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The Effect of Different Intake Air Filters on DI Diesel Engine Combustion and Its Exhaust Characteristics

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Abstract:
The role of an efficient air filter in an engine setup has increased mainly due to stringent emission regulations. The air contains lots of impurities with different sizes which by entering into the engine will cause many adverse effects to its working and performance. The DI diesel engine is operated by adopting different air filters with varied sizes, models and filtering materials. The experimental results are recorded and analyzed. This Paper deals with the discussion on the engine combustion and exhaust characteristics. When operated with different air filters (viz., AFM1, AFM2, AFM3 and AFM4). Simulation is also carried out and the experimental results are compared with them for validation.

Keywords: DI Diesel Engine, Intake Air Filters, Performance & emissions.

1. INTRODUCTION

The emission formation processes are intimately linked with the primary fuel combustion process either directly through chemical reactions or indirectly through environment conditions created by these reactions. The combustion of fuel-air mixture in internal combustion engine provides energy release along with composition changes. Thus internal combustion engine provides energy release along with composition changes[4&5]. The emission from the exhaust also depends upon the air quality because the percentage of air involvement in the combustion process is higher even than the fuel. The air contains lots of impurities of different sizes, minerals, very rough and with rugged shapes. Lots of them are invisible for the human eye, which has the minimum visibility dimension of 20µm[7]. by entering cause the reduction of the engine life. The IC engine wear inside the cylinder is influenced by the dust from the atmosphere which passes through the air filter. The filtering efficiency characterizes the quantity and the dimensions of dust particles that pass through the filter. It mainly influences the engines wear. The air filters are designed to increase their efficiency while they are loaded with dust layers. Even in small quantity, the dust from the air significant improves the filter efficiency [9&10]. The combustion characteristics such as heat release rate (HRR), cylinder pressures are presented and discussed. The exhaust gas emissions CO, CO_2, NOx, UBHC, O_2, and smoke are also presented and discussed. The discussion is presented and supported by experimental results. In the experimentation the DI diesel engine is operated by adopting different air filters with varied sizes, models and filtering materials. To make comparative study, initially the engine is run at constant speed without air filter as a base line mode. At each operating conditions the parameters like load onto the engine, fuel and air flow rates are measured. The engine is run by adopting one type of filter at once at different loads.

2. EXPERIMENTAL SETUP

The experimentation is carried out on a single cylinder, four stroke, water cooled, DI engine. The test set up is developed to carry out set experimentation procedures. The layout of the experimental set up is shown in the Fig. 2.1. and Fig. 2.2 shows Photographic View of Computerized Experimental Diesel Engine Setup.

2.2 Experimentation Procedure

The experiments are conducted on test engine in different stages. The engine is experimented without air filter considering as baseline operation to make the comparison study. In second stage the engine is run by adopting the air filter of type 1 (AFM1) - Model No. NF 1004 both with new and clogged filters one after the other. In third stage the engine is run by adopting the air filter of type 2 (AFM2) - Model No. NF615 both with new and clogged filters one after the other. In fourth stage the engine is run by adopting the air filter of type 3 (AFM3) - Model No. NF560 both with new and clogged filters one after the other. In fifth stage the engine is run by adopting the air filter of type 4 (AFM4) - Model No. 0313AC2261N both with new and clogged filters one after the other.

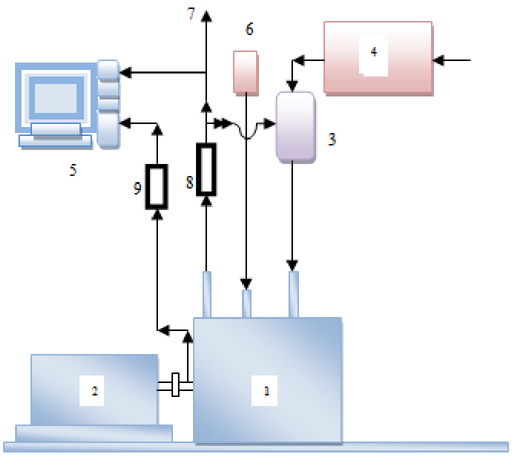

Figure.1. Layout of Experimental Set up

1) Engine, 2) Dynamometer, 3) Air Filter Housing, 4) Air surge tank, 5) Computerized data acquisition, 6) Diesel fuel tank, 7) Exhaust Manifold, 8) Exhaust gas recirculation unit, 9) Crank angle encoder.

