"PERFORMANCE AND EMISSION STUDY OF DIESEL USED TRANSFORMER OIL BLEND USING ACETYLENE GAS AIR MIXTURE ON DIESEL ENGINE"

Mr. Premal Patel[1], Mr. Bunha Himanshu[1], Assi.Prof. Ankit Patel[2]

[1]*Student, Merchant Institute of Technology,Piludara,Mahesana*
[2]*Assistant Professor,Merchant Institute of Technology, Piludara*

ABSTRACT

This project leads to the idea of using acetylene gas in the internal combustion engine such that it reduces the demand of the petroleum products that is going to be extinct in near future. It includes about the emissions of harmful gases that can be reduced by the use of acetylene instead of petroleum products. Used transformer oil (UTO) is waste oil obtained from power transformers and welding transformers. It possesses considerable heating value and properties similar to diesel fuel. A preliminary investigation on the utilization of the UTO in a single cylinder, four stroke small powered direct injections (DI) diesel engine is done. In order to improve the performance and reduce the smoke emission, a dual fuel operation was attempted in the present investigation. Acetylene was inducted as a primary fuel at four different flow rates viz 132 g/h, 198 g/h, 264 g/h and 330 g/h along with the air, to study the performance and emission behavior of a four-stroke, 4.4 kW diesel engine, while the UTO was injected as pilot fuel. The experimental results were compared with diesel-acetylene dual fuel operation in the same engine.

Keyword: -A*cetylene gas, UTO*

---

1. Introduction

The industrial revolution and increased population in the last two centuries have resulted in an increased consumption of fossil fuels. Particularly, internal combustion (IC) engines were operated with the petroleum based fuels. This resulted in increased level of carbon dioxide (CO2) in the environment significantly during the last three decades. CO2 is one of the greenhouse gases (GHG) that causes global warming. The other GHG emissions include CO, NOx, and water vapor and methane. Between the years 1970 and 2004, the GHG emissions increased at an average of 1.6% per year, with CO2emissions from the use of fossil fuels growing at the rate of 1.9% per year. The total emissions at the end of year 2009 were estimated to be 49.5 GT, and equivalent of carbon dioxide.

The landfills associated with the municipal and industrial wastes, also contribute to the GHG emissions. If the landfills are minimized by converting them into useful energy, then the source of GHG emissions can be reduced to a great extent. Among the industrial wastes, disposed tyres, plastics and oils, and refrigerants are the main contributors of GHG emissions. The used oil, a contributor to industrial waste includes brake fluids, and hydraulic, transmission, motor, crank case, gear box, synthetic and transformer oils. Such oils can be recycled and used in various ways. The first way is to change the original properties of the oil. The second way is to recover the heat energy available in it. Some of the

Behera P et al. done experimental studies on exploring the possibility of utilizing the UTO as an alternative fuel in a CI engine, were carried out. UTO was used as a fuel in the form of blend and sole fuel. The combustion, performance and emission behavior of a single cylinder, four stroke, DI diesel engine were studied with the UTO diesel blends, and UTO as a sole fuel. The engine experiments were also performed with the different injection timings using UTO as the sole fuel. The different injection timings adopted for the experiments were 18.5–27.5^o CA at a regular interval of 1.5^o CA. The brake thermal efficiency increased by about 1% compared to the standard injection timing. At the retarded injection timing of 18.5^o CA, UTO gave a maximum reduction of NO emission by about 2% at full load, compared to that of the original injection timing. In comparison with original injection *timing, an increased level of smoke by about 10.4% was noticed with 18.5^o CA. Based on the performance and emissions, the optimum injection timing was found to be 20^o CA.[1]*

G.Nagarajan and T.Lakshamanan conducted experiments on a diesel engine aspirated acetylene along with air at different flow rates without dual fuel mode. They carried out the experiment on a single cylinder, air cooled, direct injection (DI), compression ignition engine designed to develop the rated power output of 4.4 kW at 1500 rpm under variable load condition. Acetylene aspiration results came with a lower thermal efficiency reduced Smoke, HC and CO emissions, when compared with baseline diesel operation.[2]

T Lakshmanan ,G NagarajanWith the application of EGR, due to lower excess oxygen available for combustion it results in incomplete combustion leading to slight increase in CO and HC emission level. CO_2 emission increases with EGR application in the inlet air due to the presence of CO_2 in the exhaust.[3]

