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Experimental Investigation on four Stroke Single Cylinder C.I. Engine using Diesel and Acetylene with and without AL2O3 Nano Additive

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Abstract**:** ***Present experimental work is focused on reducing dependency on petroleum based fuels by using an alternative fuel i.e. acetylene and by improving fuel quality i.e. using Al2O3 nanoparticles in diesel. Previous research work shows that use of acetylene can reduce the emission of exhaust gas and nanoparticle in diesel enhances uniform combustion of fuel. This study is based on finding the performance characteristics and fuel economy of internal combustion engine at different fuel configuration. In the present investigation a four stroke single cylinder diesel engine which is run on dual fuel mode with and without nanoparticle additive with diesel. The engine is also run using nanoparticle additive in diesel and the result is compared with pure diesel condition. This experiments show that at lower acetylene flow rate engine brake thermal efficiency and fuel economy can be increased but at higher acetylene flow rate brake thermal efficiency is reduced. Based on performance and cost analysis acetylene flow rate is optimized to 0.068 kg/h for the engine used.***
Keywords: ***Ci engine, dual fuel mode, acetylene, Al2O3 nanoparticle, fuel economy.***

I. INTRODUCTION

Internal combustion engine are widely used to generate mechanical power. SI and CI engine are commonly used in automobile, earthmovers, locomotives, ships, marine, agriculture, and to provide motive power for generators, and industrial equipment. These engine uses fossil fuels petrol and diesel. These energy source are non-renewable and limited on earth. Also they increases environmental pollution. Presently due to increasing population and lifestyle energy demand is continuously increasing. This increases imports of fossil fuel to fulfil the requirement of fuel to be used in internal combustion engine. Our country invest a large amount of wealth to import petroleum fuel from Arabian countries. So any attempt that reduces the dependency on petroleum based fuel will be most welcome. The dependency on petroleum fuel can be reduced by either using an alternative fuel or by Enhance the quality of available fuel so low amount of fuel will be used for same power generation.

Many alternative fuels like vegetable oil, biodiesel, alcohol, liquefied petroleum gas (LPG), hydrogen, compressed natural gas, producer gas, biogas and acetylene can be used in IC engine. In dual fuel mode gaseous fuel can be used in CI engine without much modification. Acetylene gas has many such quality that makes it a good alternative fuel used in duel fuel mode, as compare to other alternative fuels.

TABLE I

Thermal and combustion property of acetylene and diesel

S. no.	Properties	Acetylene	Diesel
1	Formula	C_2H_2	C_8 –C_{29}
2	Molecular weight	26.04	200
3	Density, kg/m^3, at 20 ^{0}C and 1 atm,	1.092	840
6	Stoichiometric air fuel ratio, kg/kg	13.2	14.5
7	Flammability limit, volume %	2.5-81	0.6-5.5
9	Auto ignition temperature, ^{0}C	305	257
10	Lower calorific value, kj/kg	48,225	42,630
11	Lower calorific value, kj/m^3	50,636	9,600
12	Maximum deflagration speed ,	1.5	.3

	m/sec		
13	Ignition delay period, sec	--	0.002

Reduction in exhaust emission, and fuel consumption can achieved by improving the quality of fuel by adding Nano particle with liquid fuel. Especially metal nanoparticle can enhance droplet evaporation by absorbing radiation energy, increase surface area and catalyst activity, and can make the ignition delay shorter. The use of Nanoparticle in internal combustion engine causes more uniform combustion and high heat release rate and hence more complete combustion. Different metallic nanoparticle used are cerium oxide, aluminium oxide and copper oxide. Addition of Alumina nanoparticle in diesel provide better penetration of injected fuel in compressed air and improve inflammatory mechanism. Alumina nanoparticle in fossil fuel improves the combustion stability and combustion efficiency. In our experiment alumina nanoparticle are used with diesel and acetylene gas.

II. LITERATURE REVIEW

T. Lakshmana et al. [1] investigated the performance of diesel engine with fixed acetylene flow rate of 3 lpm and concluded decrease in brake thermal efficiency at this flow rate due to high heat release rate at full load condition. They also observed decrease in smoke, unburned hydrocarbon emission, and carbon monoxide emission, and increase in NOx emission, ignition delay, peak pressure and rate of pressure rise due to the acetylene.

Malaha et al. [2] used diethyl ether additive 10 to 30 % in diesel and run the engine on dual fuel mode with acetylene. Diethyl ether additive is used to reduce the NOx emission. They observed no change in brake thermal efficiency with this fuel configuration and reduction in exhaust gas temperature and brake specific energy consumption with acetylene addition.

