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Experimental Investigations on Four-Stroke D.I Diesel Engine by using Diesel-Water Emulsions in LHR

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Abstract: In this experimental investigation the ceramic coating was applied to the top surface of the piston, bottom surface of the cylinder head and valve facings. The material used for the ceramic coating was partially stabilized zirconia (PSZ). The coating was applied by plasma arc spraying process. The coated engine may be termed as Low Heat Rejection (LHR) engine or Thermal Barrier Coated (TBC) engine. The reason for applying the ceramic coating was to retain the heat produced during combustion, and accelerate the micro-explosion process taking place in case of emulsified fuels. The heat retained in the combustion chamber might lead to an improvement in the brake thermal efficiency and reduced emissions.

The performance and emission parameters of diesel, N20 biodiesel, and diesel-water emulsions were analyzed in Low Heat Rejection (LHR) engine. It was found that there was a marginal increase of brake thermal efficiency for both reference and test fuels when compared to conventional engine. Also there was more reduction in emission parameters for emulsified fuels than conventional fuel (diesel) and N20 biodiesel. DWM3 gave out the best results among all other fuels. The DWM1 has the content of 95% diesel, 4% water, and 1% surfactants. DWM2 has a composition of 91% diesel, 8% water, and 1% surfactants. DWM3 has a composition of 87% diesel, 12% water, and 1% surfactants.

I. INTRODUCTION

The father of diesel engine Dr. Rudolf planned to run the engine with extraordinary fuels like vegetable oils. However his first trial will become a failure within the exhibition held at Paris when running with 100% vegetable oil. By using the vegetable oil as fuel the improvement of agriculture gives the employment for the farmers. Due to excessive viscosity of vegetable oil the combustion efficiency has been reduced whilst compared with the diesel. The fluctuating expenses of crude oil centered the vegetable oils and animal fats to generate biodiesel for destiny generation. The plantation of soybean in USA of America Sunflower oil in India and palm oil in Malaysia are being considered as a substitute for Diesel gas. The bio fuel have to satisfy the operating conditions by means of giving better performance and it could fulfill the environmental safety. Bio diesel can deliver higher performance than diesel gas via making minor modification in engine like dual fuelling, fuel injection modification and in fuel supply system like mixing, micro emulsion, cracking and viscosity reduction.

II. LITERATURE REVIEW

Vegetable oils had been observed to comprise chemically complex ester of fatty acids and additionally their molecular weight was better [1]. Due to their higher molecular weight that they had higher viscosity and prompted essential problems in their utilization in compression ignition (CI) engines. Between 1930– 1940, vegetable oils were used as fuel for compression ignition engines however most effective in emergency situations. Various vegetable oils tested had been palm oil, soybean oil, sunflower oil, coconut oil, rapeseed oil and tung oil [2]. A lot of research work had been completed with vegetable oil as fuel and researchers had concluded that vegetable oil might be utilized in its neat form however it was now not most desirable [3]. It is well known that simplest one 1/3 of heat energy is used by the diesel engine effectively for the useful paintings. One part of strength is taken through the cooling system and another part of warmth is rejected to the surrounding due to the difference in temperature. Theoretically if the heat rejected is reduced, then thermal efficiency may be improved at least as much as the restriction set by means of the second law of thermodynamics [4]. Subsequently researches have been accomplished to retain this temperature. The combustion chamber of engines was covered with ceramics partially or completely and these engines had been known by way of various names together with semi adiabatic engines, Low Heat Rejection (LHR) engines, low heat loss engines and Thermal Barrier Coated (TBC) engines. Afterward it changed into additionally found that the viscosity of biodiesel can be slightly decreased due to the accelerated

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temperature of LHR engines In LHR engines, there has been slight increase in brake thermal performance with biodiesel because the fuel. Though other emission parameters had been in control, the emission of NOx was observed to be intentionally high with almost all biodiesel fuels.The oxides of nitrogen (NOx) are the most commonplace and dangerous pollutants within the exhaust of diesel engines except CO [5]. The reasons had been observed to be the availability of oxygen content within the biodiesel and elevated temperature in LHR engine at during combustion.In this experimental working it's been deliberate to combined effect of emulsified fuel and LHR engine. To increase the brake thermal efficiency with biodiesel-water emulsion the effect of LHR engine has been considered and to bring down the emission parameters to appropriate level emulsified fuels had been used as test fuel.

