prevent cylinder wear and extend engine life. However, incorrect air filter design adversely affects engine performance, increases fuel consumption and harms the environment by increasing exhaust emissions. Correct air filter design also affects engine wear, operating parameters and operating cost. In the experimental study, the air filter of a diesel engine was designed and made operational, the performance and exhaust emission tests of the engine were carried out and the results obtained were presented in graphs. Depending on the design changes, an increase in engine power and improvements in fuel consumption have been achieved. In addition, when the exhaust emissions were analysed, it was observed that the formation of HC, CO, decreased by an average of 7%, while NOx compounds increased by approximately 2%.

Keywords: Diesel Engine, Energy, Air Filter, Emission.

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INTRODUCTION

In order to ensure good combustion in engines, the amount of air taken into the cylinder, the oxygen level and cleanliness of the air in the cylinder are of great importance as well as the fuel. Air filter systems are used in internal combustion engines to prevent particles in the air taken into the cylinder from causing wear. The design of the air filter system is a complex issue due to the characteristics of modern engines, emission regulations, fuel economy and demands for greater comfort. Recently, the filter system includes the filter outer container and paper and the filter element. The primary function of the filter system is air filtration and flow management; the secondary function is related to acoustics, design and air mass sensing. For this reason, the filter element uses pleated papers to increase the filtration area due to space limitation. This means that the particle filtration efficiency varies depending on the filtration rate, particle and re-entrainment phenomenon above a critical value(Maddineni et al. 2019, Maddineni et al . 2018). One of the characteristic features of the air in the atmosphere is the dust concentration, measured as the mass of dust (in grams or milligrams) per 1 m^3. The dust concentration in the air varies depending on many factors. The pressure, humidity and temperature values of atmospheric air are of great importance for efficiency, power/torque and exhaust emissions in internal combustion engines. In addition, when the dust concentration in the air increases, if it is given to the engine without a good filtering, it will cause scratches and abrasions of the cylinder-piston assembly and as a result of all these, the engine will consume more fuel and oil. This situation increases both the cost of use and the level of harmful gases discharged from the exhaust to the environment. Therefore, all particulate matter <1 μm must be filtered from the inlet air of the motors to prevent premature wear of machine components(Dziubak et al. 2016.Chlopek et al.2012). These negativities are prevented with the filtration system for the air to be taken into the engine. Air intake system consists of air filter, air filter housing and air duct. These components on the system cause pressure drops that will lead to a decrease in engine power at high levels. Due to all these negativities on the air intake system, a 2-3% decrease in engine power occurs and this decrease is acceptable(Toma &Fileru. 2016, Jaroszczyk et al. 2004, Bugli&Green. 2005). When the studies in the literature are examined; a model has been developed to optimise the geometry of the air filter and to reduce the pressure drop and increase the filter usage area. With the optimisation in the intake system, combustion efficiency has been increased by providing improvements in the flow of air(Srinivasulu et al, 2016). In a different study, the lower part of the filter used in the existing system prevents the upward movement of the air. Therefore, the inlet passage was reorganised to provide a tangential upward movement. Thus, effective removal of larger dust and particles is achieved(Manikantan & Gunasekaran, 2013). In a study on air filter design, it was stated that air pressure losses and noise characteristics on the system vary according to geometry, sizing and material properties (Pehlivan, 2020, Lee et al,2017).

Unlike the literature; In this study, the effect of oil bath type air filter design changes on engine power and emissions was investigated. Better performance results were aimed by making minor design changes on the same filter container.

MATERIAL and METHOD

The design features of the oil bath air filter used as a material in the existing test engine were changed and the changes in the engine were analysed. In the new design, it is aimed to increase the volumetric flow rate by increasing the air filter inlet cross-section and the number of air inlet ducts.

Figure 1. Old type oil bath air filter

Figure 2. New type oil bath air filter

As can be seen in Figure 1, the inlet of the old type air filter was made circular. In the newly designed air filter, the air inlet duct was enlarged by using a square cross-section as shown in Figure 2. The connection cross-sectional area was thus increased from 1.38 cm2 to 1.62 cm2. The work achieved per cycle is primarily dependent on the amount of charge taken into the cylinder at the time of intake. Due to aerodynamic losses, the pressure of the air sucked into the cylinder is lower than the atmospheric pressure and the temperature is much higher, which affects the volumetric efficiency and causes changes in the characteristic properties of the engine (Wang et al. 2015).