D kumaran et al. [3] Used turpentine and diesel mixture (turpentine 40% and diesel 60 %) with acetylene to run the diesel engine and evaluate the performance characteristic. He observe small increase in brake thermal efficiency and decrease in emission of CO, UHC, and exhaust gas temperature. They concluded that tri fuel operation provide wide range of flammability, and increased thermal efficiency.

J. h. jhou et al. [5] used hydrogen and methane gas mixture and calculated the diesel engine performance on dual fuel mode. They observed peak cylinder pressure, heat release rate, and rate of pressure rise increases with increasing hydrogen percentage. With 40% energy substitution the gaseous fuel changes the thermal property of intake air fuel mixture. Due to this ignition delay increases slightly in dual fuel mode which is more apparent with increasing hydrogen addition.

S. K. Basha [7] run the diesel engine on dual fuel mode at different compression ratio. They observe increase on brake thermal efficiency with acetylene flow rate. He also observe decrease in CO, HC, and emission and optimize the acetylene flow rate of 280 gm/h.

Jadhaw et al. [8] performed experiment on SI engine on dual fuel mode with acetylene gas, they observe increase in brake thermal efficiency, and Decrease in specific fuel consumption. R. Amirante et al. [9] run the CI engine on dual fuel mode by using natural gas. They observe that effect of propane addition increases indicated mean effective pressure in all condition because propane gives more stable fast and efficient combustion process. Chiragkumar et al. [10] run the engine on try fuel mode with acetylene, turpentine and diesel.

Seyyed Hassan Hosseini et al. [11] used aluminium oxide Nano particle and diesel biodiesel blend to run the CI engine and investigate the performance of engine. They observed reduction in BSFC, CO, NOx, emission with increase in nanoparticle addition. They also observe that output power, torque, and exhaust gas temperature increases with amount of nanoparticle.

Harish venu et al. [12] compare the performance characteristic of diesel engine with diethyl ether and aluminium oxide nanoparticle. Diethyl ether and nanoparticle is added on biofuel blend. They observe that BSFC, NOx smoke and UHC emission become low with nanoparticle additive. Combustion duration increases with diethyl ether addition. Ignition delay combustion duration, and peak pressure decreases in nanoparticle addition with biofuel.

Most of the work in this area ware done to run the engine of various capacity on dual fuel mode and they observe the reduction in emission of polluting agent like CO_2, CO, NOx ,smoke, exhaust gas temperature and increase in brake thermal efficiency at part load condition in dual fuel mode.

In the previous reported research work higher acetylene flow rate ware used. It is necessary to use relatively pure gas to perform experiment, and to use the acetylene flow rate very small to calculate the performance characteristics. It is necessary to determine the effect of Al_2O_3 nanoparticle on performance characteristic of engine in condition when it is used with diesel only and when it is used in engine operated on dual fuel mode.CI engine are widely which makes necessary to do cost based analysis of engine running on acetylene gas and nanoparticles. So we can determine the way which can minimize the use of diesel, which is cost efficient and can increase the engine performance of diesel engine.

III.EXPERIMENTAL SETUP

Experimental setup contains a diesel engine test rig, an acetylene gas cylinder and a weighting machine. The diesel engine test rig consist of a diesel engine, a dynamometer, calorimeter, thermostat arrangement and electronic display, burette for measuring diesel flow and manometer. The diesel engine used is single cylinder, four stroke, and vertical head diesel engine. The specification of engine used are as follow-

A. Rated power 5 H.P
B. Rated rpm 1500
C. Bore diameter 85 m
D. Stroke length 110 mm
E. Cooling water cooled

The hydraulic dynamometer with weighing attachment is used to apply the load, which can apply 0 kg to 10 kg load on diesel engine but due to engine and loading problem reading ware taken till 4 kg load. Calorimeter is used to measure the loss of energy with exhaust gas. Thermocouple are used to measure temperature of inlet water, exit water from calorimeter and engine cooling, exhaust gas temperature at before and after calorimeter. Readings of thermocouple is shown on digital display. Water pipes are connected to engine, calorimeter, and dynamometer. The flow rate of diesel is measured with help of burette on diesel engine test rig. Diesel is poured in burette by a funnel.

