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THE EFFECT OF DIFFERENT INTAKE AIR FILTERS ON DI DIESEL ENGINE PERFORMANCE

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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 performance, 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 performance characteristics such as brake thermal efficiency(BTE), brake specific fuel consumption(BSFC), volumetric efficiency(η_{vol}), exhaust gas temperature(EGT), and 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.

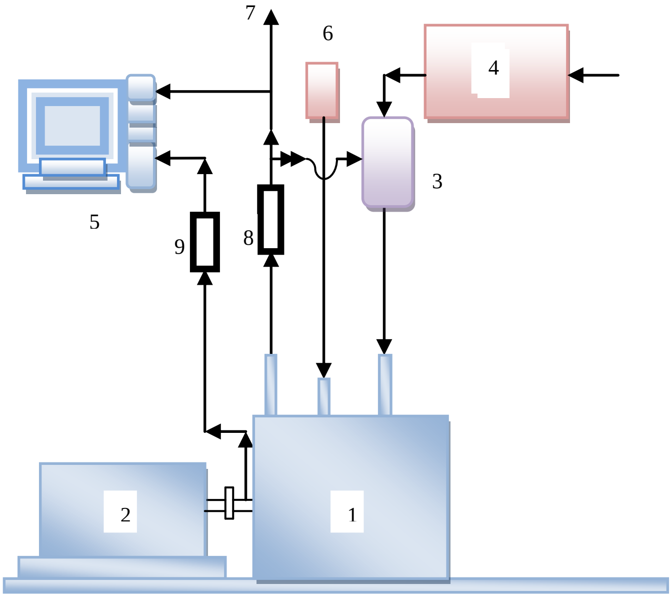


Fig: 2.1 Layout of Experimental Set up

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.

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

Table.1 Engine specification

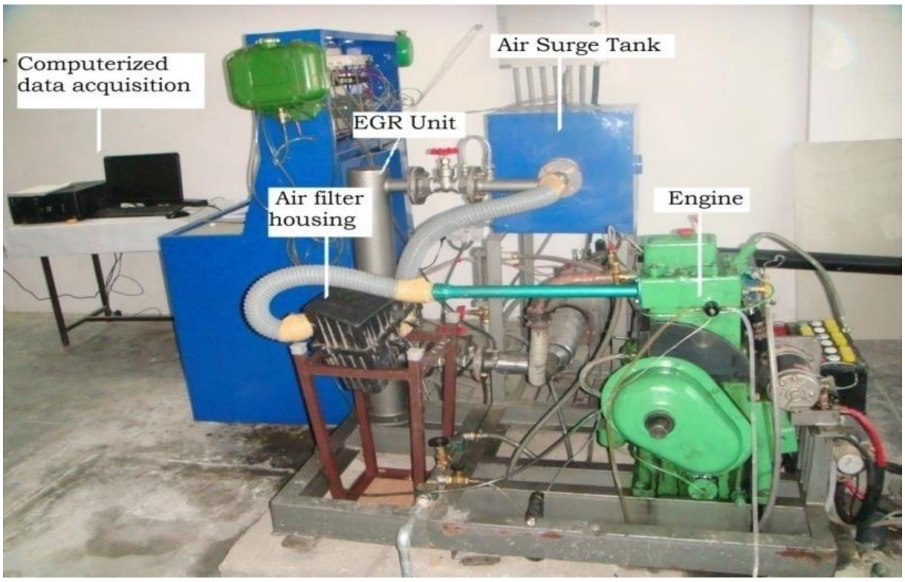


Fig: 2.2 Photographic View of Computerized Diesel Engine Setup with Air Filter Housing Arrangements and EGR Facility

Fig: 2.4(a) AFM1 (OLD& NEW)

Fig: 2.4 (b) AFM2 (OLD& NEW)

Fig: 2.4 (c) AFM3 (OLD& NEW)

Fig: 2.4 (d) AFM4 (OLD& NEW)

3. RESULTS AND DISCUSSION

3.1 PERFORMANCE CHARACTERISTICS

The effect of air filter condition on performance characteristics such as brake thermal efficiency(BTE), brake specific fuel consumption(BSFC), volumetric efficiency(η_{vol}), exhaust gas temperature(EGT) studied and analysed by drawing the graphs performance characteristics vs load on to the engine. The study is made by fitting different air filters at different conditions.

3.1.1 Brake Thermal Efficiency (BTE)

The effect of air filter condition on break thermal efficiency studied by plotting the graphs BTE vs Load. The study is made by adopting different air filters of different model AFM1, AFM2, AFM3 AND AFM4. The engine initially run without filter and compared each filter for new and old conditions. The simulated values are also considered for validation and comparison. From figures 3.1.1(a) to 3.1.1(d). Shows the BTE vs Load, for different filters. In the all the figures it is observed that all the filters are showing the similar trend to follow. As in fig 3.1.1(a) it is observed that the engine has performed well without filter when compared to old and new filters but the new filter has shown better brake thermal efficiency then the old. The percentage differences between old and new filters are in the range of 3 to 5%. When AFM2 is adopted as in fig3.1.1 (b) the engine has performed well without filter. But the new filter adopted has shown better brake thermal efficiency than the older filter. The percentage difference between old and new filters is in the range 6%to 10%. The figure 3.1.1(c) is drawn when AFM3 is used. The engine has performed well without filter when compared to old and new filters. But the new filter has shown better efficiency than the older. The percentage difference between old and new filters are in the range of 5 to 25%. The figure 3.1.1(d) is drawn when AFM4 is used. The engine has performed well without filter when compared to old and new filters.