Figure 3. Old type air filter inlet diameter 43 mm

Figure 3 shows the suction ducts of the old type air filter. The air inlet diameter of the old type filter is 43 mm.

Figure 4. New type air filter inlet diameter 60 mm

The inlet cross-section of the new type air filter is designed as 60 mm and the number of air inlet ducts has been increased. After all modifications were completed, the old type air filter shown in Figure 1 was installed first. In order to ensure the operating conditions of the engine, the engine was run without load until the radiator water temperature reached 82°C. Then, tests were carried out by applying 25-50-75-100% load to the engine with the existing air filter. After the tests applied to the old air filter were completed, the newly designed air filter shown in Figure 2 was installed in the engine.

The newly designed air filter is shown in figure 4. The technical specifications of the engine used in the tests are given in Table 1. Then, engine tests and exhaust emission measurements were carried out with old type and newly designed air filters.

Table 1. Engine specifications

Feature	**Value**
Engine type	Erin Industrial diesel engine
Displacement (lt)	1.16
Valves	4
Power (kW at rpm)	18 / 2400
Bore (Ø mm)	108
Stroke (mm)	127
Fuel supply system	Bosch 1.050 Bar High-Pressure Mechanic Pump
Compression ratio	14.6 : 1
Engine cooling system	Water
Engine weight (kg)	169

The test engine and setup used for air filter experiments are shown in Figure 5.

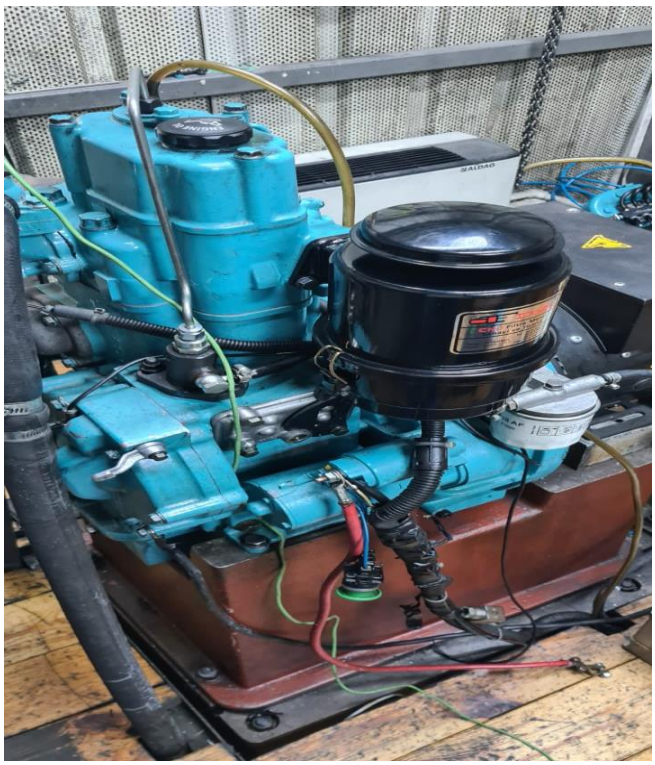

Figure 5. Test engine setup

In the experiments, the test speed was fixed at 1500 rpm and the engine load was gradually increased by 25-50-75-100%. Depending on the experimental results, graphs of the changes in the engine's characteristic features and emission levels were drawn.

RESULTS and DISCUSSION

As seen in Figure 6, the output power of the motor has increased with the new filter design at all motor loads. The main reason for this is that more air is taken into the cylinder of the engine with the design made.