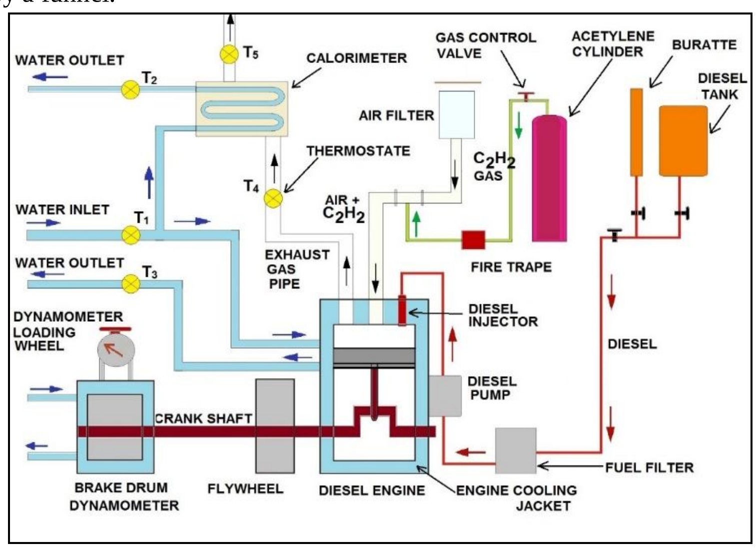


Fig.1 - Schematic diagram of experimental setup

The Acetylene gas cylinder used having total weight of 65 kg, which contain acetylene gas of approximately 7 kg. Cylinder contain gas at pressure 30 bar. A two way pressure gauge valve, in which one pressure gauge shows the cylinder pressure and another gauge shows the line pressure is fitted on cylinder. Flow of acetylene is controlled by the valve on regulator. Gas is supplied with inlet air, for this acetylene gas pipe is connected to inlet air pipe of engine. An electronic weighing machine is used to measure the change in weight of Acetylene cylinder. Least count of weight machine used is 5 grams. A fire trap is placed in acetylene gas pipe, in between acetylene cylinder and inlet air pipe to engine. The fire trap is used to stop the flame before acetylene cylinder in case of backfire from engine. Tachometer is used to measure rpm (revolution per minute) of the diesel engine. Sound level meter is used to take measurement of noise produced by engine.

IV. METHODOLOGY

First the engine is started by cranking with desired amount of fuel. The engine is operated constantly for half an hour to ensure complete combustion of diesel in combustion chamber. During conduction of experiments the fuel injection timing and injection pressure where kept constant. The engine is loaded by dynamometer to obtain engine performance parameter at different load condition. Now we close the diesel tank valve, so the diesel left on burette pipe is start to consume by diesel engine. The engine is operated with pure diesel at different load condition. At this condition diesel consumption, temperature at different points, noise level and other readings are taken.

After taking initial readings of pure diesel, engine performance have been taken on dual fuel mode by slowly opening the valves of Acetylene gas cylinder. The gas is mixed with intake air before the combustion chamber. Observation are listed at different acetylene flow rate and different load on engine.

0. 25 gm aluminium oxide nanoparticle is mixed with 1 liter of diesel by magnetic stirrer for half an hour. The mixture obtained is diesel containing nanoparticle 0.25 g/l, of diesel. Similarly the mixture of diesel containing nanoparticle 0.50 g/l of diesel and 0.75 g/l of diesel is prepared.

Now the diesel engine is run using the diesel containing nanoparticle and the observation is noted at different load. Readings are also taken on dual fuel mode for low acetylene flow rate and diesel containing nanoparticle of 0.25 g/liter.

A. Variation in brake specific fuel consumption with load

The graph on fig. 2 shows the variations of fuel consumption rate (in kg/h) at different load condition on engine, with different acetylene flow rate (in kg/h). When acetylene is started to supply with intake air diesel consumption rate start to decrease. On supplying very small amount of acetylene up to 0.059 kg/h, the flow of fresh air to combustion chamber does not affected more. Efficient and rapid combustion of gaseous fuel mixture occur due to sufficient amount of oxygen present in incoming air, and due to higher calorific value of acetylene, the consumption rate of diesel become low.

V. RESULT AND DISCUSSION

Table II

Fuel designation

Designation	Fuel
A 0	Diesel + Acetylene 0 kg /h.
A 0.059	Diesel + Acetylene 0.059 kg /h.
A 0.116	Diesel + Acetylene 0.116 kg /h.
A 0.203	Diesel + Acetylene 0.203 kg /h.
A 0.282	Diesel + Acetylene 0.282 kg /h.
A 0.379	Diesel + Acetylene 0.379 kg /h.
A 0.456	Diesel + Acetylene 0.456 kg /h.
N 0.25	Diesel + Al_2O_3 nanoparticle 0.25 gm/h
N 0.50	Diesel + Al_2O_3 nanoparticle 0.50 gm/h
N 0.75	Diesel + Al_2O_3 nanoparticle 0.75 gm/h
N 0.25 + A 0.082	Diesel + Al_2O_3 nanoparticle 0.25 gm/h + Acetylene 0.082 kg /h.
A 0.068	Diesel + Acetylene 0.068 kg /h.
A 0.409	Diesel + Acetylene 0.409 kg /h.

