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Effect of Composite Additives on CI Engine Performance and Emission

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Abstract: *This paper presents the experimental analysis on effect of composite additive on diesel engine performance and emission and also decides the best percentage of composite additive for diesel fuel which helps in maximizing the performance and control of diesel engine emission. Five different samples containing mixture of three different additives, like Oxygenated additive and Cetane improver as mentioned below in different proportion were prepared.*

1. *Dimethyl Carbonate (DMC)("D")*
2. *Ethyl Acetate ("A")*
3. *2Ethyl Hexyl Nitrate ("E")*

Following five samples by mixture of above three additives were prepared –

1. *D50A40E10*
2. *D60A20E20*
3. *D70A20E10*
4. *D70A10E20*
5. *D70A15E15*

Number in above nomenclature indicates percentage of respective additive in a sample of 100ml of composite additive. Also 5% DMC and 10% DMC were prepared along with the five samples. This 100ml of sample was mixed with 900ml of diesel fuel and was then tested on a Multi cylinder Diesel engine test rig to understand their effect on performance of engine at variable load.

Keywords: *Oxygenated Additive, Cetane Improver, Cleansing agent, HC, CO, NO_X, Opacity.*

1. Introduction

According to the World Trade organization, in 2004, the fuel market was responsible for an 11.1% share of the total trade in merchandising and primary products, corresponding to 48.1 billion dollars. Most is due to diesel that is essential for transport and heavy duty engines. It contributes to the prosperity of the worldwide economy since it is widely used due to high combustion efficiency, reliability, adaptability and cost effectiveness. However, pollutant emissions are major drawback.

They emit pollutants like particulate matter (PM), oxides of nitrogen (NOx), carbon monoxide (CO) and hydrocarbons (HC). It is commonly accepted that clean combustion of diesel engines can be fulfilled only if engine development is coupled with diesel engine fuel reformulation or additive introduction, in this way methods to reduce PM and NOx emissions include high-pressure injection, turbo-charging or the use of fuel additives[1].

The reduction of diesel engine emissions could be considered from three aspects: the combustion improvement technique, the exhaust after treatment technology, and the fuel melioration. The diesel fuel properties have become even more stringent controlling diesel exhaust emissions through fuel melioration seems to be promising because it would affect both the new and old engines. Melioration of diesel fuel to reduce exhaust emission can be performed by increasing the Cetane number, reducing fuel sulphur, reducing aromatic content, increasing fuel volatility and decreasing the fuel density to have the compromise between engine performance and engine out emissions.

The paper mainly focuses on the usage of three additives namely: Dimethyl Carbonate, 2 Ethyl Hexyl Nitrate and Ethyl Acetate. Dimethyl Carbonate was used as an oxygenating agent for complete combustion of the fuel, 2 Ethyl Hexyl Nitrate was used as a cetane improver to reduce the ignition period and improve the performance of the engine and at last Ethyl Acetate was used as a cleansing agent to remove the leftover crevices.

2. LITERATURE SURVEY

The paper published by Jianxin Wang, FujiaWu [2] poses the design principles for the oxygenated blends. DMC (di-methyl carbonate) and DMM (di-methoxy methane) were used for the test which are used both as oxygenating and cetane improving agents proved to be better than ethanol. Based on the design principles proposed in this paper, an oxygenated blend containing 50% biodiesel, 15% DMC, and 35% diesel fuel was formulated to meet the Chinese 4th Stage Standard (equivalent to Euro IV) for heavy-duty engines without using any after treatment device. The PM emissions were reduced by using the above two additives.

Yanfeng [3] conducted experiments with 2-methoxy ethyl acetate blends with diesel fuel. They observed that smoke density reduced by more than 50%. The emissions of CO and HC also decreased with an increase in MEA in the blends. The blends have almost no effects on NOx emissions and the thermal efficiency of the engine increases by 2%.

The experiment titled as Effect of Oxygenated Fuel Additive on Diesel Engine Performance and Emission carried out by Prof.A. R. Patil [4] and S. G. Taji stated that during study of available material it is found that oxygenated additives are effective method for reducing PM, CO emission. In this paper addition of 5% DMC to diesel fuel effectively reduced the soot by 52 %.

Bhavin Mehta [5] and Hiren Mandalia mentioned in their paper that DME (dimethyl-ether) helps in smoke reduction but require significant modification in diesel engine.