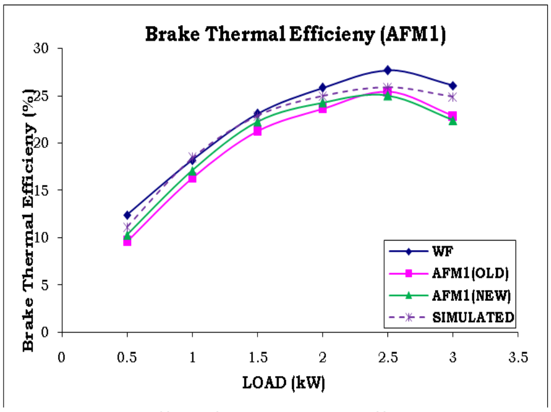


Fig: 3.1.1(a) Effect of Brake thermal efficiency adopting AFM1

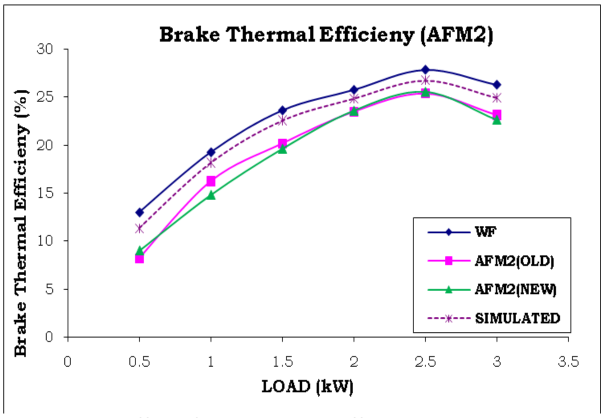


Fig: 3.1.1(b) Effect of brake thermal efficiency adopting AFM2

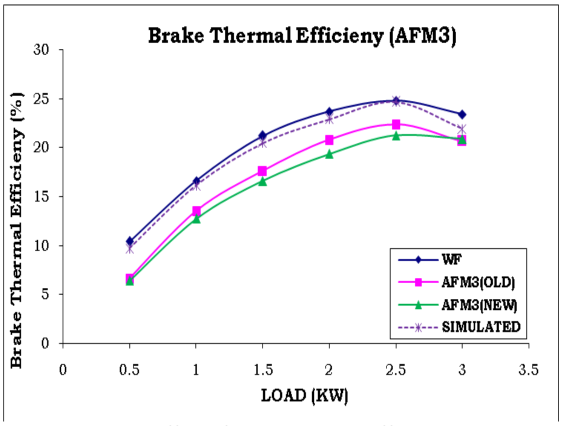


Fig: 3.1.1(c) Effect of brake thermal efficiency adopting AFM3

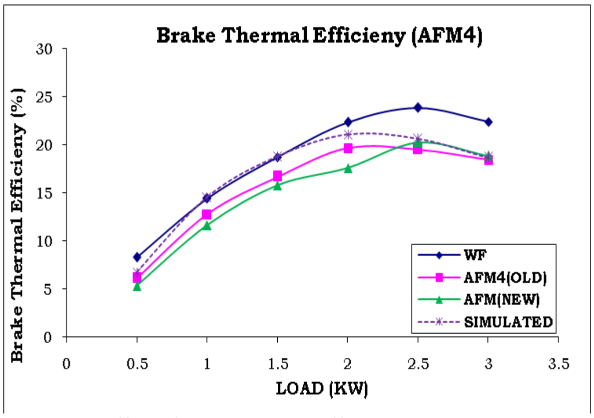


Fig: 4.1.1(d) Effect of brake thermal efficiency adopting AFM4

3.1.2 Brake Specific Fuel Consumption (BSFC)

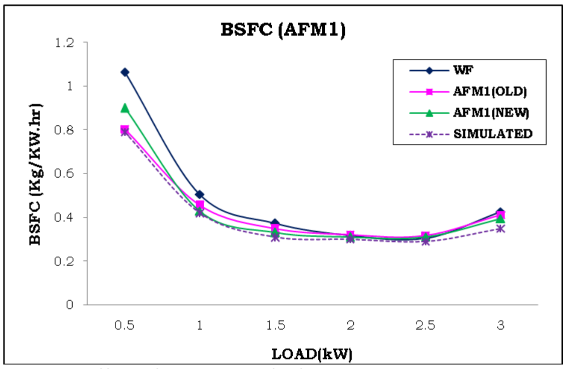


Fig: 3.1.2(a) Effect of brake specific fuel consumption adopting AFM1

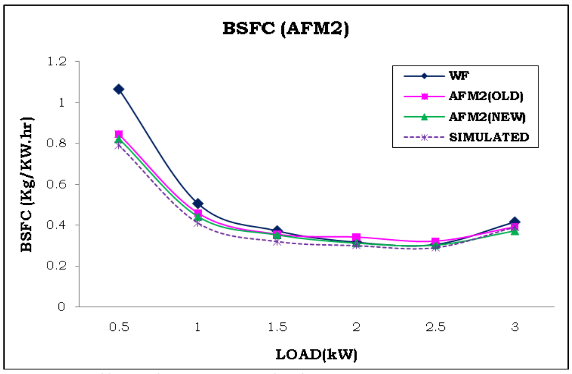


Fig: 3.1.2(b) Effect of brake specific fuel consumption adopting AFM2

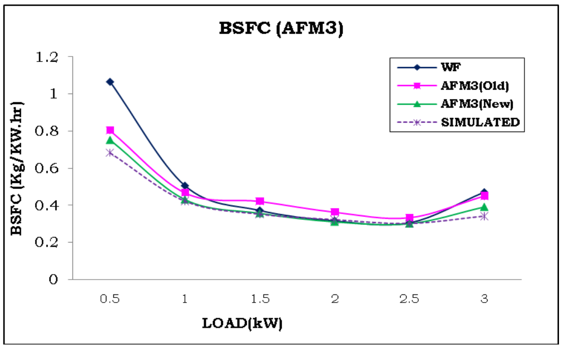


Fig: 3.1.2(c) Effect of brake specific fuel consumption adopting AFM3,

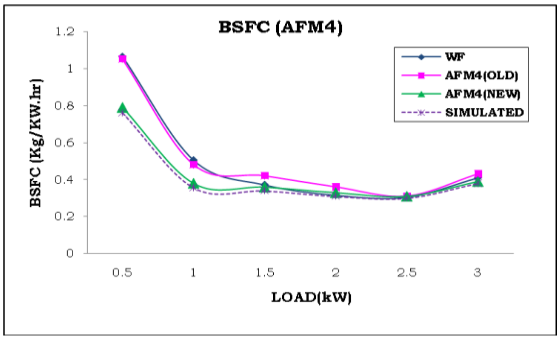
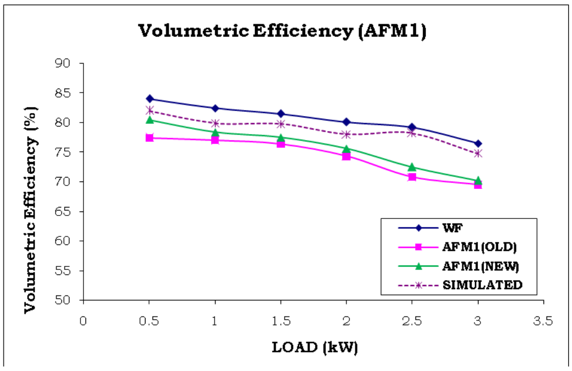


Fig: 3.1.2(d) Effect of brake specific fuel consumption adopting AFM4

The figure 3.1.2(a) explains the variation of brake specific fuel consumption against load on to the engine when the filter AFM1 is adopted. It is observed that brake specific fuel consumption is higher for newer filter than old filter. It is also observed that the engine running without filter is having higher brake specific fuel consumption. The values for brake specific fuel consumption for new filter are lower by 2 to 4% than old filter