Diesel consumption rate slightly increases when acetylene flow rate increases from 0.059 kg/h to 0.116 kg/h. The reason may be that on increasing acetylene flow rate from 0.059 kg/h to 0.116 kg/h, then a part of fresh air is replaced by acetylene gas and volumetric efficiency reduces. Acetylene has higher self-ignitions temperature compared to diesel. So diesel consumption rate increases at acetylene flow rate of 0.116 kg/h, but it is still lower than baseline diesel operation. Further increase in the acetylene flow rate, the fraction of energy supplied by acetylene increases and due to higher calorific value of acetylene diesel consumption rate reduces slowly. At acetylene flow rate of 0.379 kg/h diesel consumption rate become minimum, and large fraction of energy is supplied by acetylene gas in this condition. When acetylene flow rate increases from 0.379 kg/h to 0.456 kg/h the diesel flow rate again start to increase. This may be due to that at higher acetylene flow rate the amount of pilot fuel (diesel) in combustion chamber become very small, so the area of auto ignition by pilot fuel inside combustion chamber become very small. Also the volumetric efficiency at this condition become very low. This causes ruff running of engine due to improper combustion of gaseous fuel air mixture the need of pilot fuel inside combustion chamber increases.

When nanoparticles start to supply into the combustion chamber with diesel the requirement of diesel as compared to pure diesel operation is reduced. This may be due to improvement in fuel mixing and uniform combustion by addition of nanoparticle. Diesel consumption rate is small when running with fuel having nanoparticle density 0.25 g/l of diesel is supplied to engine as compared to pure diesel operation. Increasing Nano particle density from 0.25 g/l the diesel consumption rate increases. This may be due to reduction in possibility of atomization of fuel in higher nanoparticle density. At all Nano- particle density the diesel consumption rate is lower as compared to baseline diesel operation but when compared to dual fuel mode operation with acetylene the diesel consumption rate is higher.

When engine is operated on dual fuel mode with diesel containing nanoparticle additive 0.025 g/liter and the fuel consumption decreases compare to base line diesel operation, but it is higher when compare to dual fuel mode operation with similar acetylene flow rate without Nano particle additive on diesel. The reason may be the pre-ignition of gas air mixture due to nanoparticle additive.

B. Variation in brake thermal efficiency with load on engine at different fuel configuration

The graph in fig. 3 shows the variation in break thermal efficiency of engine with different load on engine. When operating the engine with only diesel fuel the maximum brake thermal efficiency at 2.0339 kW power is 23.62%. On dual fuel mode when very small amount of acetylene 0.059 kg/h is started to supply with intake air the brake thermal efficiency rapidly increases to 34.77% at 2.034 kW power output. This may be due to higher calorific value of acetylene as compared to Diesel, more homogeneous air fuel mixture and in small acetylene flow rate supply of fresh air to cylinder does not affected more and decrease in volumetric efficiency is negligible. Quick combustion rate of gaseous fuel due to higher flame speed in acetylene mixture helps to increase peak cylinder pressure and brake thermal efficiency at small acetylene flow rate.

On increasing acetylene flow rate from 0.059 kg/h to 0.116 Kg/h brake thermal efficiency start to decrease, due to increased diesel consumption at 0.116 kg/h compared to 0.059 kg/h acetylene flow rate. But it is still more when compared to baseline diesel operation. When acetylene flow rate further increases from 0.116 kg/h, the brake thermal efficiency gradually reduces and become low as compare to baseline diesel operation. The reason may be higher energy release rate in gaseous fuel mixture. Above acetylene flow rate of 0.379 kg/h brake thermal efficiency of engine reduces drastically due increase in diesel consumption rate and improper combustion of fuel mixture.

When operating the engine with nanoparticle in diesel the brake thermal efficiency of engine increases compared to pure diesel operation. This may be because of dropped viscosity, better fuel spraying, more complete combustion and effective energy conversion by addition of nanoparticle. Brake thermal efficiency reduces when nanoparticle density is increased from 0.25 g/l to 0.5 g/l. the reason behind this may be lower combustion duration and the reduced possibility of atomization with higher nanoparticle density on fuel mixture. The brake thermal efficiency with addition of nanoparticles in diesel is more when compared to dual fuel dual fuel mode operation with acetylene flow rate of 0.116 Kg/h and above acetylene flow rate. But the efficiency is small when comparing with acetylene flow rate of 0.059 Kg/h in dual fuel mode.