High cetane number improves cold temperature starting and idling for all engines, the main purpose of adding 2-EHN (2-Ethly Hexyl Nitrate) was to reduce the auto-ignition period, the paper proposed by G.J. Henly [6] studied the effect of cetane improver on diesel engine emissions which showed that addition of 2-EHN reduces the ignition delay, which in turn reduces the combustion temperatures as a result of which NOx emission were reduced. The BTE (brake thermal efficiency) and BSFC (brake specific fuel combustion) both were increased due to the addition of 2-EHN (i.e. cetane improver).

After doing literature survey following additives have been finalized :

Dimethyl Carbonate: It is one of most promising additive due to its high oxygen content, no carbon – carbon atomic bond, suitable boiling point and solubility in diesel fuel. Experimental analysis by G D Zeng shows that particulate matter (PM) emission can be reduced by it. Combustion analysis also indicated ignition delay is longer in DMC blend diesel but combustion duration is much shorter and thermal efficiency is increased. Also Prof. Bhavin Mehta[5] shows that around 10% of DMC has decibel effect on engine emission but only drawback is due to low cetane number, it reduces the mixture cetane number so affecting BSFC and Break Power.

DMC: 5- 7 % of fuel give max benefits (50 -75%) of blend since at 10% there is considerable drop in performance and rise in emission

2 Ethyl Hexyl Nitrate: 1 -5% of fuel (10 -15% blend) to compensate for drop in calorific value due to low cetane value of DMC

Ethyl Acetate: (25 -40 % blend)

3. PRESENT WORK

Present work has been concentrated on investigating the effect of composite additives on CI engine performance and emission. Three additives as mentioned below were selected and added in proportion of 10% by volume to diesel. Then these fuel samples were tested on multi cylinder C I Engine at constant speed of 1500rpm and variable load condition. The experimental results of performance like brake specific fuel consumption, brake thermal efficiency and smoke parameter like HC,CO,NO_X, smoke opacity, BP, were analyzed at various load points of idle, 20%, 40%, 60%, 80% and 100%.

ADDITIVES - 1.Dimethyl Carbonate (DMC) (“D”)
2. Ethyl Acetate (“A”)
3. 2Ethyl Hexyl Nitrate (“E”)

4. EXPERIMENTATION

A typical Multi-cylinder 4-stroke water-cooled diesel engine at 1500 rpm was used for the investigation purpose. The schematic diagram of the experimental set up is shown in Figure 4.1.A Hydraulic dynamometer was used for load control on the engine. Various thermocouple temperature sensors were installed at appropriate locations to measure water inlet and outlet, manifold air temperature, exhaust outlet, and heat exchanger outlet temperatures. A temperature thermocouple was installed on the surface of high pressure fuel pipe. A precision crank angle encoder was coupled with the main shaft of the engine. Two openings were made in exhaust gas pipeline for sampling purposes. The mass flow rate of intake air was measured with an orifice meter connected to a manometer. A surge tank was used to damp out the pulsations produced by the engine, for ensuring a steady flow of air through the intake manifold. An AVL 444 Di gas analyzer was used for measuring the CO, HC, and NOx emissions and the smoke density was measured using AVL 437 smoke meter.