Table.1. Engine specification

Make	Kirloskar AV-1
Engine type	4- stroke single cylinder diesel engine(water cooled)
Rated Power	3.7KW, 1500rpm
Bore & stroke	80mmx110mm
Compression rate	16.5:1 (Variable From 14.3to20)
Cylinder Capacity	553cc
Dynamometer	Electrical-AC alternator

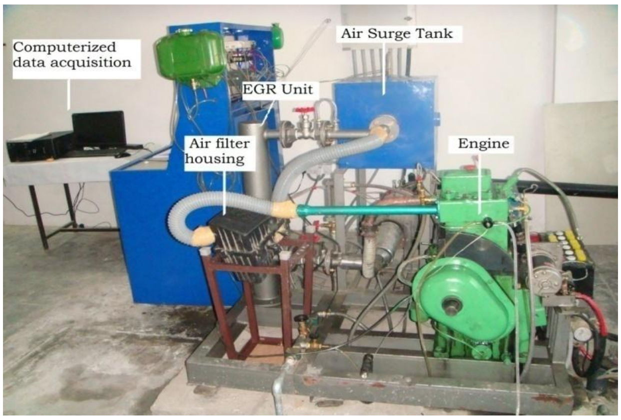

Figure.2. Photographic View of Computerized Diesel Engine Setup with Air Filter Housing Arrangements and EGR Facility

Figure.3. (a) AFM1 (OLD& NEW)

Figure.3. (b) AFM2 (OLD& NEW)

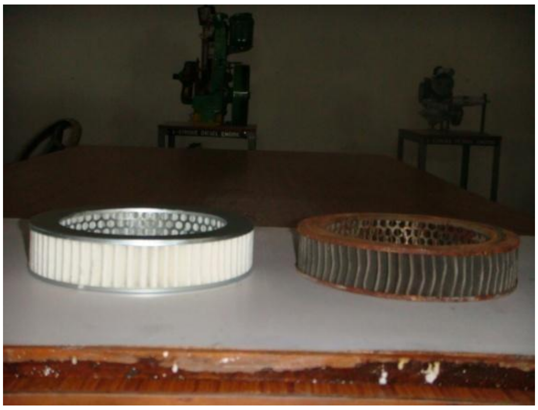

Figure.3.. (c) AFM3 (OLD& NEW)

Figure.3. (d) AFM4 (OLD& NEW)

3. RESULTS AND DISCUSSION

3.1 COMBUSTION CHARACTERISTICS

The effect of air filter condition on combustion characteristics such as cylinder pressures heat release rate (HRR) studied and analysed by drawing the graphs combustion characteristics vs crank angle on to the engine. The study is made by fitting different air filters at different conditions.

3.1.1 Cylinder Pressure

Cylinder pressure is one another parameter considered for studying the effect of air filter condition on performance of the engine. Cylinder pressure values are plotted against crank angle position in degrees. For different filters such as AFM1, AFM2, AFM3 and AFM4 by their conditions initially engine is run without filter for comparative study.

The fig 3.1.1 (a) depicts the variation of cylinder pressure against crank angle when filter AFM1 is adopted at different conditions such as new and old. It also compares the values when engine run without filter.

The simulated values are also compared in the figure. It is observed from the figure that the peak cylinder pressures are at same crank angle for two different conditions of filter old and new.

But initially the engine without filter was shown more pressure values for cylinder pressure. Similarly the figures 3.1.1 (b) to 3.1.1 (d) depicts the variation of cylinder pressure against crank angle when filters AFM2, AFM3 and AFM4 are adopted at two different conditions old and new respectively. These figures also compare the values when the engine is run without filter. The simulated values are also compared in the figures.