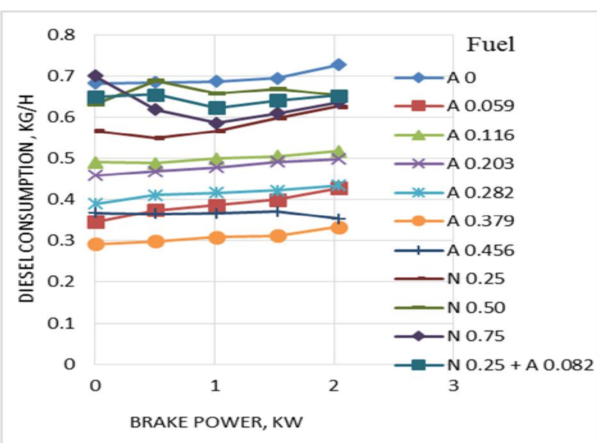


Fig. 2 Variation in mass flow rate of diesel on different engine load

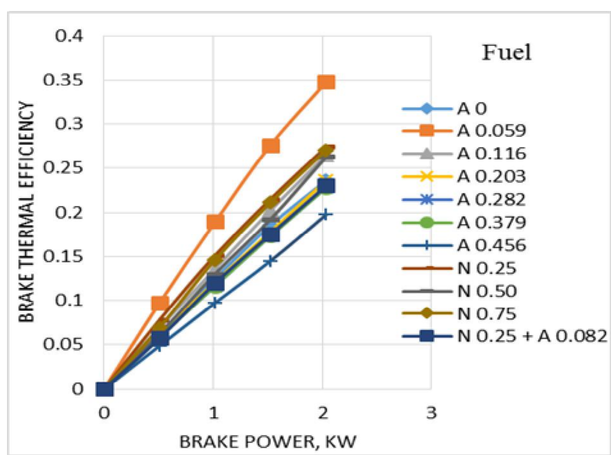


Fig. 3 Variation in efficiency with brake power

It is clear from graph when engine is operated on dual fuel mode with diesel containing nanoparticle additive the brake thermal efficiency decreases as compared to baseline diesel operation. The possible reason may be loss of energy due to pre-ignition of fuel mixture. On dual fuel mode with the engine does not completely utilize the energy of fuel.

C. Variation in brake specific fuel consumption with load

The graph on fig. 4 - Shows the variation of brake specific fuel consumption of diesel with different loading condition on engine and with different fuel configuration. For each fuel composition decreases with increasing load on engine due to increased utilization of fuel with increasing engine load. This may be due to by the fact on increasing load volumetric efficiency and temperature inside combustion chamber increases, which help in better fuel atomization and increased rate of reaction.

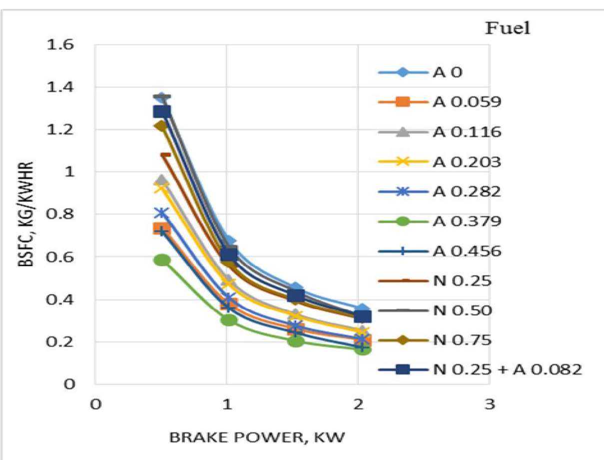
When engine is run on dual mode brake specific fuel consumption reduces as compared to baseline diesel operation. This is due to the fact that on dual fuel Mode a part of energy is supplied by gaseous fuel and also the acetylene has higher calorific value as compared to diesel. On very small acetylene flow rate of 0.059 kg/h with intake air, a large reduction in specific fuel consumption is observed. This may be due to higher calorific value of acetylene. This indicate high combustion efficiency at this low rate of acetylene flow. BSFC increases on acetylene flow rate of 0.116 kg/h as compared to BSFC at 0.059 Kg/h due to increase in diesel consumption rate. When acetylene flow rate further increases, BSFC start to reduce slowly. The minimum value of BSFC is 0.1640 kg/kW hr at acetylene flow rate of 0.379 kg/h.

On increasing acetylene flow rate from 0.379 kg/h BSFC start to increase due to increase in diesel consumption rate.

When operating the engine with diesel containing Alumina nanoparticle brake specific fuel consumption is lowered as compared to baseline diesel operation. On increasing nanoparticle density from 0.25 g/l the brake specific fuel consumption increases. This is due to more complete and uniform combustion in presence of nanoparticles. When operating the engine with nanoparticle in diesel the BSFC is more as compared to the engine operation on dual fuel mode. When running the engine on dual fuel mode with acetylene flow rate of 0.082 kg/h and diesel containing nanoparticle of 0.25 g/l the brake specific fuel consumption is low as compare to pure diesel condition. But it is higher than dual fuel mode with similar acetylene flow rate and when engine is operating with diesel containing nanoparticle additive.