III. PROPERTIES OF VARIOUS BIODIESEL FUELS AND DIESEL-WATER EMULSION

Table 3.1 Comparison of properties of diesel and other biodiesel fuels

Property	Diesel	Nerium oil	Tung oil	Polanga oil	Soap Nut oil
Kinematic viscosity at 40° C (cSt)	3.09	3.57	4.68	4.91	6.4
Calorific value (kJ/kg)	43198	42823	35692	40800	38698
Density at 15°C (kg/mm^3)	830	850	910	862	896
Flash point (° C)	56	70	86	87	91
Fire point (° C)	64	83	93	95	104

Table 3.2 Composition of diesel-water emulsion

	DWM1	DWM2	DWM3
Diesel	95%	91%	87%
Water	4%	8%	12%
Span80	0.5%	0.5%	0.5%
Tween80	0.5%	0.5%	0.5%

Table 3.3 Comparison of fuel properties of diesel and diesel-water emulsion

	Diesel	DWM1	DWM2	DWM3
Density (kg/m^3)	830	833	836	841
Calorific value (MJ/kg)	43.2	40.72	38.48	36.32
Flash point (° C)	56	58	60	62
Fire point (° C)	64	65	66	68

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IV. ENGINE SETUP AND EXPERIMENTAL PROCEDURE

The most popular engine used for agricultural pump units, farm machinery and medium scale testing is Kirloskar brand engine, that's one of the oldest brand. It has the features including sturdiness at higher pressure with rugged shape. Water cooled, naturally aspirated, single cylinder, 4 stroke direct injection compression ignition engine were used for this investigation. It had a displacement volume of 661 cc and compression ratio of 17.5:1. The engine developed 5.9 kW at 1800 rpm. Now load the engine in steps of quarter, half, three fourth and complete loads and allow the engine to stabilize at each load. The fuel injection pressure was 200bar and the manufacturer had set injection timing at 27° before TDC. The engine had a combustion chamber with overhead valves operated by means of push rods. Water jackets had been providing in the engine block to control the cooling of the engine.

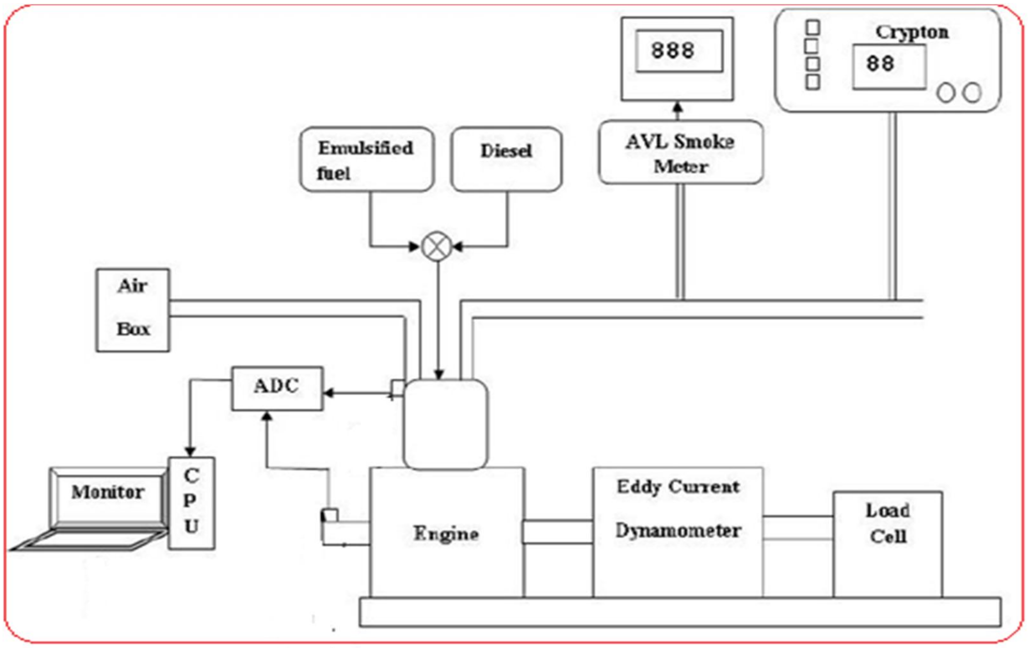

Figure 4.1 Schematic diagram of experimental layout

Figure 4.1 indicates the schematic diagram of the experimental layout used for this experimental investigation. A kirloskar SV1 engine have been coupled to an eddy current loading. Two separate fuel tanks have been maintained for reference fuel (diesel) and test fuels (biodiesel and emulsified gasoline). An AVL smoke meter and crypton fuel analyzer has been probed into the exhaust pipe.