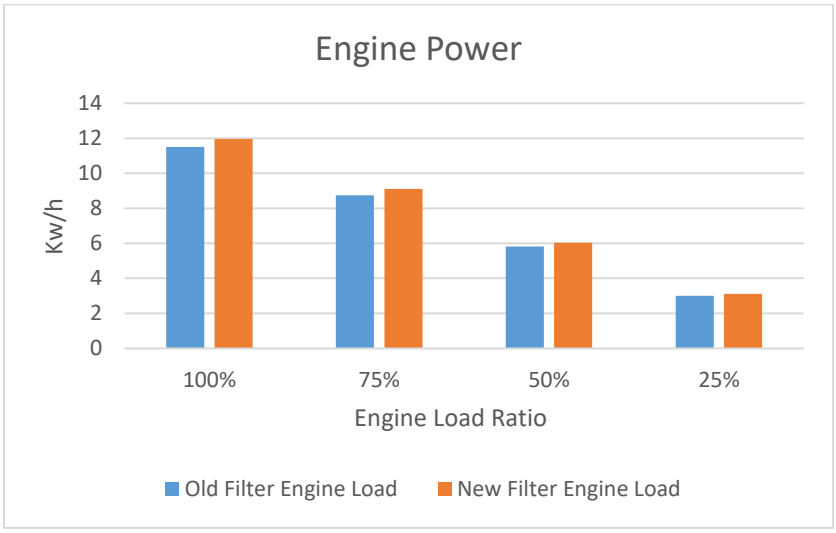

Figure 6. Effect of old and new filter on engine power according to engine load

As seen in Figure 7, CO levels in exhaust emissions after combustion decreased at all engine loads. Due to the increased air intake into the cylinder, combustion improved and CO content decreased. In other words, the decrease in the amount of CO in exhaust emissions indicates that the combustion is improved.

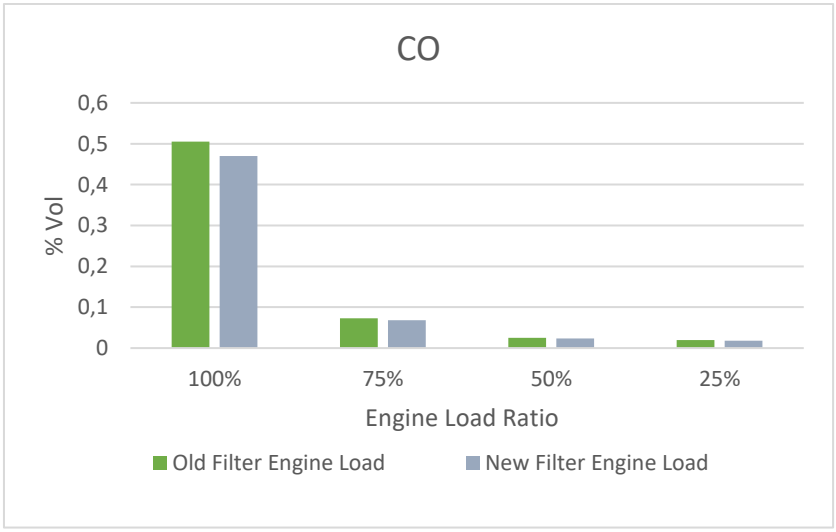

Figure 7. Effect of old and new filter design on CO level in exhaust emissions

As seen in Figure 8, unburned hydrocarbons in exhaust emissions are reduced with the new filter design at all engine loads. With the new filter design, the reduction of hydrocarbons in exhaust emissions was more effective at 25% and 50% engine loads.

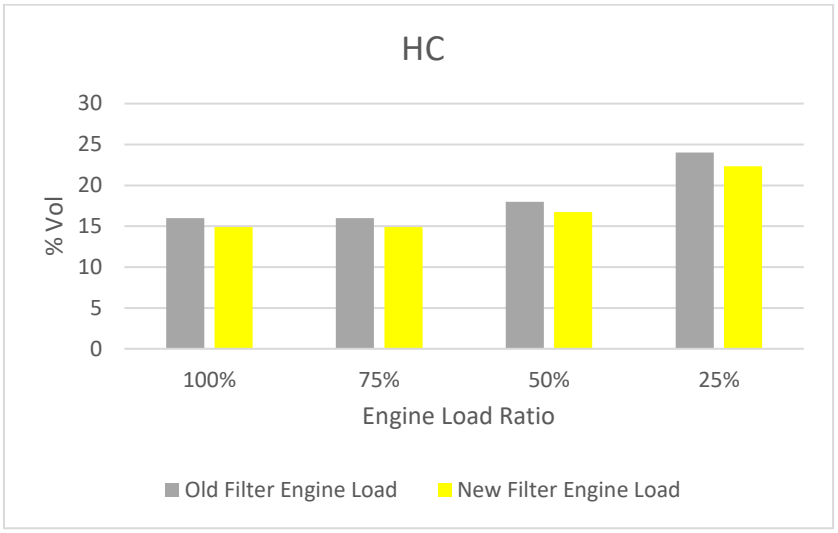

Figure 8. Effect of old and new filter design on HC level in exhaust emissions

As seen in Figure 9, NOx levels in exhaust emissions decreased at all engine loads with the new filter design. The reason why there is not a big difference in the NOx levels in the exhaust emissions is the improved combustion and the increased temperature inside the cylinder. With the new filter design, combustion has improved and the temperature in the cylinder has increased. Since the temperature increase caused NO_x formation, it could not be reduced further.