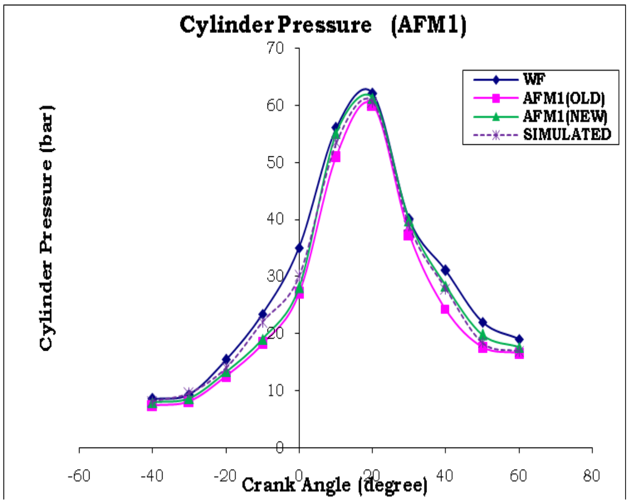

Figure.1. (a) Effect of cylinder pressure adopting AFM1

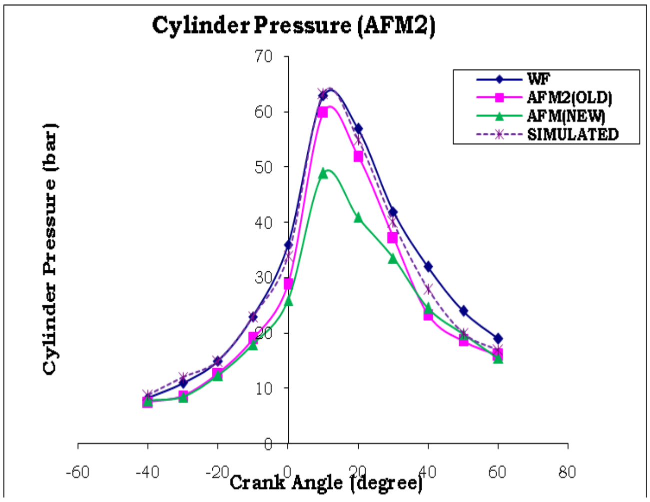

Figure.1. (b) Effect of cylinder pressure adopting AFM2

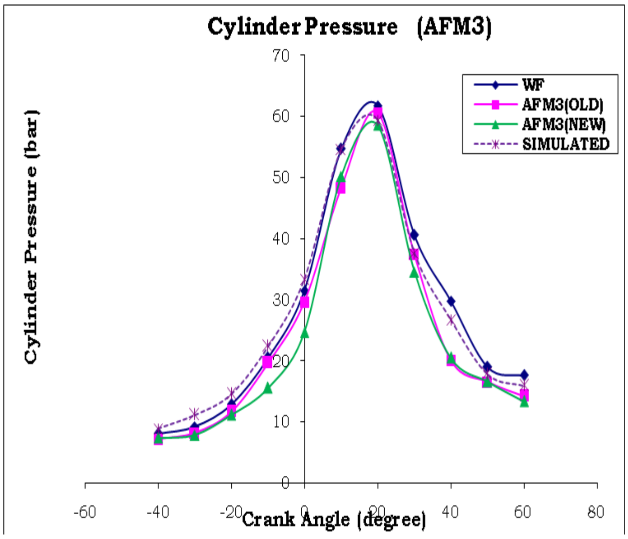

Figure.1. (c) Effect of cylinder pressure adopting AFM3

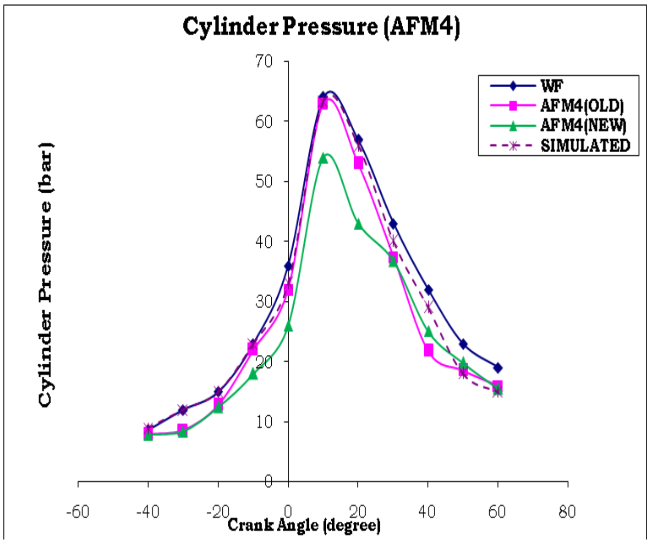

Figure.1. (d) Effect of cylinder pressure adopting AFM4

3.1.2 Heat Release Rate

Heat Release rate is considered as one more parameter for studying the effect of air filter condition on performance of the engine. Heat Release rate values are taken to plot the graph against crank angle in degrees. The graphs are drawn for filter types AFM1, AFM2, AFM3 and AFM4 for two different conditions old and new. The comparison is made for engine running without filter.The fig 3.1.2 (a) explains the variation of heat release rate against crank angle when filter AFM1 is adopted at different conditions of new and old. It is observed from the figure that the heat release rate is having highest nearly at TDC position of the piston. Similarly the figure 3.1.2 (b) to 3.1.2 (d) depicts the variation of heat release rate against crank angle when filters AFM2, AFM3 and AFM4 are adopted at two different conditions old and new respectively. The figures also compares when the engine is run without filters. The simulated values are also compared in the figures. It is observed from the figures that the heat release rate is having highest at nearly at TDC position for all the filters.