Saravanan N et al. investigated the effect of cooled EGR in hydrogen-enriched single cylinder diesel engine. They concluded that brake thermal efficiency increases by 6% without EGR; with cooled EGR it was lower than dual fuel engine and higher than neat diesel at full load operation. The NOx emissions decreased to a minimum of 464 ppm with 25% EGR. Smoke intensity decreased by 48% in dual fuel mode.[4]

T.Lakshamanan, A Avinash, G Nagarajan carried out study The brake thermal is 28% with 200 g/h of DEE. The brake thermal efficiency of acetylene-diesel dual fuel operation is 27% with 390 g/h of gas flow rate at the rated output, which is lower than diesel efficiency of 29%. Injection of DEE with acetylene marginally increases the brake thermal efficiency when compared to acetylene without DEE. Dual fuel mode shows a lower exhaust gas temperature than diesel. NOx levels are higher for acetylene dual fuel operation with 390 g/h of gas flow rate due to increase in the combustion rate. The maximum NOx emission is 16.93 g/kW h. With acetylene and DEE at 200 g/h, the NOx level decreases to 11.78 g/kW h[5].

Vijayabalan P, Nagarajan G. Were conducted experiments, using LPG in dual fuel mode in a Jatropha fueled diesel engine. The engine showed a reduction in the NOx and smoke in the entire load range, with higher brake thermal efficiency [6].

Sarjovaara et al. [7], used ethanol as a CI engine fuel utilizing dual-fuel combustion technology. Geng P, Yao C, Wei L, Liu J, Wang Q, Pan W, et al, has also carried out Research using methanol as dual fuel with diesel. Experimental results show that at low and medium loads, there is a significant decrease in the dry-soot emission in diesel/methanol dual fuel mode before the diesel, but a little increase at high load [8].

G.Nagarajan and T.Lakshamanan carried out study using a timed manifold injection technique, and inducting acetylene in a four-stroke, 4.4 kW diesel engine, with diesel as the primary fuel. Experiments were conducted for various gas flow rates of 110 g/s, 180 g/s and 240 g/s. The performance was found to be closer to that of diesel at full load. The NOx, HC, and CO emissions decreased due to lean operation, with a marginal increase in smoke emission. It was concluded that acetylene replacement of up to 24% was possible, with a reduction in emission parameters [9].

M Senthilkumar aRamesh, B Nagalinganin the paper vegetable oil use in the CI engine directly. Methyl ester of Jatropha oil and diesel were also used as pilot fuels for comparison. Dual fuel operation with orange oil induction reduced the smoke level and improved the thermal efficiency with all pilot fuels [10].

S.K. Mahla, Som Kumar, Harshdeep Shergill and Ashwani Kumar et al. in this experimental Fixed quantity of Acetylene gas was aspirated and Blend of diethyl ether with diesel (DEE10, DEE20 and DEE30) was taken and then readings were taken at various loads. From the detailed study it has been conclSSuded that the blending ratio of DEE20 gives better performance. Dual fuel operation along with addition of diethyl ether resulted in higher thermal efficiency when compared to neat diesel operation. Acetylene aspiration reduces smoke and exhaust temperature [11].*

Shaik Khader Basha , P.Srinivasa Rao , K. Rajagopal K. Ravi Kumar et al. in experimental work Brake thermal efficiency in aspirated engine mode is lower than pure diesel operation at full load A perceivable reduction in HC, CO and CO2 emissions was observed with acetylene operated dual fuel mode engine. The reduction in HC and CO2 emissions at maximum load is of 8 % and 3% respectively when compared to diesel operation. The major issue of NOx emission however is reduced with EGR [12]

N. Saravanan,G.Nagarajan, K.M. Kalaiselvan, C. Dhanasekaran et al. this Experiments are conducted on hydrogen as a supplementary fuel in diesel engine with EGR technique The brake thermal efficiency increases by 6% without EGR. The carbon monoxide emission decreases by 50% without EGR compared to neat diesel operation at full Load. The HC emission decreases by 58% without EGR condition compared to neat diesel operation.[13]

