Experimental Performance Analysis of Acetylene Aspirated Diesel Engine

Sudheer
M. Tech. Scholar
Department of Thermal Power Engineering
PDA College of Engineering Gulbarga, Karnataka

Abstract— A several studies and research has been carried out in enhancing the performance of diesel engine but the human effort is still ineffective in this challenge, in this project work an acetylene is used as alternate fuel due to its very wide flammability range and minimum ignition energy is required for ignition since the engine can run in lean mode with higher specific heat ratios leading to increased thermal efficiency. It has higher flame speed and hence faster energy release And at stoichiometeric mixtures, acetylene engines could closely approach thermodynamically ideal engine cycle. performance has been carried out on a single cylinder, direct injection, and compression ignition engine run on dual fuel mode with diesel is injected as primary fuel and acetylene inducted as secondary gaseous fuel to obtain data on engine performance with different flow rates of 0.5bar, 0.8bar is drawn to intake air manifold. From results obtained the thermal efficiency is nearer to diesel and energy consumption are less than the diesel at full load for the flow rate of 0.5bar.

Key words: Acetylene, Dual Fuel Mode, Performance, Different Flow Rates

I. Introduction

In the thermal efficiency and fuel consumption, the simple theory predicts no variations of thermal efficiency with mixture strength. However, fuel-air analysis suggests that the thermal efficiency will deteriorate as the mixture supplied to an engine is enriched. this is explained by the increasing losses due to variable specific heats and dissociation as the engine temperature are raised by enrichment towards the chemically correct ratio. The fuel-air cycle efficiency increases with the compression ratio. In a CI engine, for a given speed, and irrespective of load, an approximately constant supply of air enters the cylinder it is known to be constant air supply engine.

Due to increase in the industries and population in the last few decades have resulted in an increased consumption of fossil fuels. And there is need to search the alternative fuel particularly, internal combustion engines were operated with petroleum fuels that were derived from oil and gas industries. This resulted in increased greenhouse gases (GHG) in the environment significantly during the last two decades. The GHG emissions include, carbon monoxide, oxides of nitrogen, carbon dioxide. These gases are the main sources for global warming and ozone depletion

In the present study acetylene was used as an alternative fuel blended with Diesel, and its performance in a compression ignition engine was conducted. In dual fuel mode the combustion reaction is started with pilot fuel and continues with primary fuel. Here diesel as pilot fuel acetylene as a primary fuel for the engine and. The gas burns after going through the following stages: Gas enter in the engine cylinder along with intake air in the suction stroke. In the compression stroke the air and acetylene gas gets mixed and compressed. When the compression stroke finished, diesel is injected conventionally by injectors controlled by governor. In the present experiment, acetylene was inducted with various flow rates 0.5bar, 0.8bar to the intake air manifold of the engine and diesel injected conventionally in the cylinder. The dual fuel operation (Diesel + Acetylene) at compression ratio 17.5:1

In a dual fuel mode of combustion the pilot biodiesel fuel auto-ignites first and acts as a deliberate source of ignition for the primary fuel–air mixture. The combustion of the gaseous fuel occurs by the flame initiation by auto-ignition of biodiesel pilot injection at unspecified location in the combustion chamber. This ignition source can develop into propagation flame, similar to spark ignition (SI) engine combustion. Thus, dual fuel engine combines the features of both SI and CI (compression ignition) engine in a complex manner.

So using of gaseous fuel in CI engine means the engine is running on dual fuel mode. This work proves the use of acetylene gas as an alternative fuel without a large investment. This method involves burning of acetylene gas of little quantity along with karanja oil methyl ester (KOME) in engines.

The promising alternative fuels for internal combustion engines are hydrogen and acetylene gas, LPG (liquefied petroleum gas), CNG (compressed natural gas), many of the gaseous fuels can be obtained from renewable sources. They have a high self-ignition temperature; hence they cannot be used directly in diesel engines. In dual fuel mode, gaseous fuel called primary fuel is either inducted along with intake air or injected directly into the cylinder and compressed but does not auto ignite due to its very high self-ignition temperature Ignition of homogeneous mixture of air and gas is achieved by timed injection of small quantity of biodiesel called pilot fuel near the end of the compression storke. Diesel engines however can be made to use a considerable amount of gaseous fuels in dual fuel mode without incorporating any major changes in engine construction. It is possible to trace the origin of the dual fuel engines to Rudolf Diesel, who patented an engine running on essentially the dual fuel principle.

II. Literature review

Nakul aggarwal [1] conducted an experiment on analysis of engine performance by using acetylene in ci engine operated on 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 induction results in the peak pressure are increasing with increased flow rate of acetylene due to instantaneous combustion of gaseous fuel. Exhaust gas temperatures are increasing with increasing acetylene flow rates as peak pressures are increasing and heat input also increasing with increasing flow rate. And CO, UHC emission levels are increasing with acetylene induction flow rates.

G.Nagarajan and T.Lakshamanan [2] 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.

S.K. Mahla [3] An experimental investigation has been carried out on a single cylinder, direct injection (DI), and compression ignition (CI) engine tested with pure diesel and diesel- Acetylene dual fuel mode with diethyl ether (DEE) as oxygenated additive. Experiments were conducted to study the performance characteristics of DI diesel engine in dual fuel mode by aspirating Acetylene gas in the inlet manifold, with diesel- diethyl ether blends (DEE) as an ignition source. 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 concluded 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.