A. Experimental Procedure

1) The experimental investigation involved the checking of the first conditions of fuel level in the tank, engine oil level, coolant level, and different producer settings of the engine.
2) The engine was allowed to run until the stable condition was reached.
3) Then the engine load was increase gradually from no load situation to full load circumstance. All different measuring equipments had been switched on and the important settings had been carried out as in step with the manual manufacturing given within the manuals of the producer.
4) The application of loads was at 5 level and they were at 0%, 25%, 50%, 75%, and 100% respectively.
5) Whenever the fuel change was carried out, the fuel traces have been wiped clean very well and the engine was left to operate for atleast half-hour to stabilize the new condition.
6) The engine was dismantled and thermal barrier coated piston and cylinder head with valve facing with had been assembled.
7) The engine was allowed to run for 30 minutes with diesel fuel to check the study conditions in running and emission characteristics.
8) Without changing different manufacturer settings diesel-water emulsion was taken as test fuel and research have been continued. After thorough cleaning of fuel line, fuel tank assessments were accomplished with nerium-water emulsion.
9) After the engine experiments have been completed, the experimental records calculation and the evaluation have been achieved.

V. EXPERIMENTAL UNCERTAINTIES

Parameters	Systematic Errors (±)
Speed	1 ± rpm
Load	± 0.1 N
Time	± 0.1 s
Brake power	± 0.5 kW
Temperature	± 1°
Pressure	± 1 bar
NOx	± 10 ppm
CO	± 0.02%
CO_2	± 0.02%
HC	± 11 ppm
Smoke	± 1 HSU

Table 5.1 Experiment uncertainties

The engine was allowed to run for few minute for the consistent study state of exhaust gasoline temperature, cooling water temperature, and the lubricating oil temperature. The steady state situation was checked for emissions having attained regular steady state values. The steady state tests have been repeated thrice for finding out experimental uncertainties. The awareness of fuel was measured for 10 mins and the averages of all consequences are given inside the table 5.1

VI. RESULT AND DISCUSSION

A. *Brake Thermal Efficiency (BTE)*

Figure 6.1 shows the curve between brake power and brake thermal efficiency of diesel, N20 biodiesel, and diesel water emulsion in low heat rejection (LHR) engine. The max. brake thermal efficiency acquired with diesel fuel at three fourths of the load was found to be 30.15 %. The increase in efficiency was found to be 0.72%, 0.89%, and 0.93% for DWM1, DWM2, and DWM3 respectively while as compared to diesel. On comparing uncoated and LHR engine, it became seen that there was increase in the efficiency of diesel, N20, and emulsified fuels. LHR engines operate at a better temperature than the conventional engine as it is insulated with thermal barrier coating and heat retained during combustion is more than the conventional engine. The max. efficiency for diesel fuel in LHR engine at three fourths of the load was observed to be 28.49 % which was 0.31% better than uncoated engine. The increase in efficiency was observed to be 0.475%, 0.5396%, 0.57%, and 0.58% for N20, DWM1, DWM2, and DWM3 respectively whilst in comparison to uncoated engine. LHR engines also decreased the viscosity of N20 biodiesel and caused higher atomization of heavier molecules of biodiesel fuel.

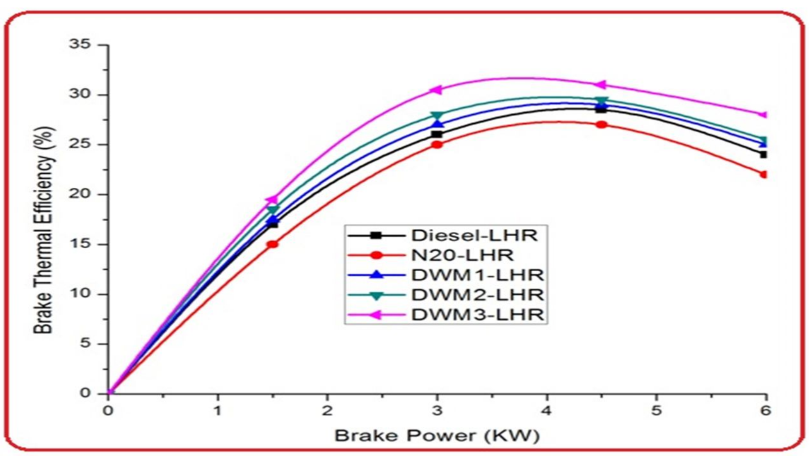

Figure 6.1 Brake power Vs brake thermal efficiency (BTE) emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