S. Swami Nathan, J.M. Mallikarjuna, A. Ramesh In this literature the value of NO emission is extremely low with maximum about a 20 ppm The thermal efficiencies are comparable to the base diesel engine and a slight increase in brake thermal efficiency is observed with optimized EGR operation. The average HC level is about 2000 *ppm in the HCCI mode with acetylene as against only about 300 ppm with diesel in the CI mode. So increase the hc level in HCCI mode with EGR.[14]*

Vijayabalan et al. In this experiment liquefied petroleum gas (LPG), was mixed with air, compressed, and ignited by a small pilot spray of diesel. Dual fuel engine showed a reduction in NOx and smoke in the entire load range. However, it suffers from the problem of poor brake thermal efficiency and high hydrocarbon and carbon monoxide emissions. In order to improve the performance at lower loads, a glow plug was introduced inside the combustion chamber. The brake thermal efficiency improved by 3% in the glow plug assisted dual fuel mode, especially at low load, and also reduced the hydrocarbon, carbon monoxide, and smoke emissions by 69%, 50% & 9% respectively.[15]

SwamiNathan et al. Conducted experiments in a CI engine by using acetylene as a fuel in homogeneous charge compression-ignited mode along with preheated intake air. The efficiency achieved was very near to diesel. NOx and smoke level reduced considerably. However, HC level increased.[16]

Above all and lot many other literature is studied on alternate fuel research. From literature it is found that on lot many different fuels like biodiesels, alcohols, vegetable oils and different gaseous fuels like LPG,CNG, Hydrogen , Methane, Acetylene and lot many fuels are investigated. Majority of experiments are conducted on Diesel Engines as it escapes more harmful exhaust and Diesel Engines are on more use worldwide.

3 Experimentation: *The property of the UTO depends upon the service life of the transformer oil. Although the actual service life varies widely depending on the manufacturer, design, quality of assembly, materials used, maintenance, and operating conditions, the expected life of a transformer is about 40 years. The physico chemical properties of the Acetylene, UTO and diesel are compared with those of diesel, and are given in Table 1.The technical specifications of the test engine are given in Table 2. The engine was coupled to a hydraulic dynamometer. A schematic diagram of the experimental arrangement is shown in Fig. 1.*

The engine was modified to work on dual fuel mode, by inducting acetylene in the intake pipe at a proper distance to avoid overheating, in the intake port. The acetylene stored in a high-pressure cylinder at a pressure of 15 bar was reduced to a pressure of 1 bar by a pressure regulator. The flow of acetylene was controlled by a needle valve, and measured by a calibrated gas flow meter. Acetylene enters the injector through anon-return valve, a flash back arrestor and flame trap. Four acetylene flow rates viz 132, 198, 264, 330 g/h, were used in the study. The flow rate was regulated with the help of a regulator. Fig. 1 shows the arrangement of duel fuel operation.

The fuel consumption was determined, by using calibrated burettes with an accuracy of 0.1 CC. A thermocouple in conjunction with a temperature indicator was connected at the exhaust pipe that indicated the exhaust gas temperature. The exhaust gas constituents; CO, HC and NO were measured by the AVL gas analyzer (AVL, DiGas444).

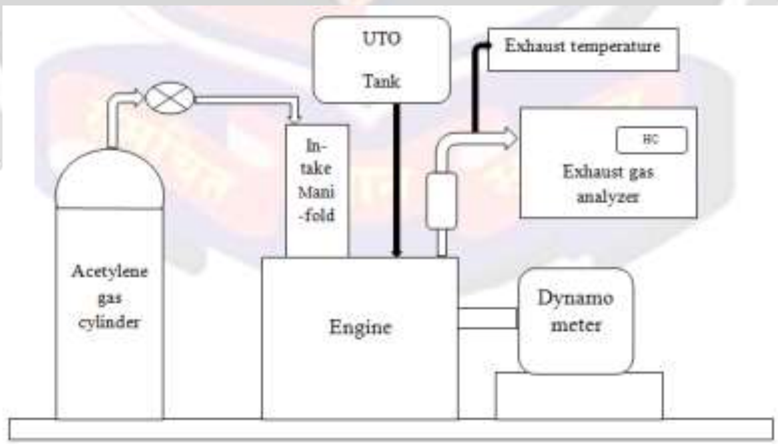

Figure. 1 The arrangement of duel fuel operation.