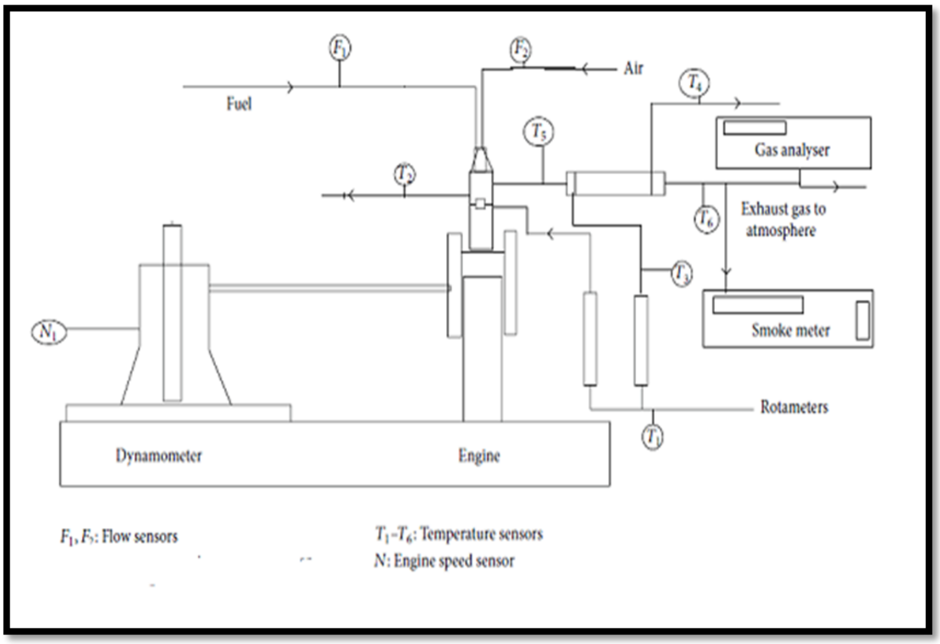

Figure 4.1. *Experimental Test Rig Setup*

During the tests with Fuel sample, first, the engine was started with diesel until it was warmed up and then fuel was switched to various diesel-additive blends. After finishing the tests with diesel-additive blends, the Engine was always switched back to diesel fuel and the engine was run until the additives had been purged from the fuel line, injection pump, and injector. This was done to prevent starting difficulties at the later time. Initially the test engine was operated with base fuel diesel for about 10 minutes to attain the normal working temperature conditions. After that the baseline data was generated and the corresponding results were obtained. The engine was then operated with blends of Composite additives mentioned above for different load condition. At every operation the engine speed was checked and maintained constant. The different performance and emission parameters analyzed in the present investigation were brake thermal efficiency (BTE), brake specific fuel consumption (SFC), exhaust gas temperature (EGT), carbon monoxide (CO), unburned hydrocarbons (UHC), nitrogen oxides (NOx), and smoke opacity.

Parameter	**Specification**
Engine Type	Multi Cylinder DI, Water cooled
No of cylinder	03
Rated Power	27.9kW,1500rpm
Displacement	3300cc
Bore * Stroke Length	110mm x 116mm
Compression Ratio	18:1
Orifice Diameter	50mm
Orifice Coefficient of Discharge	0.65
No. of Nozzle Holes	5

Figure 4.2. *Diesel Engine Test Rig specification*

5. Result and Discussion

5.1 Engine Performance

The engine performance indicators considered were brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and exhaust gas temperature.

LOAD Vs BSFC

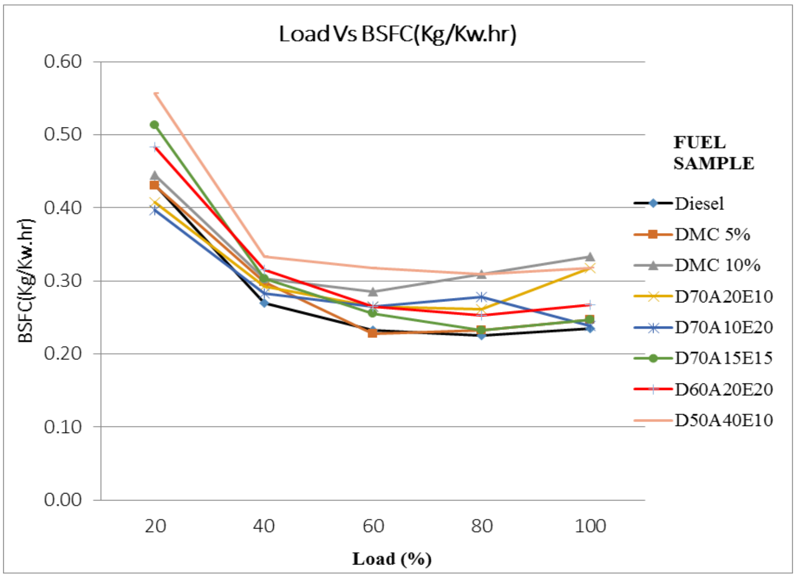

Fig.5.1.1. *Load (%) Vs Brake Specific Fuel Consumption (Kg/Kw-hr)*

Fig.5.1.1 shows BSFC variation of different additives at different load conditions. Diesel and sample

D70A15E15 shows lowest BSFC value throughout the test. As per graph we observe that at 20% load diesel shows 0.42 BSFC and at 100% load the value of BSFC decreases to 0.23. The addition of cetane improver i.e. 2EHN improves the combustion process and reduces BSFC. It is observed that composite additive show higher value of BSFC as compared to diesel because of high A/F ratio and low calorific value. It can be observed for DMC 5% the value of BSFC is 0.41 at 20% load it is 0.27 at full load while for sample D7A15E15 it is 0.51 at 20% load and 0.25 at full load which is quite close that for diesel.