and by 3to 5% when engin3 is running without air filter. Similarly the figure 3.1.2(b) to 3.1.2(d) explains the variation of brake specific fuel consumption against load on the engine when the figures AFM2, AFM3 and AFM4 are adopted respectively. It is observed that the brake specific fuel consumption is lower for newer filters than the old filters. It is also observed that when the engine runs without filter is giving higher brake specific fuel consumption.

3.1.3 Volumetric efficiency

The figure 3.1.3(a) explains the variation of volumetric efficiency against load on to the engine when the filter AFM1 is adopted. It is observed that volumetric efficiency is higher for newer filter than old filter. It is also observed that the engine running without filter is having lower volumetric efficiency. The values for volumetric efficiency for new filter are higher by 5 to 10% than old filter and by 4to 6% when engine is running without air filter. Similarly the figure 3.1.3(b) to 3.1.3(d) explains the variation of volumetric efficiency against load on the engine when the figures AFM2, AFM3 and AFM4 are adopted respectively. It is observed that the volumetric efficiency is higher for newer filters than the old filters. It is also observed that when the engine runs without filter is giving lower volumetric efficiency.



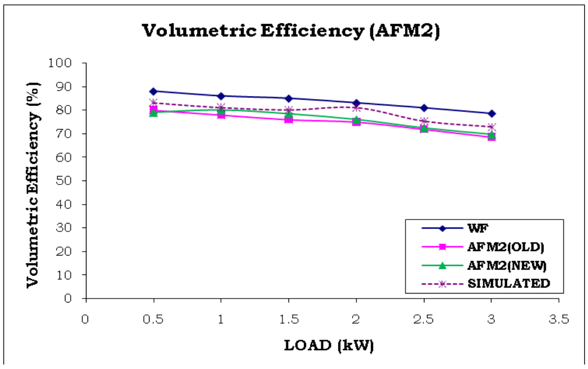
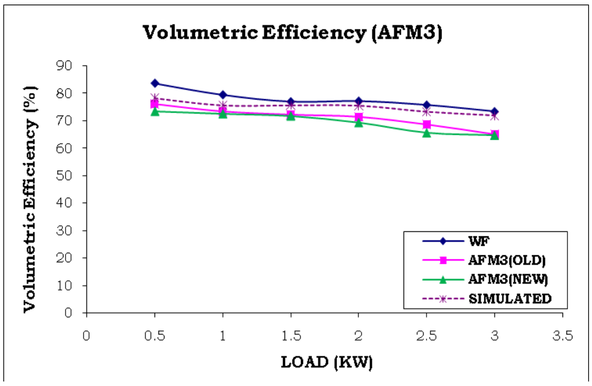