Table 1 Property of Acetylene, Hydrogen and Diesel

Properties	***Acetylene***	***Hydrogen***	***Diesel***
Formula	C_2H_2	H_2	C_8-C_{20}
Density kg/m^3 (At 1.01325 bar & 293^{o}K)	*1.092*	*0.08*	*840*
Auto ignition temperature (^{o}K)	*578*	*845*	*527*
Stoichiometric air fuel ratio (kg/kg)	*13.2*	*34.3*	*14.5*
Flammability limits (Volume %)	*2.5-81*	*4-74.5*	*0.6-5.5*

Properties	Acetylene	Hydrogen	Diesel
Flammability limits (Equivalence ratio)	0.3-9.6	0.1-6.9	---
Adiabatic flame temperature (^oK)	2500	2400	2200
Lower calorific value (kJ/kg)	48225	120000	42500
Max deflagration speed (m/s)	1.5	3.5	0.3
Ignition energy (mJ)	0.019	0.02	---
Lower heating value of Stoichiometric mixture (kJ/kg)	3396	3399	2930

Properties	UTO	Diesel
Kinematic viscosity (CP@ 27^{o}C)	10-13	2.4
Flash point, °C	156	70
Fire point, °C	162	76
Density kg/m^3	880-900	860
Lower calorific value (kJ/kg)	39120-39900	44800
Sulphur content (%)	0.02-0.03	0.045-0.05
Cetane number	42-45	40-55
Carbon residue (%)	0.1-0.5	0.1

Table 2 Specification of Test engine to be used

Manufacturer	Fieldmarshal
Engine Type	4 stroke Direct Injection CI engine
kW Rating	4.4 kW
Rated RPM	1500 RPM
Compression Ratio	17.9:1
Bore (mm)	85mm
Stroke(mm)	110mm
No. of cylinders	1
Cubic Capacity(cc)	625 CC
Fuel Consumption (g/Kw/h)	245 g/Kw/h
Cooling Type	Water cooled

4 Results and discussion:

4.1 Investigation of UTO and its diesel blends

4.1.1 Brake specific energy consumption (BSEC)

When two different fuels of different heating value and density are blended and used as fuel in an engine, the BSEC is more reliable than the brake specific fuel consumption Fig. 3 illustrates the variation of the BSEC with engine load for UTO, diesel blends and diesel.

The energy consumption for all the tested fuels decreases with an increase in the load as expected. The BSEC is the lowest for diesel among all the tested fuels in this study, throughout the load spectrum. As the percentage of UTO increases up to 40% in the blend the specific energy consumption decreases. This may be attributed to more and better complete combustion of the UTO–diesel blends. UTO40 shows the lowest value of BSEC at full load. UTO50, UTO60 and UTO exhibited higher specific energy consumption than that of UTO40.

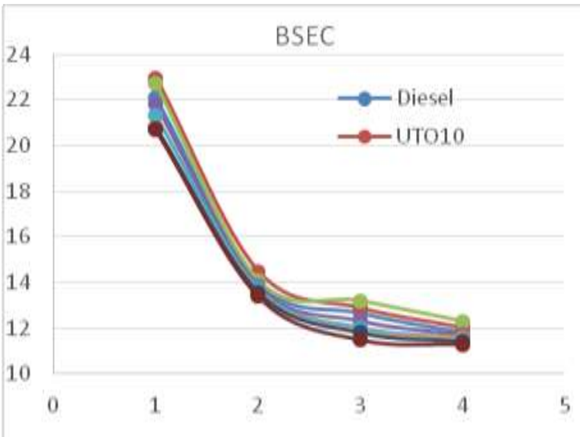

Figure 3. Variation in the BSEC with brake power forthe UTO and its diesel blends

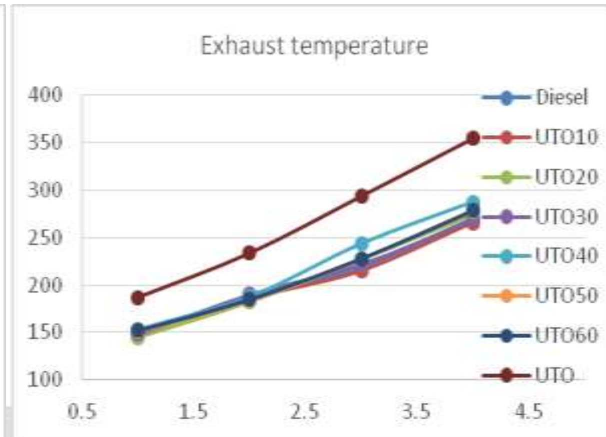

Figure 4. Variation of the exhaust gas temperature with brake power for the UTO and its diesel blends