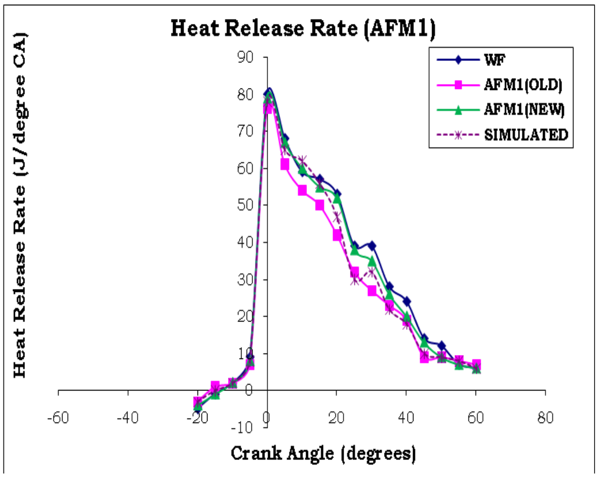

Figure.2. (a) Effect of Heat release rate adopting AFM1

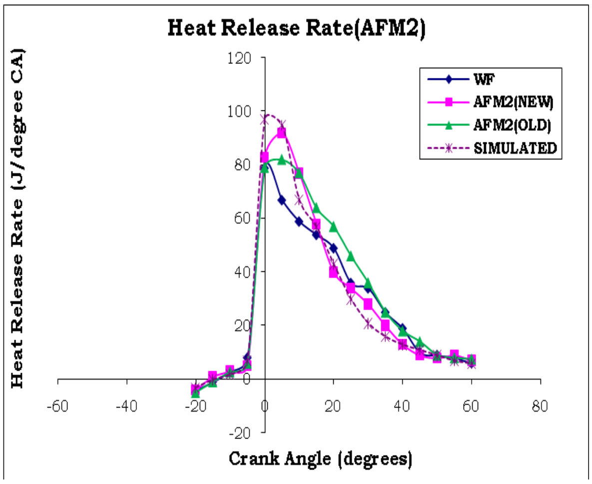

Figure.2. (b) Effect of Heat release rate adopting AFM2

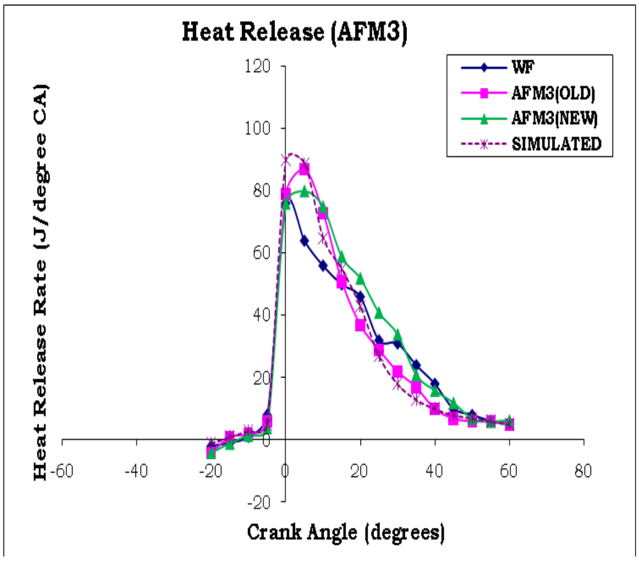

Figure.2. (c) Effect of Heat release rate adopting AFM3

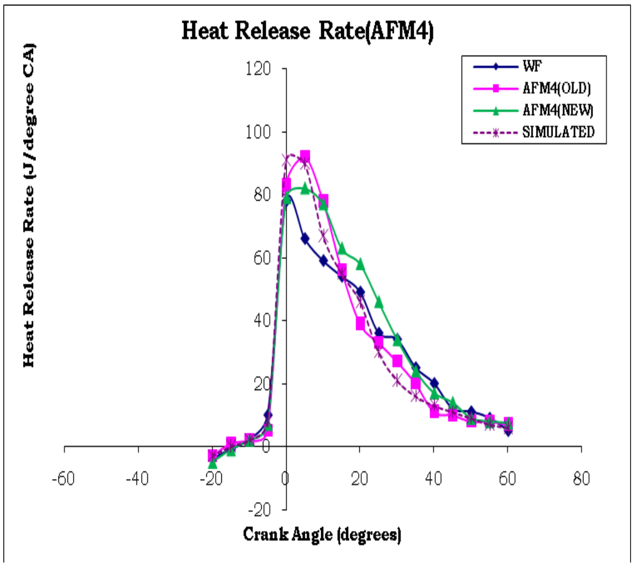

Figure.2. (d) Effect of Heat release rate adopting AFM4

3.2 EXHAUST GAS EMISSIONS

The effect of air filter condition on the exhaust gas emissions CO, CO_2, NOx, UBHC, O_2, and smoke are also presented by drawing the graphs exhaust gas emissions vs load on to the engine. The study is made by fitting different air filters at different conditions.

3.2.1 Carbon monoxide (CO)

The air filter condition affects the CO emission from the engine exhaust. This is studied by adopting different air filters at new and old conditions. The CO emissions are recorded and plotted in the graphs. Figure 3.2.1(a) to 3.2.1(d) shows CO in the exhaust emission from the engine for AFM1, AFM2, AFM3 and AFM4 respectively. From figure 3.2.1(a) it is observed that the values of CO emission are little lower when engine runs without filter. The CO values are higher at lower loads when runs with filter, and further they are reduced at higher loads. At lower loads the values of CO are in the range of 50 to 65 g/kW-h. However they are recorded very low at higher loads and are in the range of 10-25 g/kW-h. Similarly from figures 3.2.1(b) to 3.2.1(d) for air filters AFM2, AFM3, AFM4 it is observed that the CO values are little lower when engine runs without filter. The CO values are little higher at lower loads at lower loads but further they are recorded lesser when load on to the engine is increased