Fig: 3.1.3(a) Effect of volumetric efficiency adopting AFM1 **Fig: 4.1.3(b) Effect of volumetric efficiency adopting AFM2**



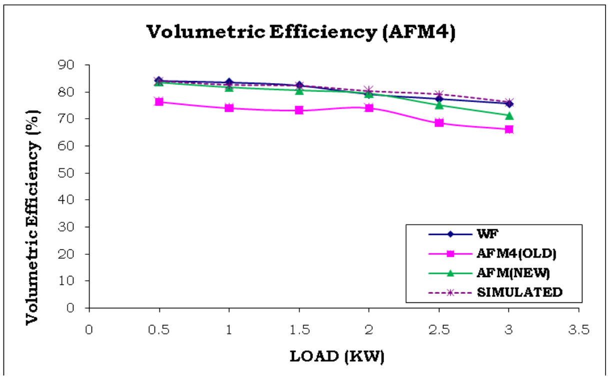
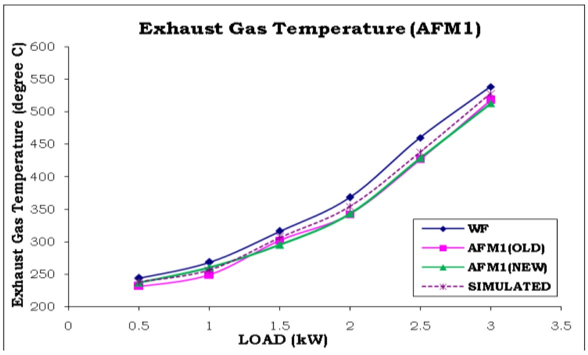


Fig: 3.1.3(c) Effect of volumetric efficiency adopting AFM3 **Fig: 4.1.3(d) Effect of volumetric efficiency adopting AFM4**

4.1.4 Exhaust Gas Temperature (EGT)



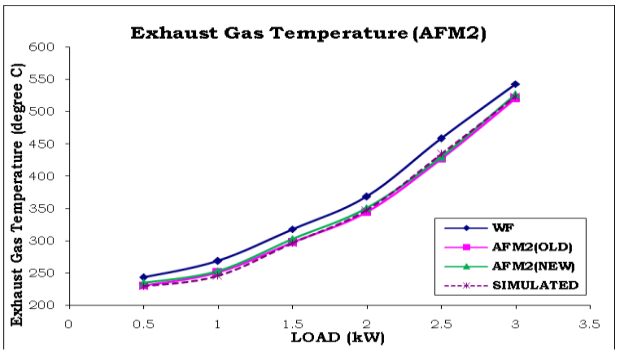


Fig: 3.1.4(a) Effect of Exhaust gas temperature adopting AFM1 **Fig: 4.1.4(b) Effect of Exhaust gas temperature adopting AFM2**

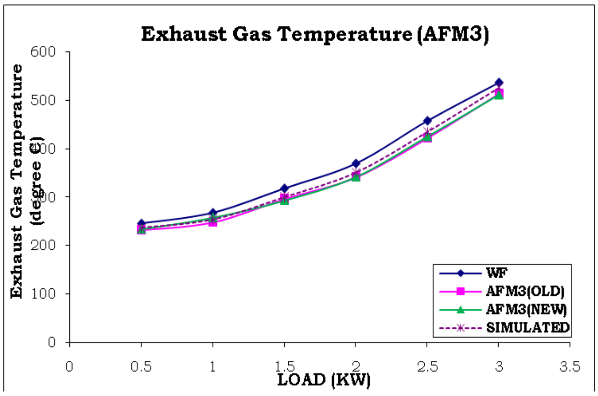


Fig: 3.1.4(c) Effect of Exhaust gas temperature adopting AFM3

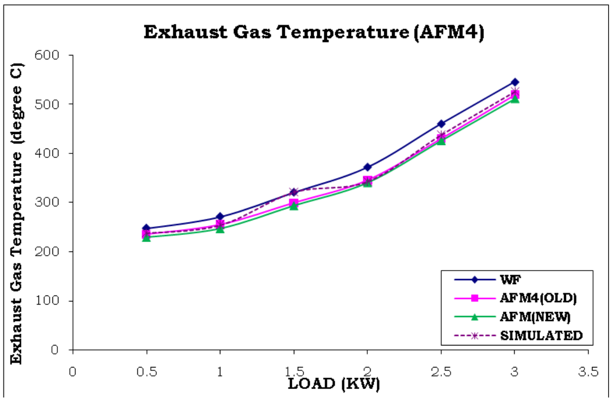


Fig: 3.1.4(d) Effect of Exhaust gas temperature adopting AFM4

The figure 3.1.4(a) explains the variation of exhaust gas temperature against load on to the engine, when the filter AFM1 is adopted. It is observed that exhaust gas temperature is lesser for new filter than old filter. It is also observed that the engine running without filter is having higher exhaust gas temperature the EGT values for new filter are lower by 2 to 5 % than old filter and by 4 to 6% when engine is running without filter. The figure 3.1.4(b) explains the variation of exhaust gas temperature against load on to the engine when AFM2 filter is adopted. The figure 3.1.4(c) explains the variation if exhaust gas temperature against load on to the engine when AFM3 filter is adopted. It is observed that exhaust gas temperature is lesser for new filter than old filter. The figure 3.1.4(d) depicts the variation of exhaust gas temperature against load on to the engine when AFM4 filter is adopted. It is observed that exhaust gas temperature is lesser for new filter than old filter. It is also observed that the engine running without filter is having higher exhaust gas temperature.