4.1.2 Exhaust gas temperature

Fig. 4 shows the variation of the exhaust gas temperature with load for different tested fuels. The exhaust gas temperature increases with an increase in the engine load for UTO and its diesel blends and diesel. The exhaust gas temperature for UTO and its diesel blends is higher than that of diesel in the entire operation as a result of higher viscosity and density of UTO. Among the UTO–diesel blends the exhaust gas temperatures of UTO40, UTO60, UTO50, UTO20, UTO30 and UTO10 are sequentially lower than that of UTO, but higher than that of diesel at full load.

4.1.3. Nitric oxide emission

The variation of NO emission for UTO, diesel blends and diesel for different engine loads, is shown in Fig. 5. NO emission in a CIengine strongly depends on the combustion temperature and oxygen availability. It can be observed from the figure that the NO emission increases with an increase in load for UTO, diesel blends and diesel as expected. The NO emission for UTO and its diesel blends are higher compared to that of diesel. Higher NO emission for UTO and its diesel blends may be associated with higher combustion temperatures advanced injection timings

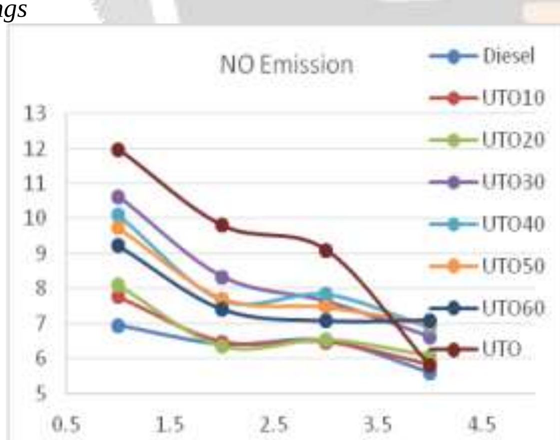

Figure 5. Variation of the NO emission with brake power for the UTO and its diesel blends

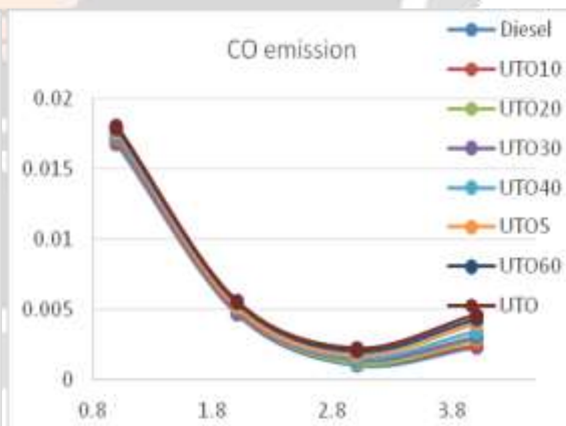

Figure 6. Variation of CO emission with brake power for the UTO and its diesel blends

4.1.4. Carbon monoxide emission

The variation of the carbon monoxide emission for the UTO, diesel blends and diesel for different engine loads is shown in Fig. 6. It can be observed from the figure that the CO emission is marginally higher for the UTO–diesel blends compared to that of diesel at full load. The CO values are the lowest for diesel and the highest for UTO, at full load. The higher CO emissions for UTO may be attributed to local rich regions and poor mixture formation in some locations of the combustion chamber. However, CO value for all the tested fuels is less than 0.01%.

4.1.5. Hydrocarbon emission

The variation of unburned hydrocarbon emission for UTO, its diesel blends and diesel for different loads is shown in Fig. 7. It can be observed that the UTO–diesel blends generate higher unburned hydrocarbon as compared to that of diesel. HC emission for UTO and its diesel blends are higher as a result of higher viscosity, density and poor mixture formation. It can be observed that the lowest and highest values of HC emission are recorded with diesel and UTO respectively. However the emission for UTO and its blends are close to diesel at full load.