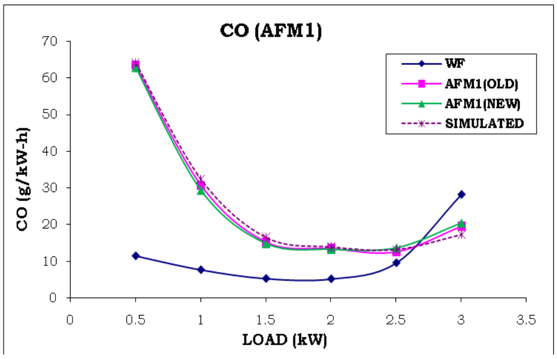

Figure.3.(a) Effect of CO adopting AFM1

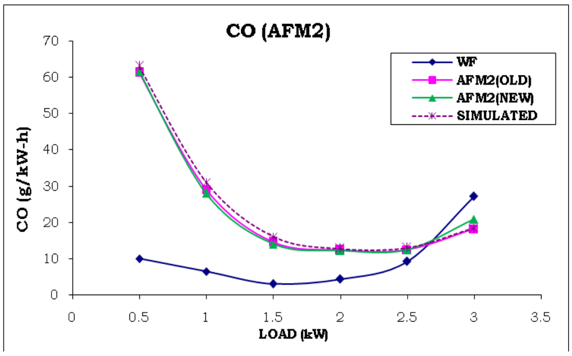

Figure.3. (b) Effect of CO adopting AFM2

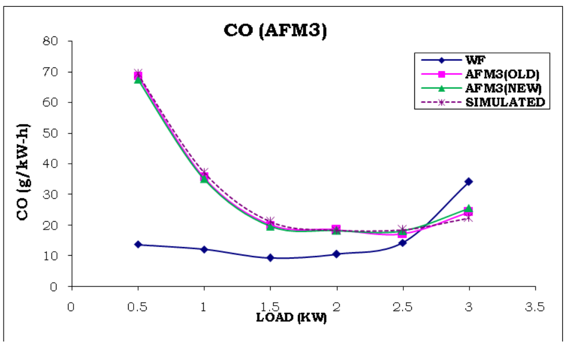

Figure.3. (c) Effect of CO adopting AFM3

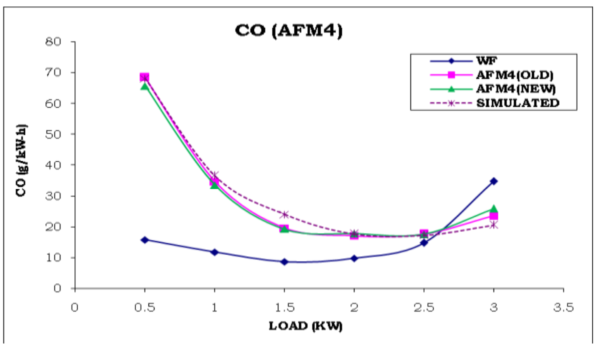

Figure.3.(d) Effect of CO adopting AFM4

3.2.2 Carbon dioxide(CO_2)

From figure 4.3.2(a) it is observed that the values of CO_2 emission are little higher when engine runs without filter. The CO_2 values are lower at lower loads when runs with filter, and further they are increasd at higher loads. At lower loads the values of CO_2 are in the range of 2 to 4%. However they are recorded low at higher loads and are in the range of 3 to 5%. Similarly from figures 3.2.2(b) to 3.2.2(d) for air filters AFM2, AFM3, AFM4 it is observed that the CO_2 values are little higher when engine runs without filter. The CO_2 values are little higher at lower loads at lower loads but further they are recorded higher when load on to the engine is increased.