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

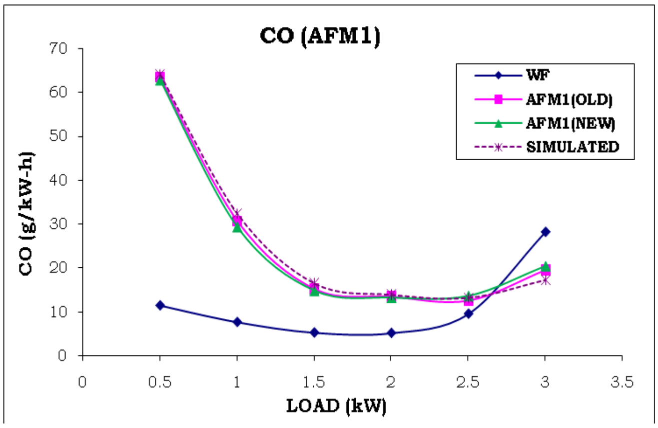


Fig: 3.2.1(a) Effect of CO adopting AFM1

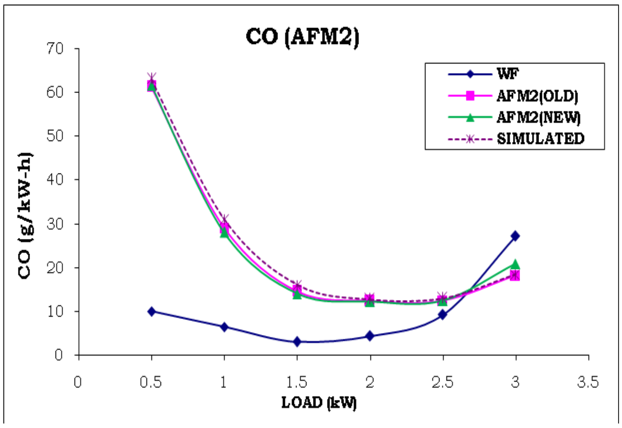


Fig: 3.2.1 (b) Effect of CO adopting AFM2

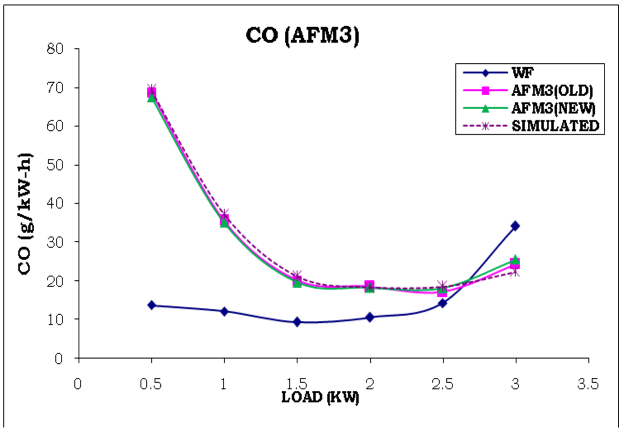


Fig: 3.2.1(c) Effect of CO adopting AFM3

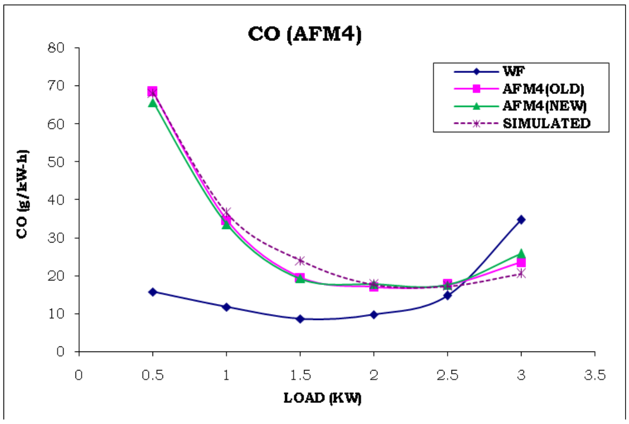


Fig: 3.2.1(d) Effect of CO adopting AFM4

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.