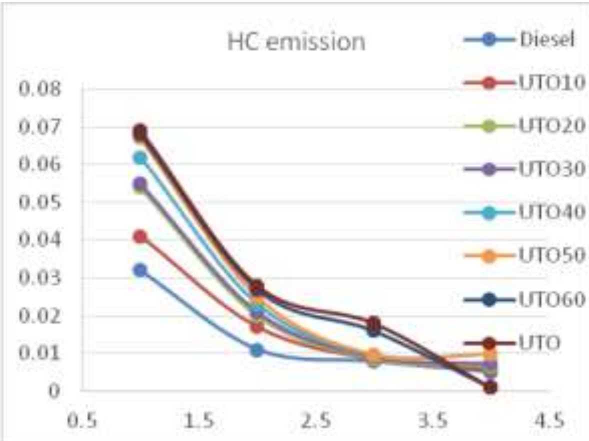

Figure 7. Variation of HC emission with brake power for the UTO and its diesel blends

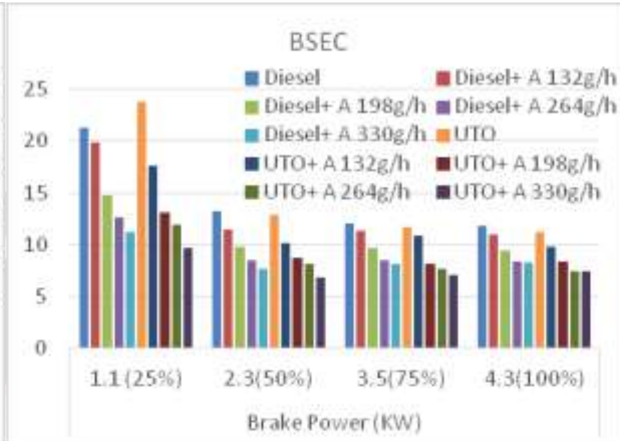

Figure 8. Variation of brake specific energy consumption with brake power

4.2 Investigation of Diesel and UTO with Acetylene (Dual Fuel Mode)

Different flow rates of acetylene were inducted with air in the suction. Four different flow rates of acetylene 132, 198, 264 and 330 g/h were used in this study. The flow rates are indicated after UTO in the dual operation.

4.2.1 Brake specific energy consumption (BSEC)

Figure 8 shows the BSEC for diesel and the UTO with acetylene, at different flow rates. By the induction of acetylene, specific energy consumption decreases compared to that of diesel and the UTO operation. This may be due to the high heat release rate, which leads to high cylinder pressure and better utilization of the heat input.

4.2.2 Exhaust gas temperature

Figure 9 illustrates the variation of the exhaust gas temperature with brake power for diesel and the UTO at different acetylene flow rates. The decrease in the exhaust gas temperature with increase of acetylene flow rate may be due to the earlier of energy release in the cycle.

4.2.3. Nitric oxide emission

The variation of the NO emission with brake power is depicted in Fig. 10. It can be observed that the UTO emits lower NO emission levels as compared to that of diesel. As the brake power increases the combustion gas temperature increases, which in turn, increase the formation of NO emission. In dual fuel operation, with the acetylene induction, the NO emission increases maximum brake power for both diesel and the UTO. This is due to the enhancement of combustion rate, which increases the temperature, and thus increases the NO emission.

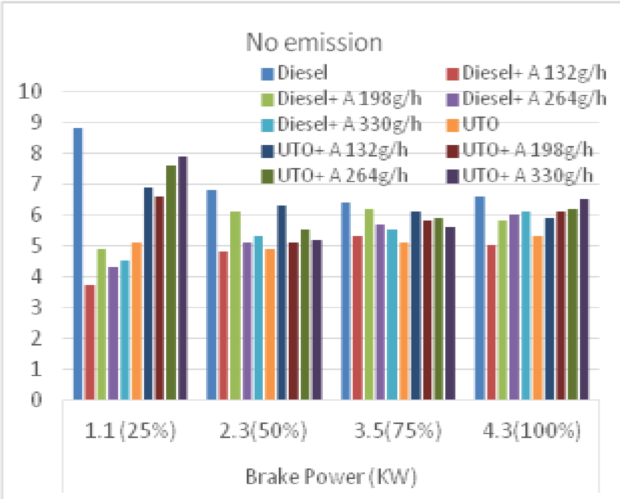

Figure 9. Variation of NO with brake power.