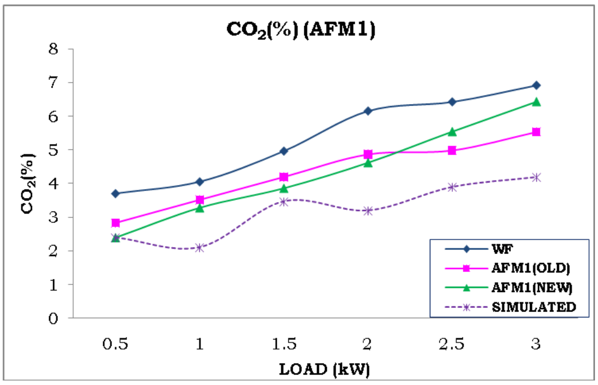

Figure.4. (a) Effect of CO_2 adopting AFM1

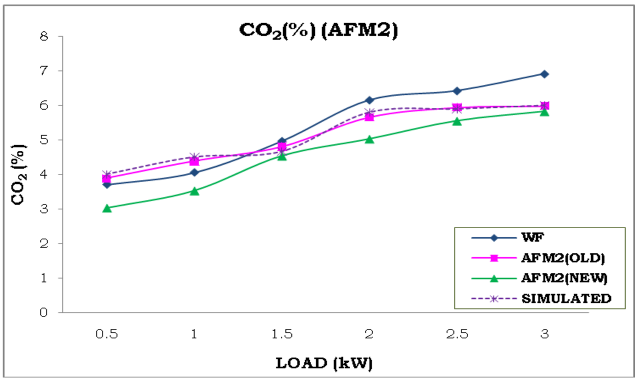

Figure.4. (b) Effect of CO_2 adopting AFM2

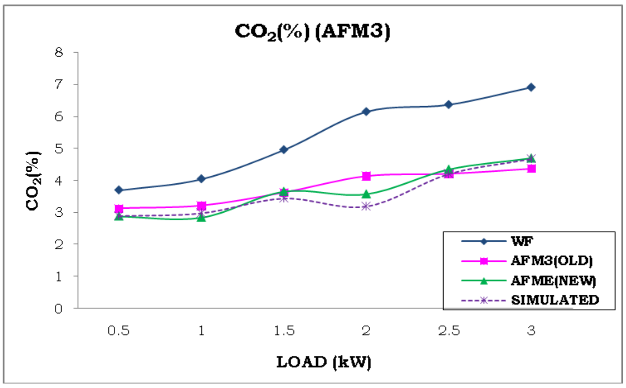

Figure.4. (c) Effect of CO_2 adopting AFM3

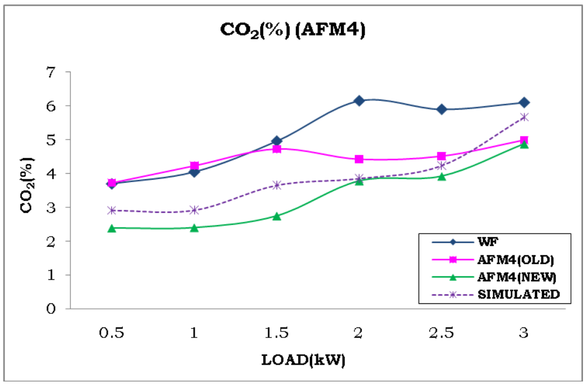

Figure.4. (d) Effect of CO_2 adopting AFM4

3.2.3 NOx Emission

Figures 3.2.3(a) to 3.2.3 (d) shows NOx emitted from the engine for AFM1, AFM2, AFM3 and AFM4 respectively. In figure 3.2.3 (a) it is noted that, the values of NOx are lower compared to old filter. Also it is noted that NOx values are very high when the engine is run without filter. The values of NOx remain in the range 15 g/kW-h to 45g/kw-h when engine runs without filter, and they remain with range between 10g/kW-h to 15g/kW-h for new filters. It is remarkable range which is observed the percentage difference in old and new filter values are lying in the range of 2 to 10%. Similarly from figure 3.2.3 (b) to 3.2.3 (d) it is observed that, the NOx values are higher when the engine runs without filter and range of NOx values remain between 12to 48g/kW-h.