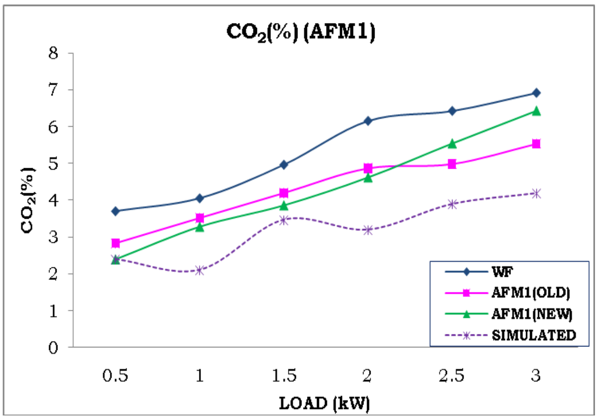


Fig: 3.2.2(a) Effect of CO_2 adopting AFM1

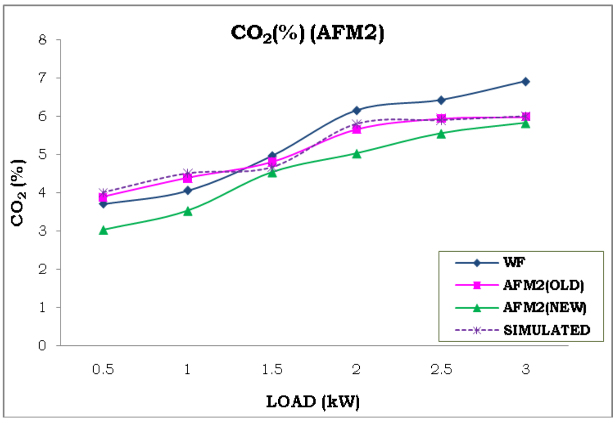


Fig: 3.2.2(b) Effect of CO_2 adopting AFM2

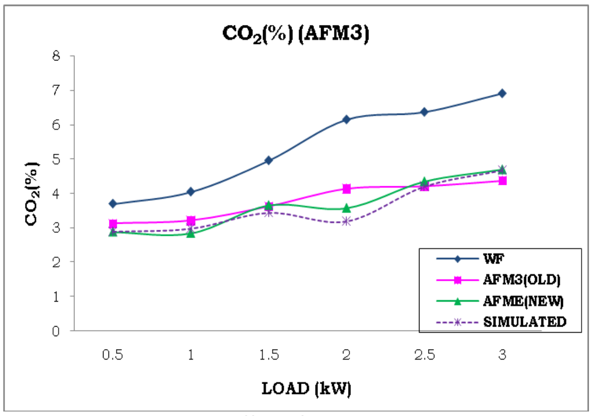


Fig: 3.2.2(c) Effect of CO_2 adopting AFM3

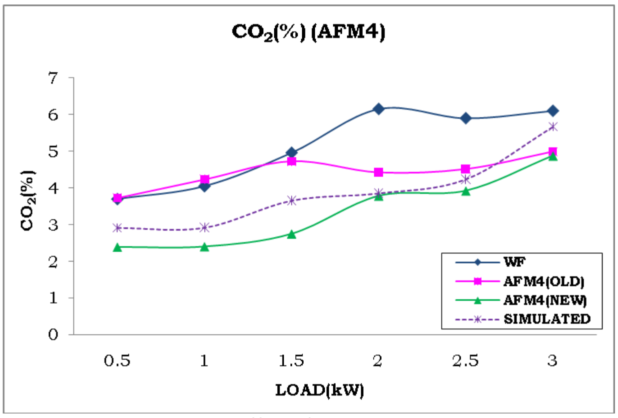


Fig: 3.2.2(d) Effect of CO_2 adopting AFM4

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.