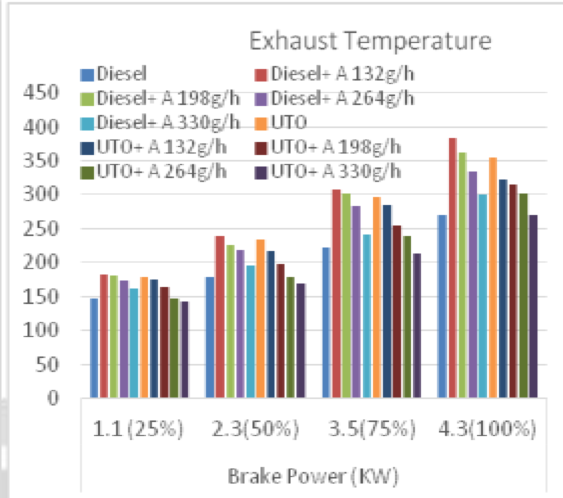

Figure 10. Variation of the exhaust gas temperature with brake power.

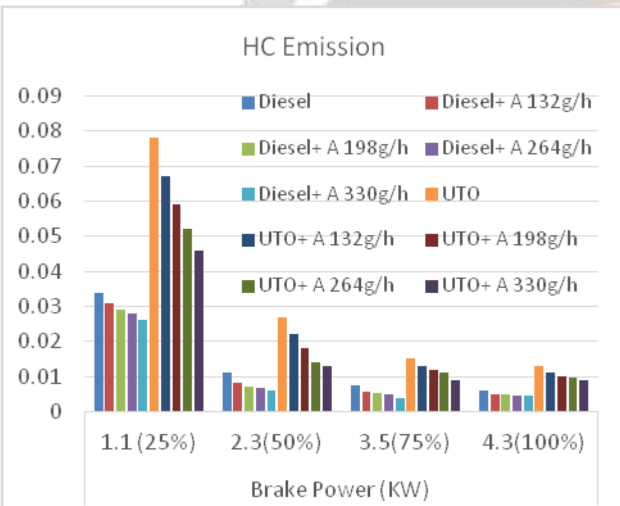

Figure 11. Variation of HC with brake power.

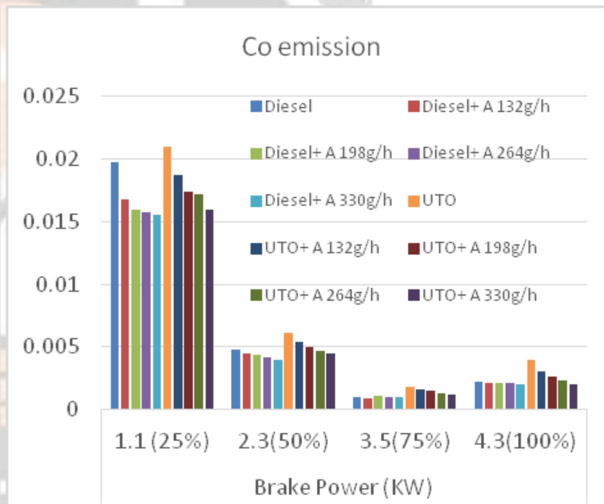

Figure 12. Variation of CO with brake power.

4.2.4. Carbon monoxide emission

CO is present in the exhaust gas is due to unavailability of oxygen for complete combustion process. Higher concentration of the CO emission in the exhaust is a clear indication of incomplete combustion of the pre-mixed mixture. Figure 11 shows the CO emission with brake power for diesel and UTO for different acetylene flow rates. An observation of the figure shows that CO emissions are lower in dual fuel operation when compared with sole diesel and the UTO operation. The decrease in the CO emission may be due to operation of dual fuel engine in lean range than the UTO.

4.2.5. Hydrocarbon emission

Figure 12 depicts the variation of HC emissions with brake power with for diesel and UTO for different acetylene flow rates. Due to the poor mixing of UTO with air as a result of this higher viscosity and density the HC emission is high. It is observed from the figure that HC emission in dual fuel mode is always lower than diesel and the UTO operation. The reduction in HC emission in the case of dual fuel mode is due to the higher burning velocity of acetylene and due to the lean operation of the engine.