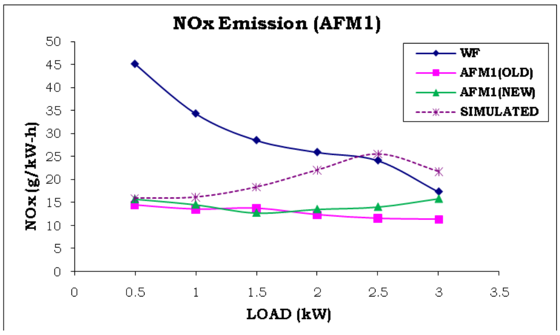

Figure.5. (a) Effect of NO_X adopting AFM1

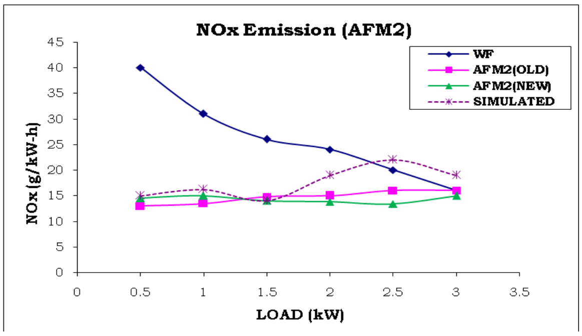

Figure.5. (b) Effect of NO_X adopting AFM2

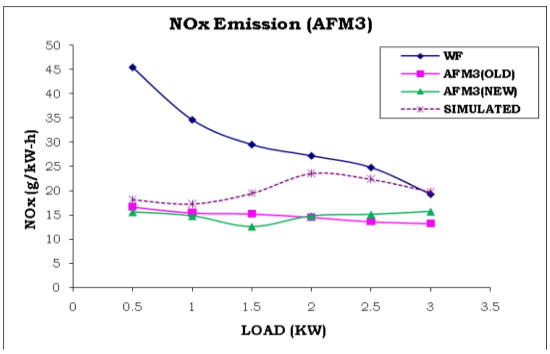

Figure.5. (c) Effect of NO_X adopting AFM3

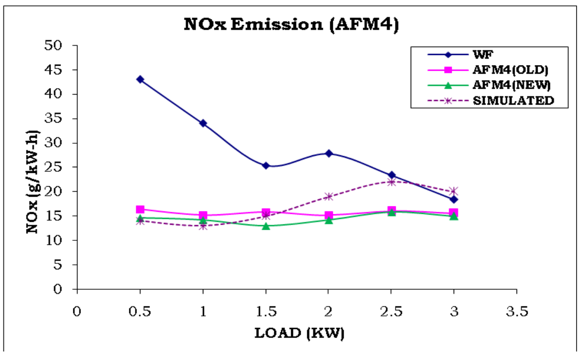

Figure.5. (d) Effect of NO_X adopting AFM4

3.2.4 UBHC Emission: The Figure 3.2.4(a) to 3.2.4 (d) shows UBHC in the exhaust emission from the engine for AFM1, AFM2, AFM3 and AFM4 respectively. In figure 3.2.4 (a) it is noted that the values of UBHC are little lower for without filter the UBHC values are little higher for lower loads but further they are recorded lesser when load on to the engine is increased. At lower loads the values of UBHC are in the range of 7 to 8 g/kW-h. However they are recorded very low at higher loads and are in the range 0.5 to 2 g/kW-h. Similarly from figure 3.2.4 (b) to 3.2.4 (d) it is observed that the UBHC values are little lower for condition of without filter for air filters AFM2, AFM3 and AFM4. The UBHC values are little higher at lower loads but further they are recorded lesser when load on to the engine is increased.

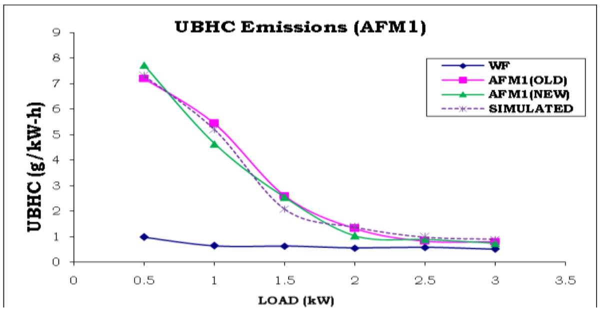

Figure.6. (a) Effect of UBHC adopting AFM1

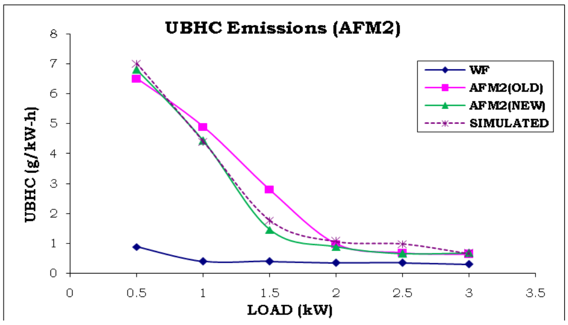

Figure.6. (b) Effect of UBHC adopting AFM2

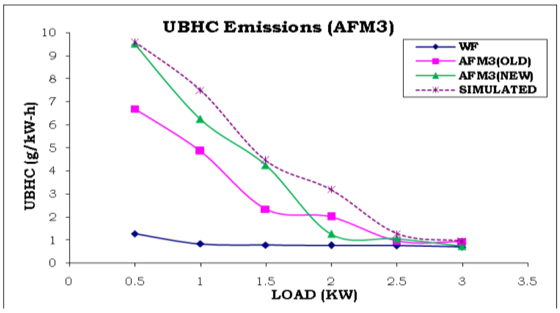

Figure.6. (c) Effect of UBHC adopting AFM3

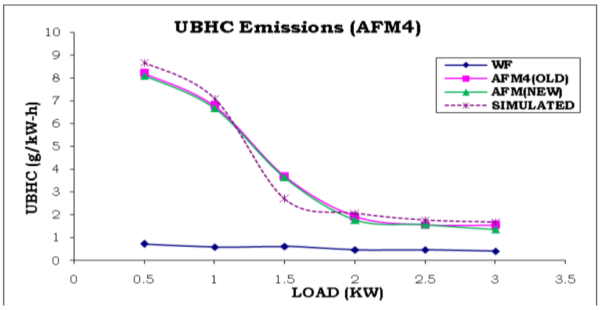

Figure.6. (d) Effect of UBHC adopting AFM4

3.2.5Smoke

In figure 3.2.5 (a) it is observed that, the smoke values are higher when the engine run without filter. They are in the order of 15 to 25 HSU. It is noted that the older. As depicted in the figure that the smoke level is increased for higher loads. The percentage difference in the smoke values for new and old filter is marginally lying in the range of 2 to 5%. Similarly from figure 3.2.5 (b) to 3.2.5 (d) it is observed that, the smoke values are higher when the engine is run without filter. They are also in the order of 18 to 28 HSU. It is noted that the new filters of AFM2, AFM3 and AFM4 gives lower smoke than the older. As depicted in the figures that the smoke level is increased for higher loads.