D. Variation in exhaust gas temperature

he graph on fig. 5 shows the variation in temperature of exhaust gases from engine on various load. It can be observed from the graph that for each fuel composition the exhaust gas temperature increases with increasing load on engine. This may be due to increase in fuel flow rate with increasing load. High temperature produces by combustion of more fuel with increasing load. So exhaust temperature increases with load on engine.



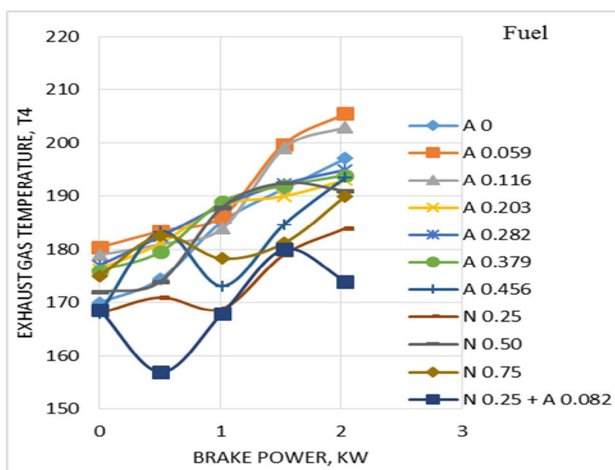


Fig.4 Graph between brake power and Brake specific fuel consumption Fig. 5 Graph between brake power and exhaust gas temperature

On acetylene flow rate of 0.059 kg/h the exhaust gas temperature is higher. This may be due to high calorific value of gaseous fuel and rapid combustion of air fuel mixture. When acetylene flow rate for the increases from 0.059 kg/h, the exhaust gas temperature start to reduce due to reduction in fresh air intake and volumetric efficiency. At acetylene flow rate of 0.116 Kg/h the exhaust gas temperature is still higher than baseline diesel operation. When acetylene flow rate further increases to higher value of 0.456 Kg/h, diesel consumption rate starts to increase and the exhaust gas temperature fluctuates below and above the baseline diesel operation in this condition. This may be due to improper combustion.

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When running the engine with Alumina nanoparticle in diesel, the exhaust gas temperature is low as compared to baseline diesel operation except in case for nanoparticle density of 0.5 g/l, this may be due to uniform combustion of fuel mixture in presence of nanoparticle. When compared to dual fuel mode operation the exhaust gas temperature is low when running the engine with nanoparticle in diesel. When running the diesel engine on dual fuel mode with diesel containing nanoparticle the exhaust gas temperature fluctuates and it is low compared to all fuel configuration. In this condition due to pre ignition of gaseous mixture the pressure and temperature inside combustion chamber is reduced.

E. Variation in noise level with different load

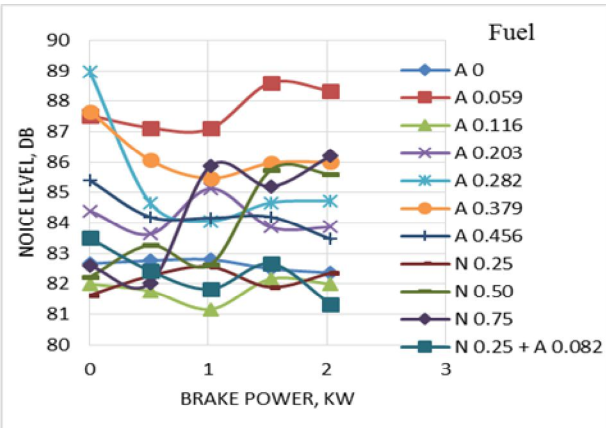

Fig. 6 Graph between brake power and noise level

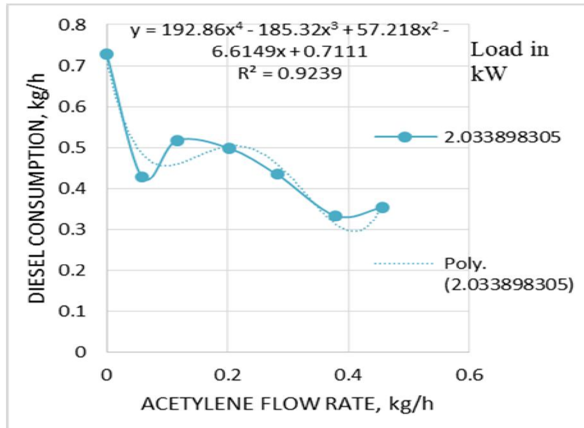

Fig. 7 Graph between acetylene flow rate and diesel consumption

The graph on fig. 6 shows the variation of noise level with different load on engine and in different acetylene flow rate. The noise level is measured in decibel in three different places near from experimental setup and their average is calculated and plotted in graph.