Subsequently efficiency of N20 biodiesel were more in LHR engine than conventional engine. In case of emulsified fuels, micro explosion of water droplets was still increase and subsequently the atomization and the mixture of fuel have been higher than conventional engine. Rapid vaporization of water droplets and secondary atomization in LHR engine increase the combustion reaction still better than the conventional engine.

B. Specific Energy Consumption (SEC)

Figure 6.2 illustrates the consequences obtained for specific fuel consumption in LHR engine for diesel, N20 biodiesel, and diesel-water emulsion. From the curve is is clear that specific fuel consumption increased with the increase in the load because the engine fed on more fuel at high load. Specific energy consumption of diesel is observed to be the bottom amongst other test fuels. The specific energy consumption of diesel at full load was observed to be 14636.77 kJ/kWh.

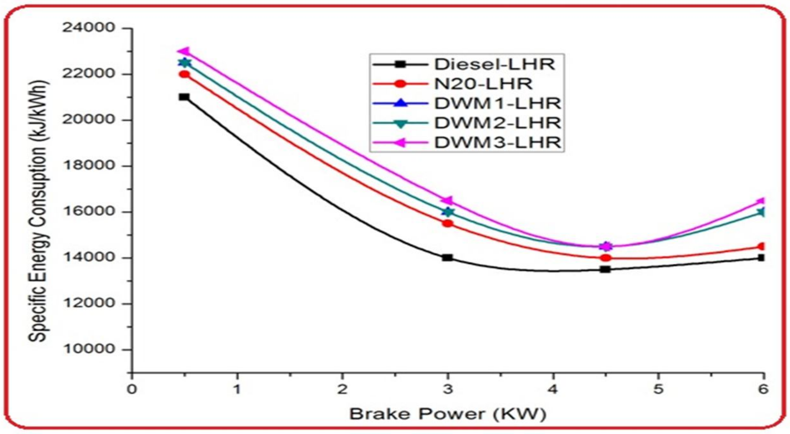

Figure 6.2 Brake power Vs specific fuel consumption (SEC) of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

The higher calorific value of diesel might be attributed to the lowest specific fuel consumption amongst other test fuels. The increase in specific power consumption was found to be 1443.24 kJ/kWh, 1837.24 kJ/kWh, 2034.24 kJ/kWh, and 2054.24 kJ/kWh for N20 biodiesel, DWM1, DWM2, and DWM3 respectively while in comparison to diesel. The increase in specific energy consumption was observed to be least with N20 biodiesel between different test fuels (DWM1, DWM2, and DWM3). Calorific value of N20 biodiesel is better than that of emulsified test fuels and for this reason fuel consumption is less. The increase in specific fuel consumption might be because of the decrease calorific value of the emulsified fuels. Marginal reduction of specific energy consumption is observed in low heat rejection (LHR) engines in comparison to the conventional engine. The reduction of SEC was determined to be 224.032 kJ/kWh, 245.995 kJ/kWh, 251.995 kJ/kWh, 254.995 kJ/kWh and 258.495 kJ/kWh respectively with diesel, N20, DWM1, DWM2, and DWM3 respectively in comparison to the conventional engine. The positive effect of higher combustion temperature because of the thermal barrier coating decreased the specific energy consumption in LHR engine.

C. Exhaust Gas Temperature

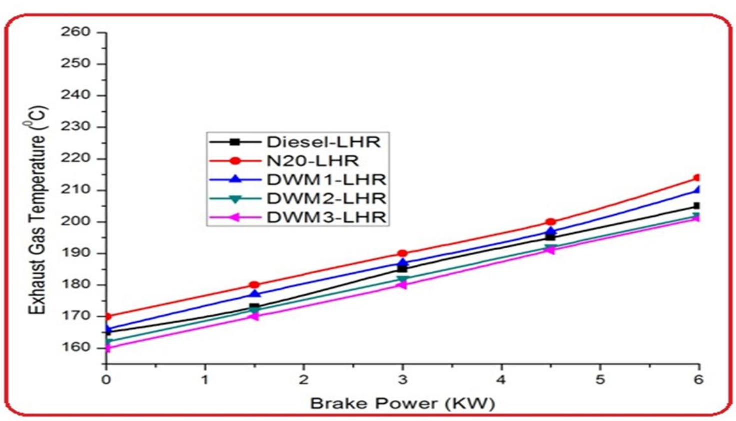

Figure 6.3 Brake power Vs exhaust gas temperature of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