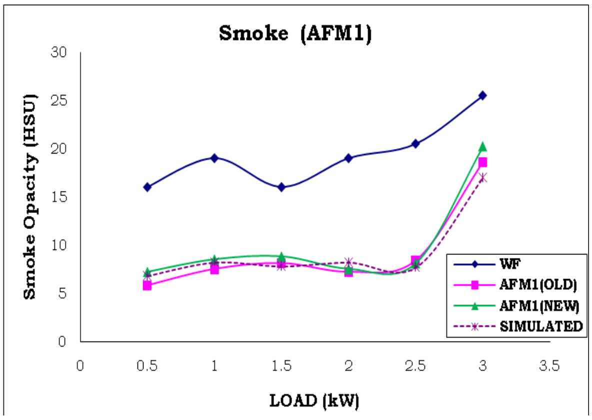

Figure.7. (a) Effect of smoke adopting AFM1

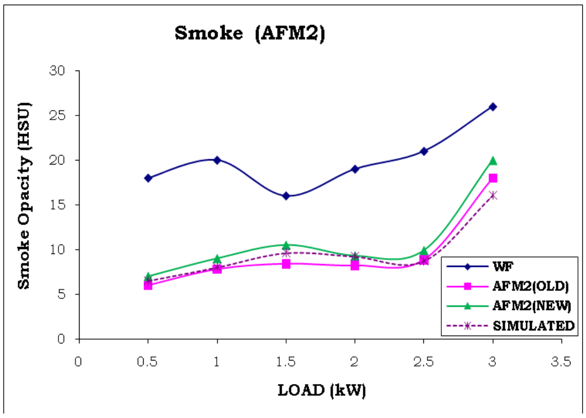

Figure.7. (b) Effect of smoke adopting AFM2

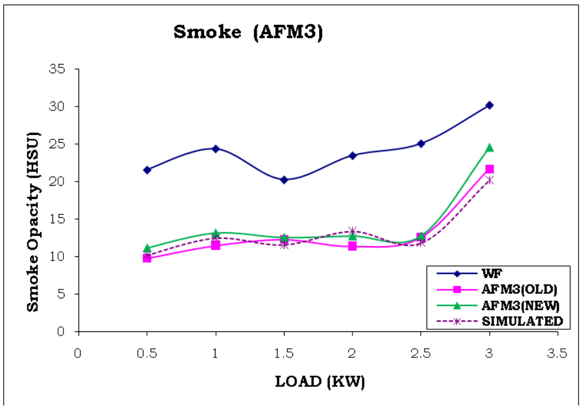

Figure.7. (c) Effect of smoke adopting AFM3

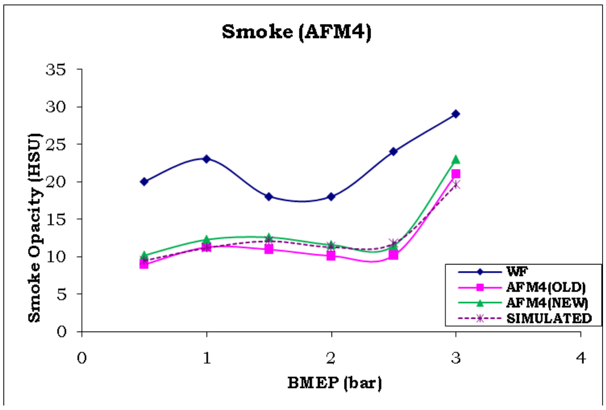

Figure.7. (d) Effect of smoke adopting AFM4

4. CONCLUSIONS

In the present work experiments have been carries out to study the impact of engine performance and its emissions using different intake air filters, the following observation were made.

- The filters adopted in the experiments are having resin- impregnated cellulose paper, because they are the low cost and the ability to pleated into densely packed pleated block with well defined pleat shapes.
- Heat release rate shown gradual increased rate at combustion stage in the range of 25 to35 J/oCA for new filter. This is due to the uniform supply of quality air.
- Carbon monoxide emissions are in the range of 5 to 10g/ KW-h at lower loads for all filters due to less oxygen availability, however they are drastically reduced when the engine operated at closer to rated load. This is due to increase in pressure differential across the filter and the amount of air induced in the cylinder. However AFM2(NEW) filter has given lower CO emission in the range of 2 to 4% lower because its better geometrical design.
- The NOx emissions are less by 10 to 15 g/KW-h with modified filters compared to conventional old filters. This is due to lower temperature of the air entering through filter instead of directly entering into the engine cylinder.
- Unburned hydrocarbon emissions are higher by 8g/KW-h for all the types of filters at lower loads when compared to engine running without filters. Because of their importance in filtering atmospheric air.
- It is observed in the present work the smoke emissions are similar trend lying in the range of 2 to 5%. This due to increase in smoke with increase in engine load due to overall richer fuel-air ratios, longer duration of diffusion combustion phase and reduced oxygen concentration.
- The filter AFM4 has given better results in brake thermal efficiency for a 15% of exhaust gas recirculation due to the design factors of AFM4 filter.

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