On no load condition high noise level is observed and increasing load it reduces first and then slowly increases. This may be due to the reason that on increasing load diesel consumption slowly increases. This reduce the effect of acetylene and rate of pressure rise inside the combustion chamber and reduced noise level. It is observed that noise level is higher in 0.059 kg per hour and minimum in 0.116 kg per hour of acetylene flow rate. From acetylene flow rate of 0.203 kg per hour the noise level increases with increasing acetylene flow rate.

The noise level increases with addition of Alumina nanoparticle with diesel. The noise level is low compared to baseline diesel operation in case when nanoparticle is added in very small amount. On increasing nanoparticle density noise level from engine is increased above baseline diesel operation. When running the engine on dual fuel mode with diesel containing nanoparticle. The noise level fluctuates above and below when compared to engine operation on pure diesel condition and when diesel contains nanoparticle 0.25 g/liter. Noise level reading is also affected by different factors like vibration in any engine component, reflection of sound in room which may results in unappropriated reading of noise level meter.

F. Optimization for minimum diesel consumption rate

To obtain the acetylene flow rate that can provide minimum diesel consumption, a graph is plotted between acetylene flow rate and diesel consumption as shown in fig. a trend line is drawn on the curve of 2.0339 kW loading on engine. Acetylene flow rate of 0.409 kg/h is optimized for minimum diesel consumption rate.

G. Optimization for maximum brake thermal efficiency

To optimizing acetylene flow rate for maximum brake thermal efficiency a trend line is drawn on the curve of 2.0339 kW loading on engine as shown in fig. Based on the calculation the acetylene flow rate of 0.068 kg/h is optimized for maximum brake thermal efficiency on dual fuel mode.

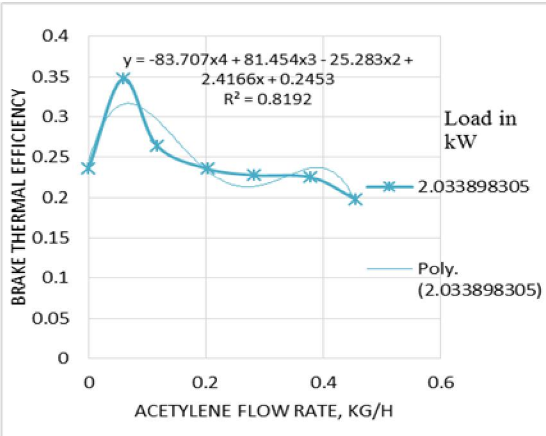

Fig. 8 Graph between acetylene flow rate and efficiency

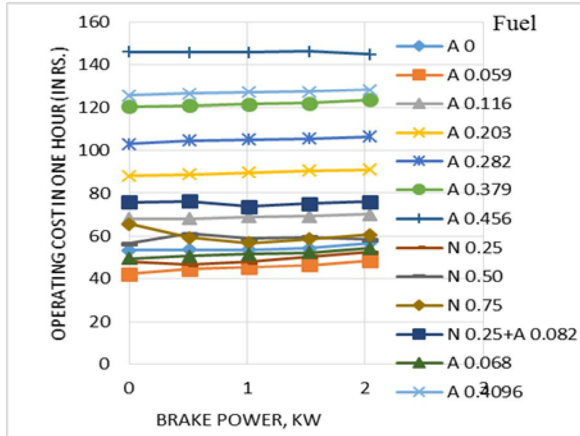

Fig. 9 Variation in operating cost in Rs. of engine with load

H. Variation in operating cost of engine with load

The graph on fig. 9 shows the variation in operating cost of engine for one hour when it is running on pure diesel and when it is running on with fuel configuration.

Total operating cost = diesel consumption *cost of diesel per kg + acetylene consumption *cost of acetylene per kg +nanoparticle used in gram * cost of nanoparticle.

VI. CONCLUSION

A. From the experiments it can be concluded that diesel engine can successfully run on dual fuel mode using acetylene with small modification. By using acetylene in small amount 0.059 kg/h the brake thermal efficiency can be improved, diesel consumption rate reduced by 41.23% and operating cost of engine is reduced by 14.58% for the engine used.

B. On dual fuel mode the diesel consumption can be reduced by 54.11 % at high acetylene flow rate of 0.379 kg/h. At this condition the brake thermal efficiency is reduced by 4.6 %, but the operating cost of engine increased by 117.07% of pure diesel operation. On dual fuel mode diesel flow rate can be reduced to a certain value, on further increasing gas flow rate the diesel flow rate start to increase.