Figure 6.3 shows the curve between brake power and exhaust gas temperature of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine. The exhaust gas temperature is observed to be increase with increasing the load for both reference gas and all test fuels. It is probably because of more fuel consumption during higher masses and hence more heat energy was produced. The increase in exhaust gas temperature was found to be 4.87% and 1.24% for N20 biodiesel and DWM1 respectively. The exhaust gas temperature was observed to be reduced by 0.98% and 1.96% for DWM2 and DWM3 respectively. But when compared with the conventional engine the exhaust gas temperature become extended for each reference fuel and test fuels. The increase in exhaust gas temperature might be due to the temperature retained in the combustion chamber due to the thermal barrier coating and the same might have been carriedout by using the combustion product to the exhaust gas.

D. Unburnt Hydrocarbon (Hc) Emission

Figure 6.4 shows the unburnt hydrocarbon (HC) emission for diesel, N20 biodiesel, and diesel-water emulsion in LHR engine. The unburnt hydrocarbon emission for diesel was found to be 73.89 ppm at max. load condition. The decrease in HC emission were found to be 4.994 ppm, 6.895 ppm, 8.875 ppm, and 10.848 ppm for N20 biodiesel, DWM1, DWM2, and DWM3 respectively in comparison with diesel fuel. It also found that the HC emission is much less in LHR engine whilst in comparison with the conventional engine for both reference and test fuels.

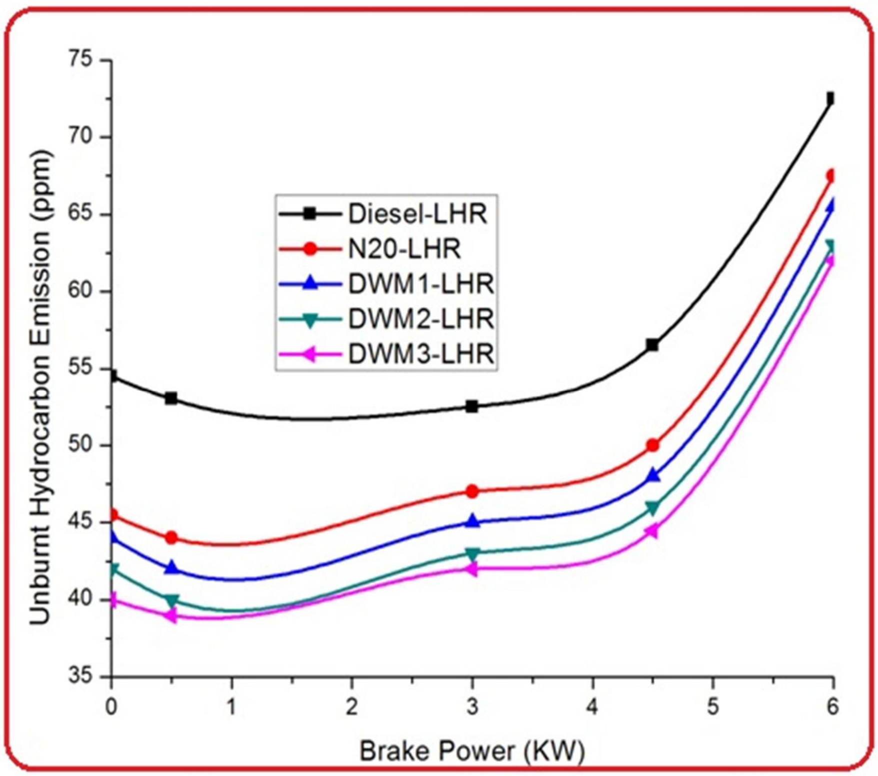

Figure 6.4 Brake power Vs unburnt hydrocarbon (HC) emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

The reduction in HC emission in LHR engine is observed to be 0.98 ppm, 1.004 ppm, 1.12 ppm, 1.25 ppm, and 1.34 ppm for diesel, N20 biodiesel, DWM1, DWM2, and DWM3 respectively in comparison with the conventional engine. HC emission were found to be minimal for DWM3 in both conventional and LHR engine. The oxygen content in the N20 biodiesel and better combustion temperature in LHR engine resulted in the reduction of hydrocarbon emission. In emulsified fuels, rapid micro-explosion of water droplets caused fine atomization of fuel droplets and brought about homogeneous mixture formation, which further resulted in entire combustion.