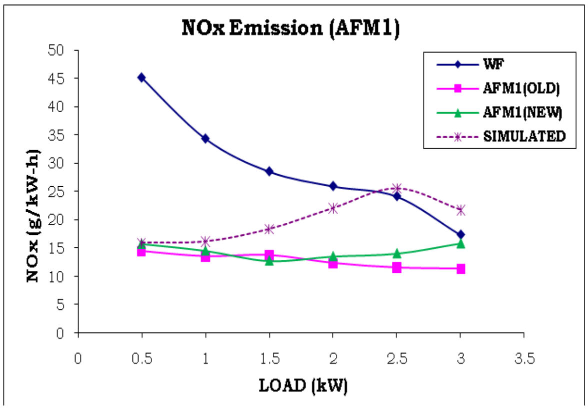


Fig: 3.2.3 (a) Effect of NO_X adopting AFM1

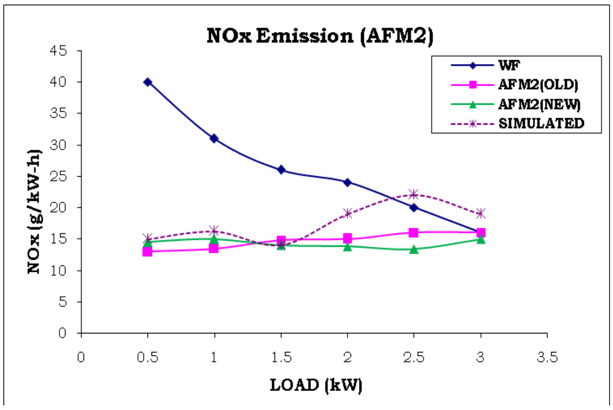


Fig: 3.2.3 (b) Effect of NO_X adopting AFM2

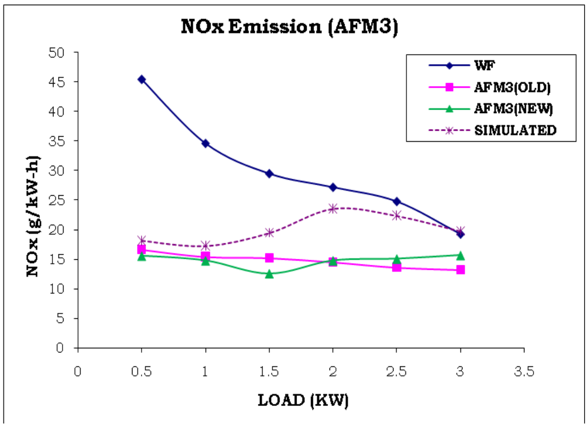


Fig: 3.2.3 (c) Effect of NO_X adopting AFM3

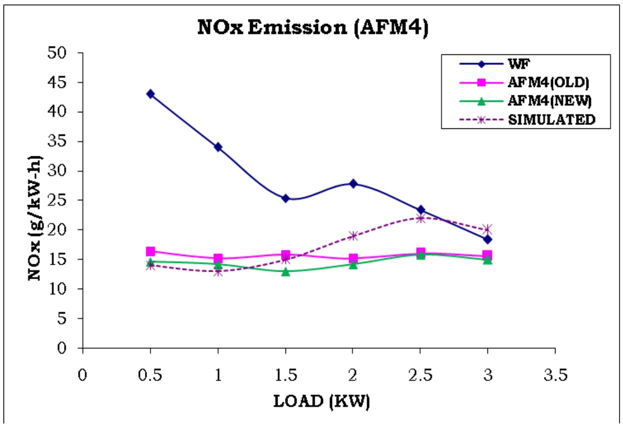


Fig: 3.2.3 (d) Effect of NO_X adopting AFM4

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.

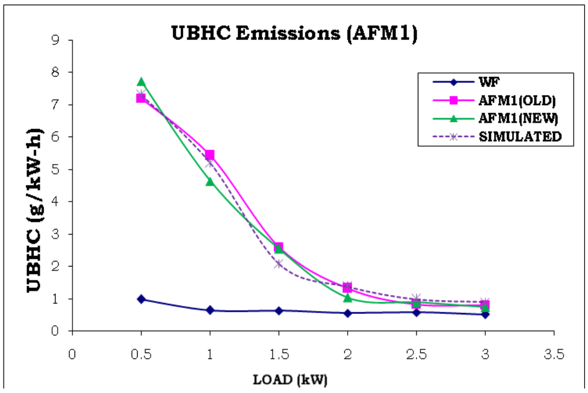


Fig: 3.2.4 (b) Effect of UBHC adopting AFM2

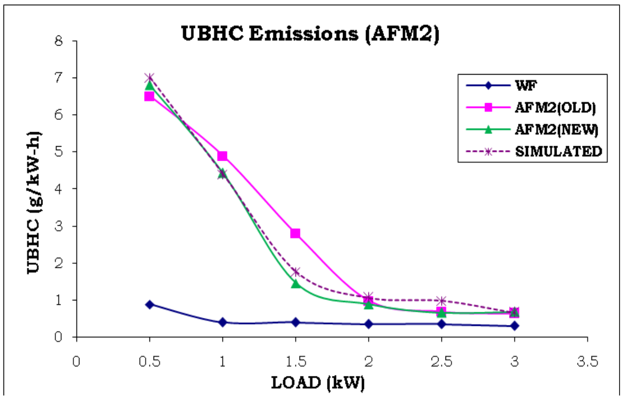


Fig: 3.2.4 (a) Effect of UBHC adopting AFM1

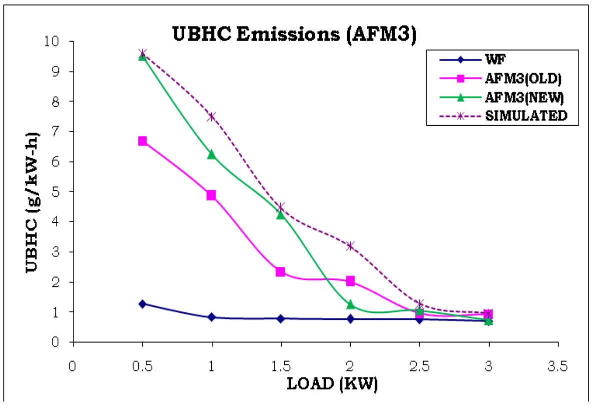


Fig: 3.2.4 (c) Effect of UBHC adopting AFM3

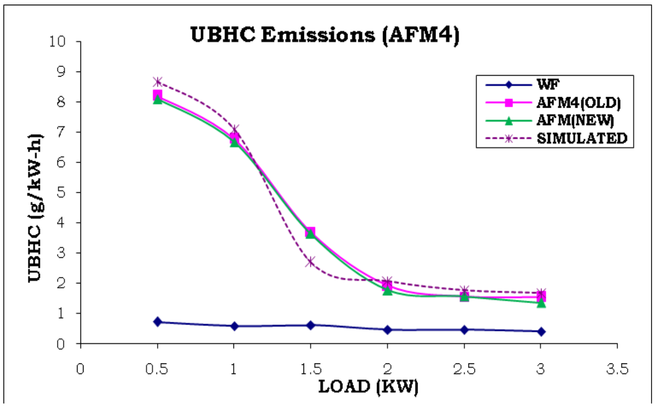


Fig: 3.2.4 (d) Effect of UBHC adopting AFM4

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.