5. Conclusion

A single cylinder, four stroke, air cooled, direct injection diesel engine developing a power of 4.4 kW at the rated speed of 1500 rpm, was operated successfully on diesel and the UTO with acetylene at different flow rates. The following conclusions are drawn based on the experimental results:

- *The UTO can be used as a fuel in the CI engines as it possesses a heating value. Considering the specific energy consumption, UTO40 can be the optimum blend among the UTO diesel blends tested.*
- *The HC and CO emissions for the UTO and its diesel blends are marginally higher than those of diesel operation at full load.*
- *The NO emission is higher for the UTO–diesel blends than diesel at full load.*
- *The UTO results in a higher exhaust temperature compared to that of diesel at maximum brake power. It is reduced in the dual fuel mode by about 23.7% for the UTO at maximum brake power.*
- *The NO emissions are found to increase by about 9% and 23% with diesel and the UTO operation with acetylene at different flow rates.*

References

[1] Behera P, Murugan S. Combustion, performance and emission parameters of used transformer oil and its diesel blends in a DI diesel engine. ELSEVIER .J Fuel 2013; 104:147–54.

[2] Lakshmanan T, Nagarajan G. Experimental investigation on dual fuel operation of acetylene in a DI diesel engine.ELSEVIER, J Fuel Process Technology 2010; 91:496–503.

[3] T Lakshmanan ,G Nagarajan Study on using acetylene in duel fuel mode with exhaust gas recirculation ELSEVIER ,J Energy 2011;3547-3553.

[4] Saravanan N, Nagarajan G, Kalaiselvan KM, Dhanasekaran C. An experimental investigation on hydrogen as a dual fuel for engine system with exhaust gas recirculation technique .ELSEVIER. J Renewable Energy 2008; 33:422–7.

[5] T. Lakshmanan A. Avinash G. Nagarajan Experimental study on DI diesel engine with acetylene in dual fuel mode with DEE as an ignition enhancer,ELSEVIER J Transportation Research Part D 2017 p 372-380.

[6] Vijayabalan P, Nagarajan G. Performance, emission and combustion of LPG diesel dual fuel engine using glow plug. Jordan J Mech Indust Eng 2009; 3:105–10.

[7] Sarjovaara T, Alantie J, Larmi M. Ethanol dual-fuel combustion concept on heavy duty engine.ELSEVIER, J Energy 2013; 63:76–85.

[8] Geng P, Yao C, Wei L, Liu J, Wang Q, Pan W, et al. Reduction of PM emissions from a heavy-duty diesel engine with diesel/methanol dual fuel. ELSEVIER, J Fuel 2014; 123:1–11.

[9] Lakshmanan T, Nagarajan G. Experimental investigation of timed manifold injection of acetylene in direct injection diesel engine in dual fuel mode.ELSEVIER, J Energy 2010; 35:3172–3178.

[10] Senthil MK, Ramesh A, Nagalingam B. Complete vegetable oil fuelled dual fuel compression ignition engine. SAE 2001 [2001-28-0067].

[11] S.K. Mahla, Som Kumar , Harshdeep Shergill and Ashwani Kumar. Study The Performance Characteristics Of Acetylene Gas In Dual Fuel Engine With Diethyl Ether Blends International Journal on Emerging Technologies 2012: 80-83.

[12] Shaik Khader Basha , P.Srinivasa Rao, K. Rajagopal K. Ravi Kumar Experimental Study On The Performanace Of An Acetylene Aspirated Diesel Engine Using Egr. International Journal of Applied Engineering Research 2016: 5346-5351.

[13] N. Saravanan, G. Nagarajan, K.M. Kalaiselvan, C. Dhanasekaran "A experimental investigation on hydrogen as a dual fuel for diesel engine system with exhaust gas recirculation technique". ELSEVIER J Renewable Energy 2008;33:422-427.

[14] S. Swami Nathan, J.M. Mallikarjuna, A. Ramesh "Effects of charge temperature and exhaust gas re-circulation on combustionand emission characteristics of an acetylene fuelled HCCI engine".ELSEVIER J Fuel 89 ;2010 p515–521.

[15] P.Vijayabalan, G. Nagarajan "Performance, Emission and Combustion of LPG Diesel Dual Fuel Engine using Glow Plug" JJMIE, Pages, 105–110, 2009.

[16] Swami Nathan S, Mallikarjuna JM, Ramesh A. HCCI engine operation with acetylene the fuel. SAE Paper No. 2008-28-0032.