LOAD Vs BRAKE THERMAL EFFICENCY

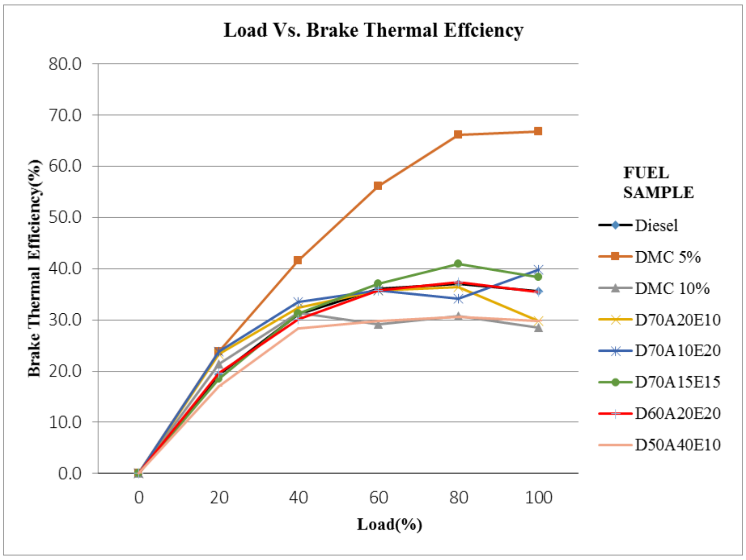

Fig. 5.1.2. *Load (%) Vs Brake Thermal Efficiency (%)*

Fig. 5.1.2 shows Brake thermal Efficiency variation of fuel sample at various load condition. It can be seen that brake thermal efficiency of diesel and fuel sample increases continuously till 80% load and then there is sudden drop in it because the A/F ratio decrease at high load. Sample D70A15E15 shows brake thermal efficiency of 19.2% at 20% load while 38.4% at full load. The brake thermal efficiency increases with high load at constant speed due to reduction in heat losses and increase in brake power. The reason for high efficiency is complete combustion due to presence of enough oxygen molecules in fuel consumption. It is observed that sample D70A15E15 shows around 8-10% rise in brake thermal efficiency at higher loads than diesel.

LOAD Vs EGT

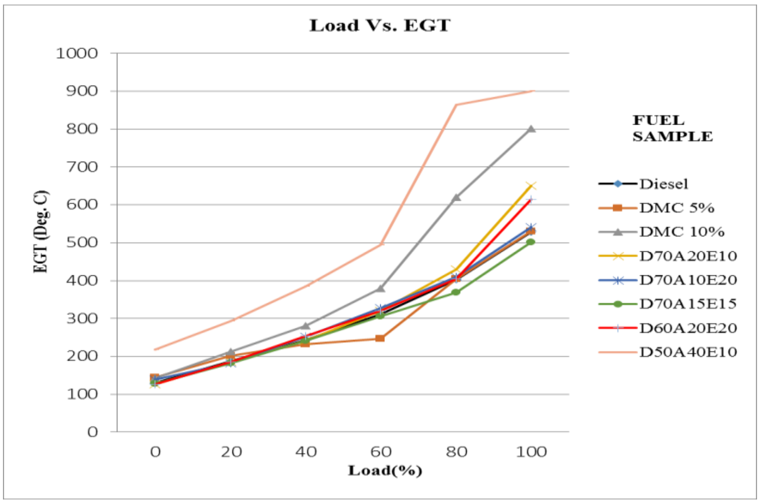

Fig. 5.1.3. *Load (%) Vs Exhaust Gas Temperature (°C)*

Fig. 5.1.3 shows Exhaust Gas temperature behaviour of different additives at different load condition. It is observed that the behaviour of diesel and additive sample are quite close to each other except that of DMC 10% and D50A40E10 which show sudden rise in the temperature at high loads because of incomplete combustion of additive in combustion chamber which gets burned in the exhaust due to high temperature at exhaust port. It can be seen that sample D70A15E15 show lowest value of EGT at full load.