E. Carbon Monoxide (CO) Emission

Figure 6.5 suggests the curve among brake power and carbon monoxide emission for diesel, N20 biodiesel, and diesel water emulsion in LHR engine. The CO emission at maximum load for diesel was observed to be 0.0909% in LHR engine.

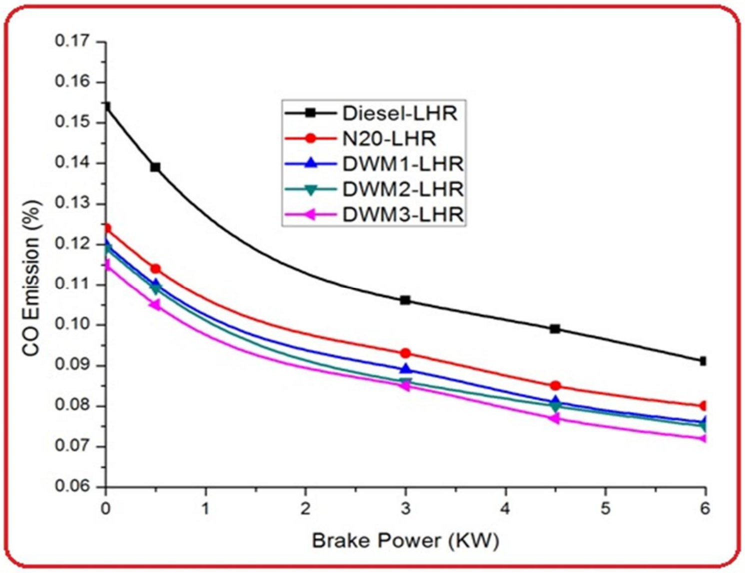

Figure 6.5 Brake power Vs carbon monoxide (CO) emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

The reduction in CO emission was found to be 0.0126%, 0.0154%, 0.0175%, and 0.0205% for N20 biodiesel, DWM1, DWM2, and DWM3 respectively when as compared to diesel fuel. It also determined that reduction in CO emission was observed to be 0.00091%, 0.00158%, 0.00231%, 0.002438%, and 0.002412% for diesel, N20 biodiesel, DWM1, DWM2, and DWM3 respectively as compared with the conventional engine. The reduction in CO emission in LHR engine is probably attributed to the homogeneous combustion that befell because of the higher running temperature than the conventional engine. The dissociation of OH radicals was more rapid in LHR engine than within the conventional engine, which caused higher atomization of fuel and in addition caused better combustion. Homogeneous combustion in LHR engine brought about much less CO emission than the conventional engine. The CO emission was determined to be the minimum for DWM3 among all the test fuels.

F. Smoke Opacity Emission

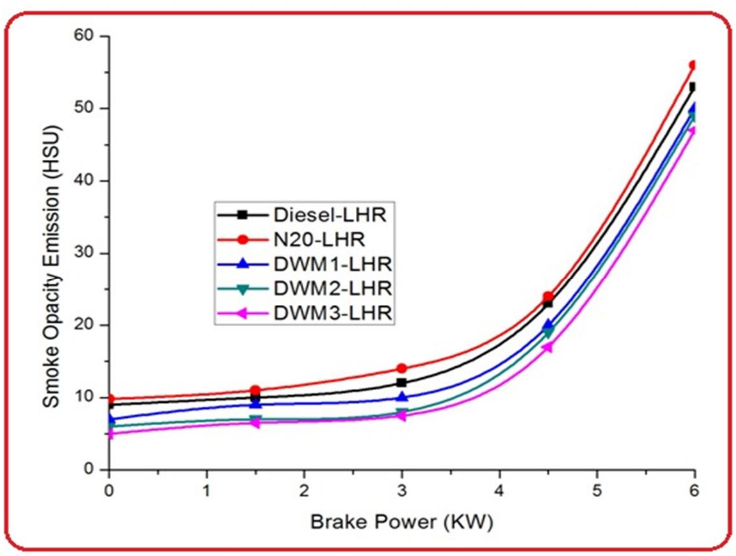

Figure 6.6 Brake power Vs smoke opacity emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