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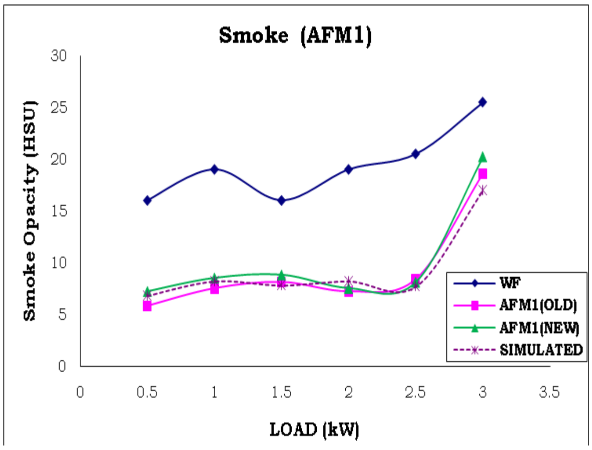

Fig: 3.2.5(a) Effect of smoke adopting AFM1

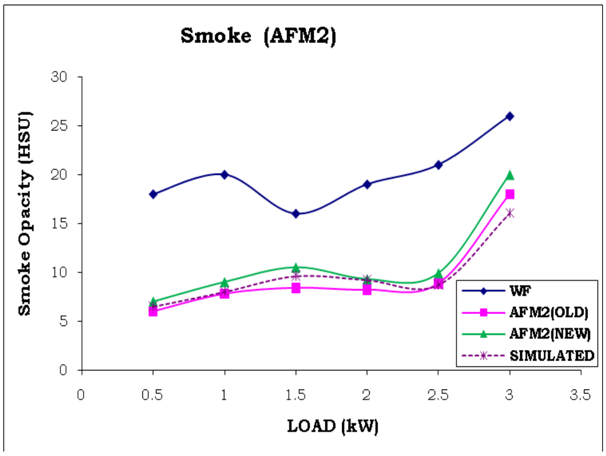

Fig: 3.2.5 (b) Effect of smoke adopting AFM2

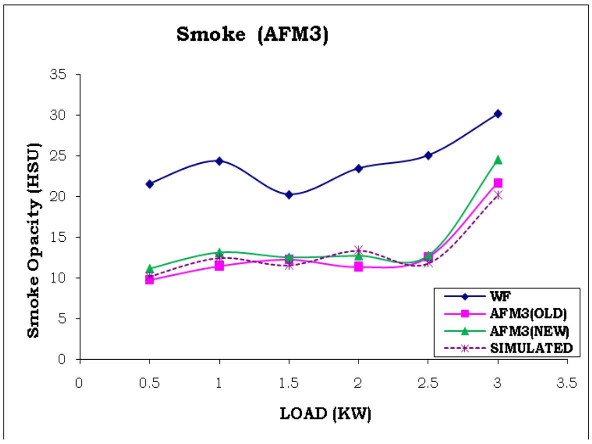

Fig: 3.2.5 (c) Effect of smoke adopting AFM3

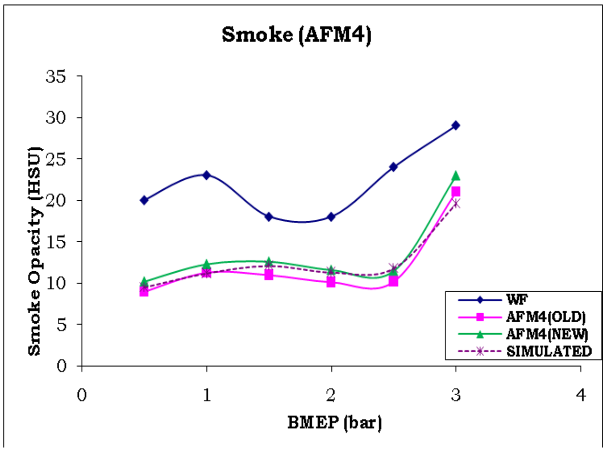

Fig: 3.2.5 (d) Effect of smoke adopting AFM4

CONCLUSIONS

In the present work experiments have been carries out to study the impact of engine performance and its emissions using air filters. The experiments are conducted on four stroke DI water cooled diesel engine different air filters with varied parameters.

- 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.
- Engine performance is sensitive to induction pressure when they run without turbo or supercharger. So the filters are to be selected carefully to suit the engine which does not affect its performance and emissions.
- The brake thermal efficiency of the engine with new filter is increased about 9% compared to the clogged old filter engine. This is due to the quantity of fresh air into the induction system.
- The volumetric efficiency has increased about 4 to 8% for AFM3(NEW) filter compared to conventional filters. The reason is the pressure differential between the induction manifold and cylinders.
- The exhaust gas temperature increased for all old filters in the average range of 10 to 20^{0}C. This is due to the less availability of fresh air for combustion in later stages which are leading to late combustion.
- Cylinder pressure closer to TDC position of piston for filter AFM2(NEW) the pressure development is high and in the range of 5 to 9%. The reason is geometrical design and filter material of this type of filter.
- Heat release rate shown gradual increased rate at combustion stage in the range of 25 to35 J/^{o}CA 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.

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