5.2 Emission Characteristics:

LOAD Vs CO

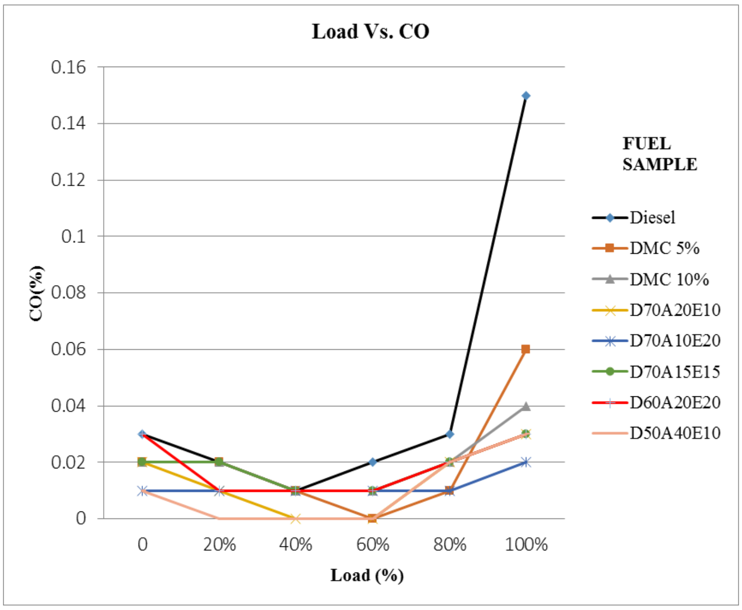

Fig. 5.2.1. *Load (%) Vs CO Emission*

Fig 5.2.1 shows variation of CO emission with respect to load. It is observed that CO emission in diesel is highest in all fuel sample at full load. The reason is that as load increase air/ fuel ratio becomes richer and richer and more fuel doesn't find sufficient O2 due to above reason. Sample D70A20E10 follows the regular emission behaviour but with reduced level of emission i.e. 0.02 at 0% and 0 at 40% load, this is due to the reduced ignition lag by presence of cetane improver 2EHN and cleaning agent ethyl acetate in the fuel sample. It is also observed that sample D50A40E10 has increased percentage of ethyl acetate which would be the possible reason for reduced level of emission which are close to zero in the range of 20-60% load and peak emission 0.03 at 100% load, it shows peak emission of 0.03 which is 6 times lower than diesel emission. It is seen that sample D70A15E15 shows similar characteristic to that of sample D50A40E10.

LOAD Vs HC

Fig 5.2.2 shows variation of HC emission with respect to load. It can be seen for diesel the emission is 60 ppm at 0% load and reduces to 35 ppm in range 0f 40-60% load, the peak value goes to 70 pm at 100% load. DMC 5% and 10% are showing less HC emission than diesel due to presence of oxygen and higher volatility. HC emission for other sample starts increasing due to presence of ethyl acetate and 2EHN in the composition. Sample D60A20E20 shows that the presence of 2EHN and ethyl acetate is of little help at starting but shows stable emission of 45 ppm in the range of 20-60% load and at full load the presence of 2EHN reduces the ignition lag thus reducing emission level to 58 ppm. Sample D70A15E15 shows around 10% drop in HC at idle condition while around 20% drop at full load due to availability of oxygen at rich carbon nucleus in air fuel mixture formation hence resulting better combustion.