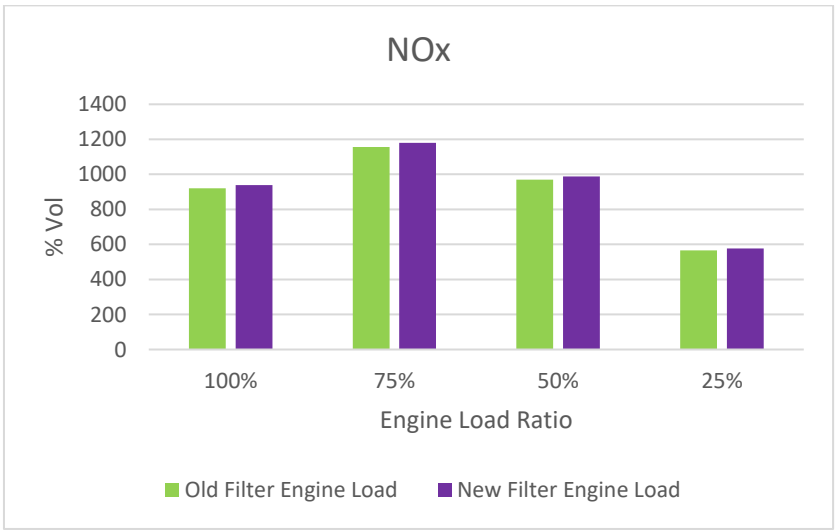

Figure 9. Effect of old and new filter design on NO_x level in exhaust emissions

When Figure 10 is examined, it is seen that the new filter design reduces fuel consumption at all engine loads. It was determined that the new filter design provides benefits by saving fuel and reducing harmful gases released into the environment.

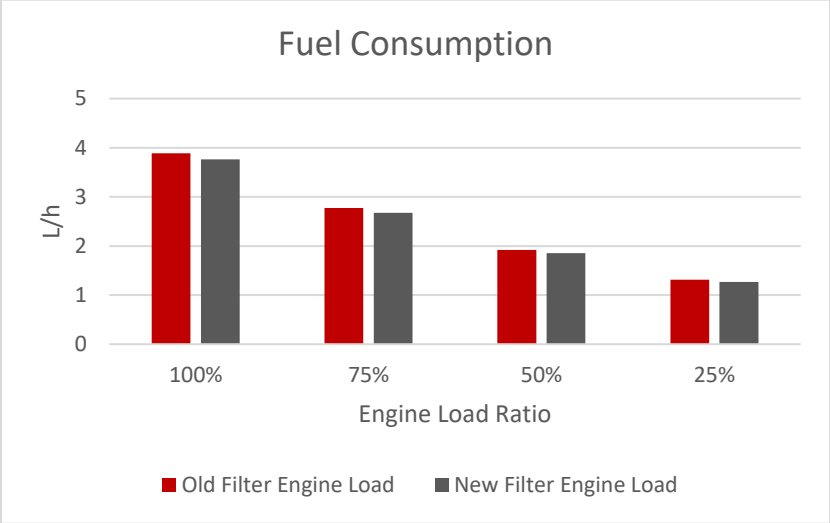

Figure 10. The effect of old and new filter design on engine fuel consumption

Conclusion

This study was carried out at Erin Engine R&D Centre and a new type of air filter was designed for single cylinder engines used for agricultural irrigation. With the use of the new type of air filter, improvements in engine characteristics and exhaust emissions were achieved under all test conditions.

In the experimental study, the air filter of a diesel engine was designed and made operational and the results obtained by performing performance and exhaust emission tests of the engine were presented in graphs. Depending on the design changes made in the air filter, approximately 4% increase in engine power and 4% savings in fuel consumption were achieved. In addition, when the exhaust emissions were examined, it was observed that HC, CO formation decreased by an average of 7% while NOx compounds increased by about 2%. As a result of better combustion in the cylinder with the newly designed air filter, it was found that there was a small increase in NO_x emissions as the temperature increased.

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