C. When diesel containing nanoparticle additive on 0.25 g/l, the diesel consumption rate has been decreased by 13.83 % and efficiency is increased by 16.05%. In this condition the cost is reduced by 6.56%.

D. On dual fuel mode the exhaust gas temperature is higher compared to pure diesel operation. Using nanoparticle additive the exhaust gas temperature can be reduced.

E. From the analysis the acetylene flow rate is optimized to 0.068 kg/h for dual fuel mode operation and when running the engine with alumina nanoparticle additive in diesel, 0.25 g/l nanoparticle is proposed for better performance characteristic and low cost operation.

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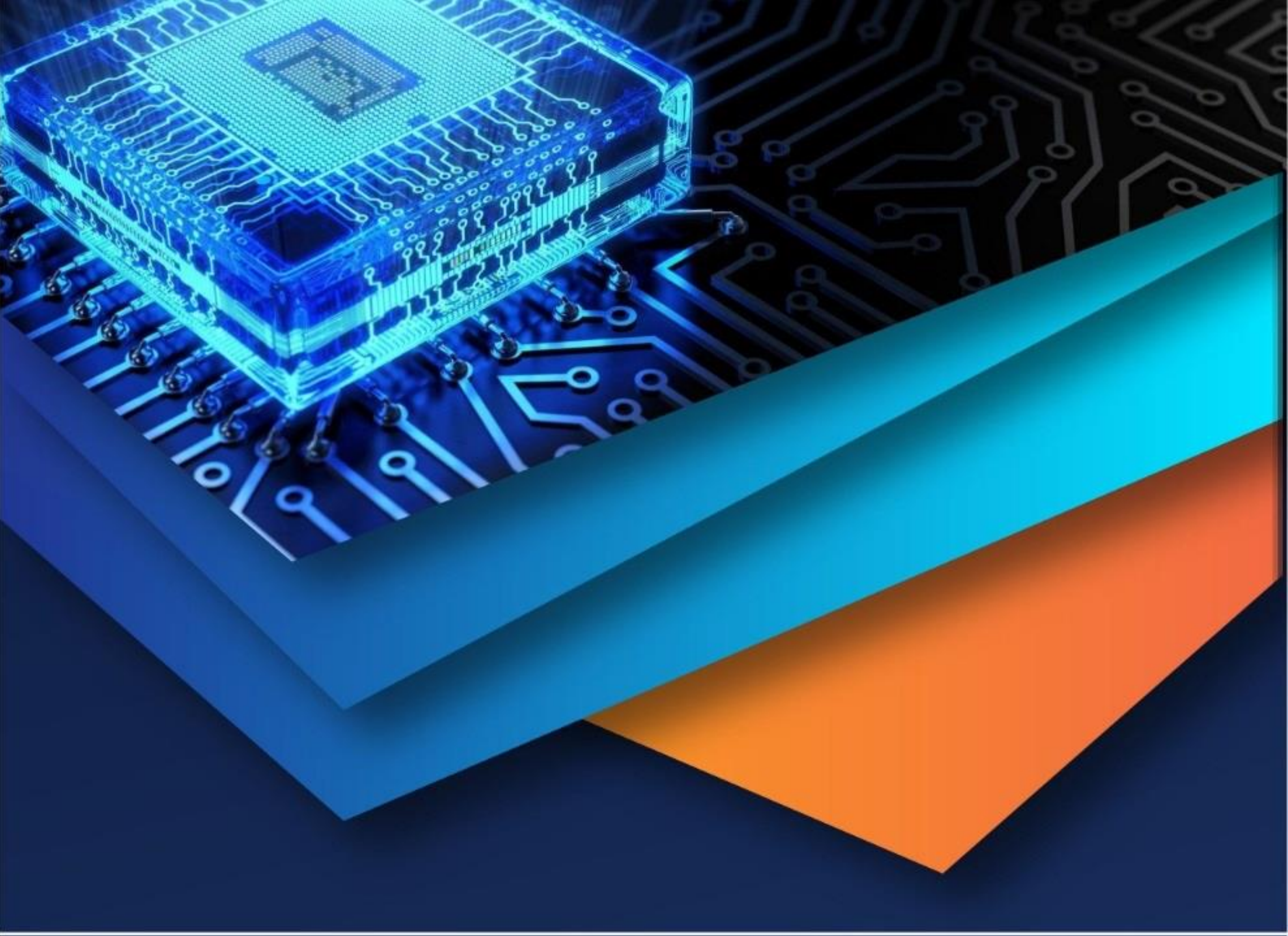

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