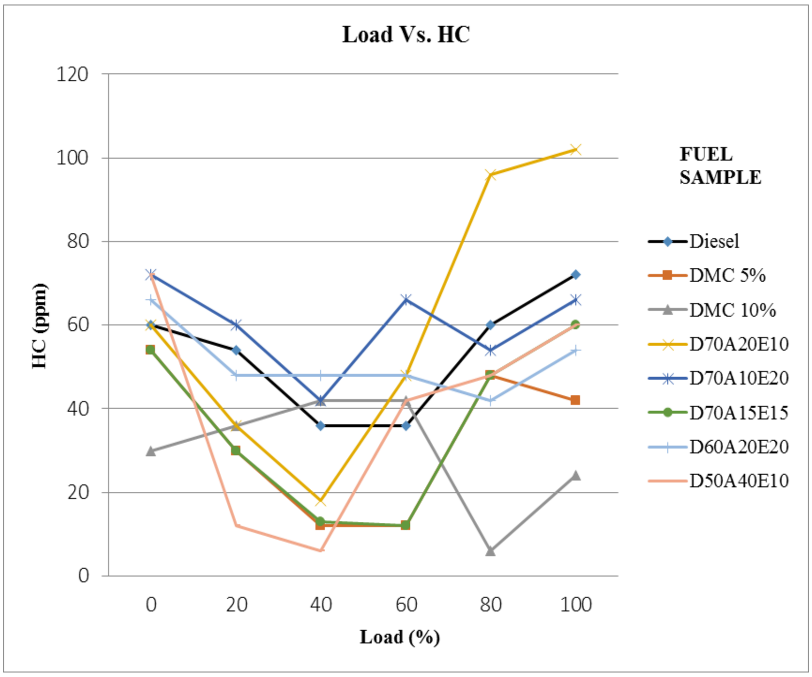

Fig 5.2.2. *Load (%) Vs. HC Emission (ppm)*

LOAD Vs NO_X

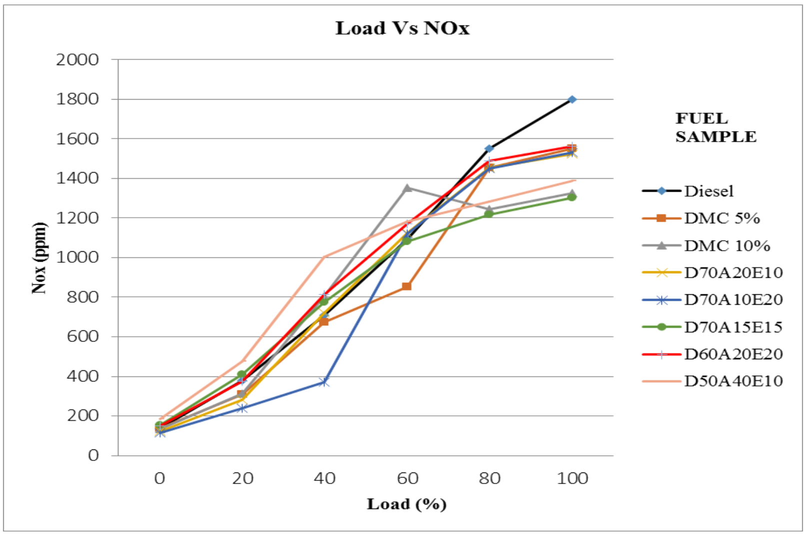

Fig. 5.2.3. *Load (%) Vs NOx Emission (ppm)*

Fig 5.2.3 shows variation of NOx emission with respect to load. It is observed that diesel gives 1800 ppm NOx emission at full load. While all the other sample show reduction in NOx formation due low Exhaust Gas Temperature. Sample D70A20E10 and D60A20E20 gives the peak emission of around 1500 ppm, compared to others the reason for this is due to the presence of cetane improver which reduces the delay time, it leads to complete combustion reducing after burning effect. Sample D70A15E15 show rise in 8% rise in NOx formation due to presence of N in 2EHN till 60 % loading after that these is 25 % drop in NOx formation due reduction of burned gas temperature for given mass of fuel and air burned and also high equivalence ration tends to cool the charge reducing NOx emission.