Figure 6.6 suggests the graph between brake power and smoke opacity emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine. From the experiment it was found that the smoke emission of diesel fuel at full load was determined to be 52 HSU, which was 1.2 HSU less than the conventional engine. Smoke emission found to be 5.2% more for N20 biodiesel than diesel. The reduction in smoke emission is found to be 6.33%, 9.02%, and 13.4% respectively for DWM1, DWM2, and DWM3 respectively compared with diesel. The homogeneous combustion due to higher atomization than the conventional engine might be the reason for decreased smoke emission. The atomization and mixing had been observed to be still higher than the conventional engine, due to the better working temperature of LHR engine. The reduction in smoke emission found to be 2.1 HSU, 2.five HSU, 2.9 HSU, and 3.2 HSU for N20 biodiesel, DWM1, DWM2, and DWM3 respectively while as compared to conventional engine.

G. Oxides of nitrogen (NO_x) emission

Figure 6.7 indicates the graph between brake power and oxides of nitrogen (NOx) emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine. The plausible causes for the NOx emission are high combustion temperature and availability of oxygen within the fuel. The most NOx emission of diesel was determined to be 487.83 ppm in LHR engine at full load, which became 4.83 ppm more than the conventional engine. The NOx emission of N20 biodiesel was observed to be 73 ppm more than diesel fuel. The oxygen availability within the N20 biodiesel and higher operating temperature of LHR engine might be the reasons for the higher NOx emission. The decrease in NOx emission was found to be 125.44 ppm, 145.81 ppm, and 161.98 ppm for DWM1, DWM2, and DWM3 respectively in LHR engine while compared to diesel. Unexpected fall in the combustion temperature because of vaporization of water droplets reduced the rate of reaction between oxygen and nitrogen and caused less NOx emission. The increase in NOx emission in LHR engine was determined to be 4.83 ppm and 11 ppm for diesel and N20 biodiesel respectively as compared with the conventional engine.

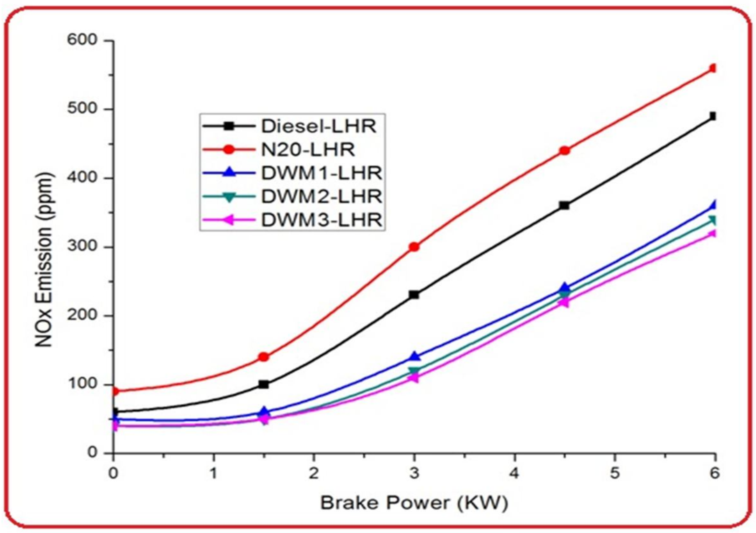

Figure 6.7 Brake power Vs oxides of nitrogen (NO_x) emission of diesel, N20 biodiesel, and diesel-water emulsion in LHR engine

VII. CONCLUSION

A. The brake thermal efficiency of DWM3 was found to be the best amongst all other fuels test within the engine. The efficiency of DWM3 was observed to be better than the performance obtained within the conventional engine.
B. The specific energy consumption of all fuels observed to be much less in LHR engine while as compared to the conventional engine. The SFC of diesel fuel was found to be the lowest of all.
C. The exhaust gas temperature turned into discovered to be higher for both reference fuel and all test fuels in LHR engine, than the conventional engine.
D. The unburnt hydrocarbon is observed to be better for diesel whilst in comparison to other test fuels. For DWM3 it was the lowest amongst other fuels used. HC emission of DWM3 was dfound to be still reduced in LHR engine while in comparison to the conventional engine.
E. The carbon monoxide (CO) emission is found to be higher for diesel when as compared to different test fuels.
F. Emulsified fuels (DWM1, DWM2, and DWM3) produced less smoke opacity emission whilst compared to diesel and biodiesel fuel. Smoke opacity emission was found to be the lowest for DWM3.
G. The oxides of nitrogen (NOx) emission were observed to be the best for N20 biodiesel amongst other fuels test within the LHR engine. Emulsified fuels produced less NOx emission than diesel and biodiesel fuels. The NOx emission was observed to be the lowest for DWM3 among all different fuels tested.