LOAD Vs SMOKE

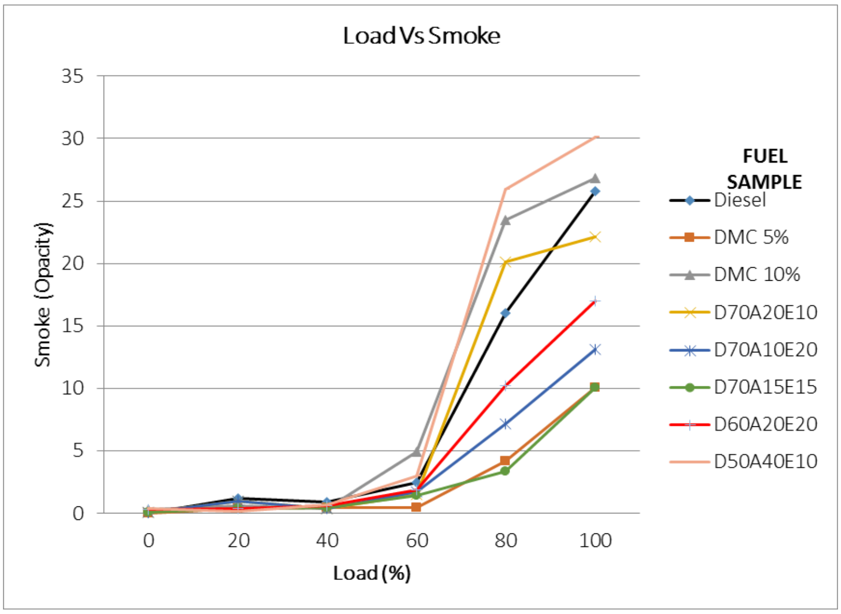

Fig 5.2.4. *Load (%) Vs Smoke (% Opacity)*

Fig 5.2.4 shows variation of smoke with respect to load. Diesel gives zero smoke at zero load due to presence of excess air while give 25% at full load due to richness of fuel. So smoke is dominated at full load. It is observed that sample D50A40E10 and DMC 10% gives highest smoke at full load while sample D70A15E15 give lowest smoke at full load. Sample D70A15E15 shows 60% drop in smoke opacity .The reason for this is firstly very rich fuel–rich core exist at high load because of relatively long injection period but with use of DMC an oxidizer effectively introduce in to fuel rich region and suppress soot formation in combustion chamber.

6. Conclusion

In this research a preliminary investigation was carried out to study the effect of composite additive on performance and emission characteristic on diesel engine. The results obtained for constant engine speed (N=1500 rpm) with various engine load can be summarized as follows:-

- **BSFC:-** Sample D70A15E15 has BSFC very close to that of pure diesel and the fuel consumption is low .The running cost of D70A15E15 is very close to that of diesel. The BSFC value for D70A15E15 is greater than BSFC of diesel by 8-10%.
- **BRAKE THERMAL EFFICIENCY:-**Sample D70A15E15 shows high brake thermal efficiency because of lower BSFC. Sample D70A15E15 shows increase in BTE by 6% at full load in comparison with diesel.
- **EGT:-**Sample D70A15E15 shows lowest EGT than any other sample and due to this there is also less formation of NOX. It lowers the loss of heat energy through exhaust. Sample D70A15E15 show around 5% drops in EGT thus lower the loss of heat energy through exhausts gases.
- **CO:-** Sample D70A15E15 contains equal amount of cetane improver and cleansing agent which helps in reducing ignition lag and shows 80% drop in CO emission as compared to diesel.
- **HC:-** Sample D70A15E15 shows 15% drop at high load as compared to diesel and the same proportion of cetane improver and cleansing agent removes the left over particulate matter.

- **NO_X:-** Sample D70A15E15 shows lower NOX formation at high loads as compared to diesel it shows 25-30% drop at full load.
- **SMOKE:-** Sample D70A15E15 shows 60% drop in smoke formation as compared to diesel at full load conditions.

From the above conclusion we can say that sample D70A15E15 is a better option as fuel additive as compared to other composites because it shows better results in all parameters.

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REFERENCES

[1] Angelo C. Pinto, Lillian L.N. Guarieiro, "The Role of Additives for Diesel and Diesel Blended (Ethanol or Biodiesel) Fuels: A Review". Energy and Fuels 2007, Vol. 21, Pg. 2433-2445.

[2] Jianxin W, Fujia W, Jianhua X, "Oxygenated blend design and its effects on reducing diesel particulate emissions". Fuel, 2009; Vol. (88), Pg.4.

[3] Gong Yanfeng, Liu Shenghua, "A new diesel oxygenate additive and its effects on engine combustion and emissions" Applied Thermal Engineering,Vol. 27(1), 2007, Pg. 202-207.

[4] Mr. A. R. Patil, Prof. S. G. Taji "Need of Composite Additives for Diesel Fuel A Review" IJERT, Vol.2 - Issue 11, November – 2013.

[5] Bhavin H. Mehta, Hiren V Mandalia "A Review on Effect of Oxygenated Fuel Additive on the Performance and Emission Characteristics of Diesel Engine", National Conference on Recent Trends in Engineering & Technology, 13- 14 May 2011.

[6] Green, G.J., Henly, "Fuel Economy and Power Benefits of Cetane-Improved Fuels in Heavy-Duty Diesel Engines," SAE 972900 (1997).

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