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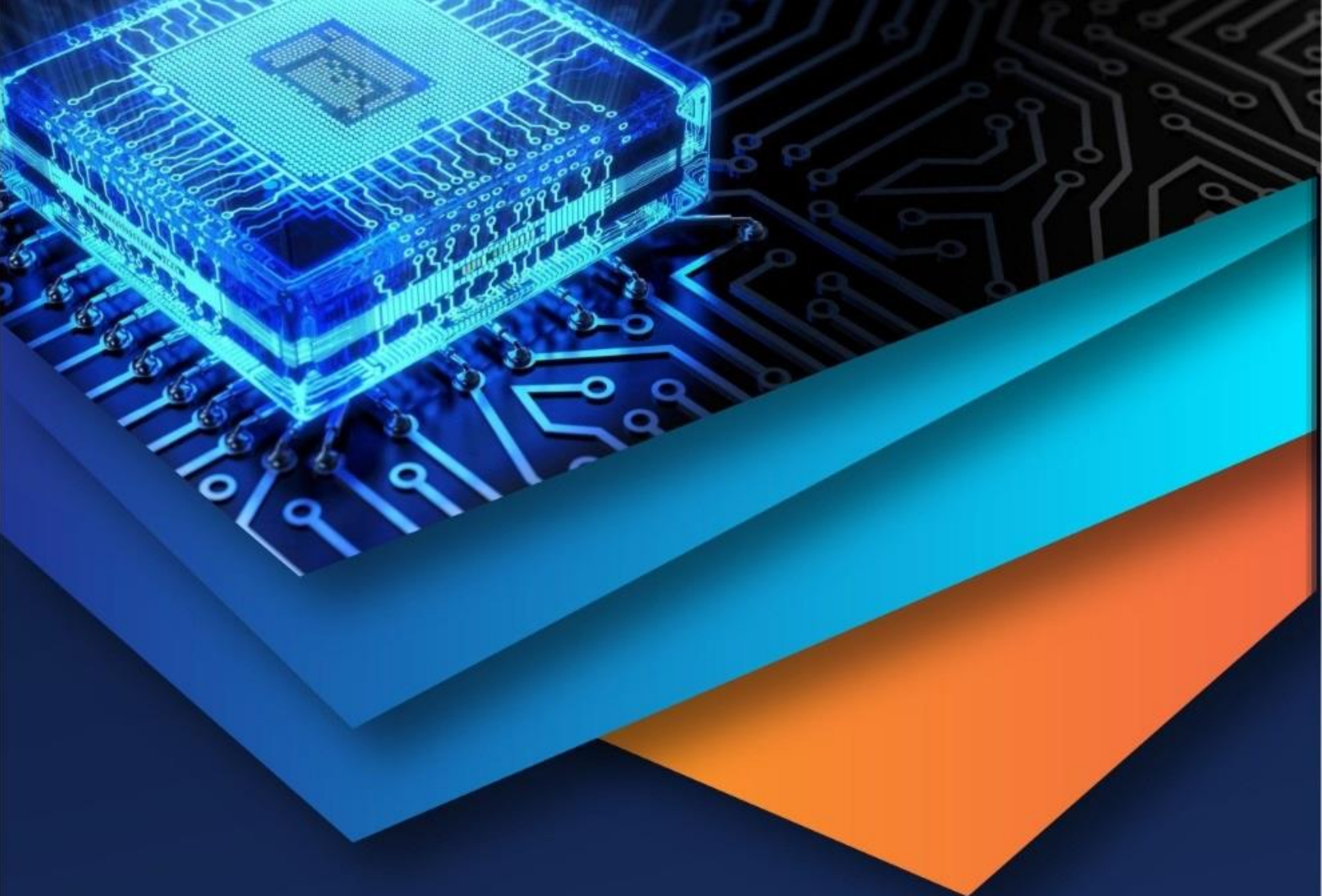

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