Kapil Dev Choudhary, Ashish Nayyar [4] conducted an experiment on "Optimization of Induction Flow Rate Acetylene in CI Engine Operated on Duel Fuel Mode" acetylene was inducted with various flow rates viz 5lpm, 6lpm, 7lpm and 8lpm to the intake air manifold of the engine and diesel injected conventionally in the cylinder. The combustion, performance and emission distinctiveness of the diesel were evaluated and compared with dual fuel operation (Diesel + Acetylene) at compression ratio 18:1. The peak cylinder pressure increases with increase in the induction flow rates of acetylene up to 7 lpm and again decreases. The peak cylinder pressure for acetylene induction of 7 lpm at compression ratio 18:1 is 63.96 bar and it is highest among that of all induction flow rates and the base line diesel operation. The heat release rate is increasing with increasing the induction flow rates of acetylene. By induction of acetylene results show less CO & higher NO_X emissions at all loads when compared to base line diesel operation.

Pritinika behera, Abhishekh kumar Jha & S. Murugan [5] conducted an experiment on "Dual Fuel Operation of used Transformer Oil with Acetylene in a DI Diesel Engine" dual fuel mode was attempted in the presented investigation. Acetylene was inducted as secondary at three different flow rates along with the air, to study the performance and emission behavior of a four-stroke, 4.4 kW diesel engine, while UTO was injected as the pilot fuel with the optimized injection timing. The acetylene flow rates used in the study are 132 g/h, 198 g/h, 264 g/h and 330 g/h. The experimental results were compared with diesel with acetylene in the dual fuel operation in the same engine. Higher thermal efficiency and reduction in exhaust gas temperature by about 24 % was observed at full load. Smoke was reduced by about 13.7%, in comparison with the UTO operation at full load.

Swami Nathan [6] had conducted experiment in CI engine by using acetylene as a fuel in HCCI mode along with preheated take charge heating. The efficiencies achieved were very near to diesel. NO_x and smoke level were reduced drastically. However, HC level was increased.

Karim [7] has done extensive research to understand the nature of the combustion process in the dual fuel. He has used variety of gases like methane, ethane, propane, butane, hydrogen, ethylene, and acetylene as primary fuel. It is generally accepted that performance of dual fuel engines, irrespective of the type of gaseous fuel employed, is better at medium and high loads. However, it has been reported that at low outputs efficiency is slightly inferior to the base line diesel engine. Researchers have stressed the need to control the quantity of both pilot and gaseous fuel depending on load conditions for better performance.

Ashok Kumar [8] studied suitability of acetylene in SI engine along with EGR, and reported that emission got drastically reduced on par with hydrogen engine with marginal increase in thermal efficiency

Wulff [9] used mixture of acetylene and alcohol to burn in spark ignition engine and in compression ignition engine in a controllable way in dual fuel mode. It exhibited higher efficiency than conventional engine, with cleaner burning better than that of fossil fuels. The combustion was under lower temperature, and this prolonged the life expectancy of the engine.

III. ACETYLENE PRODUCTION & PROPERTIES

The main reason behind preferring Acetylene (C_2H_2) in this project is due to its very wide flammability range and minimum ignition energy is required for ignition since the engine can run in lean mode with higher specific heat ratios leading to increased thermal efficiency. It has higher flame speed and hence faster energy release and at stoichiometeric mixtures, acetylene engines could closely approach thermodynamically ideal engine cycle. High self-ignition temperature of acetylene allows larger compression ratios than diesel engines. Acetylene is not an air gas, but a synthesis gas generally produced from the reaction of calcium carbide with water. and produces a very hot flame over 3000°C when combined with oxygen. A gaseous hydrocarbon, it is colorless, has a strong garlic odor, is highly combustible, unstable, It was burnt in "acetylene lamps" to light homes and mining tunnels in the 19th century. Acetylene is conventionally produced by reacting calcium carbide with water. The reaction is spontaneously occurring and can be conducted without any sophisticated equipment or apparatus. Such produced acetylene has been utilized for lighting in mine areas, by street vendors, etc. Acetylene

Due to lower quenching distance similar to hydrogen, flame cannot be quenched easily in the combustion chamber. Due to lower ignition energy, high flame speed, wide flammability limits, and short quenching distance lead to premature ignition and also lead to undesirable combustion phenomenon called knock, the primary problems that have to be encountered in operation of acetylene engines.

In the present work, a single cylinder, direct injection air, and cooled diesel engine were modified to work in the dual fuel mode with acetylene as the secondary inducted fuel and karanja oil methyl ester as the primary injected fuel. The performance and emission at different output with fixed quantity of aspirating acetylene are presented in this work.

Properties	Acetylene
Formula.	C_2H_2
Density kg/m^3 (At 1 atm & 20 ^{o}C)	1.092
Auto ignition temperature (^{o}C)	305
Stoichiometeric air fuel ratio, (kj/kg)	13.2
Flammability Limits (Volume %)	2.2 - 81
Flammability Limits (Equivalent ratio)	0.3 - 9.6
Lower Calorific Value (kJ/kg)	48,225
Lower Calorific Value (kJ/m^3)	50,636
Max deflagration speed (m/sec)	1.5
Ignition energy (MJ)	0.019
Lower Heating value of Stoichiometeric mixture (kJ/kg)	3396

Table 1: Acetylene properties

IV. EXPERIMENTAL SET UP & METHODOLOGY

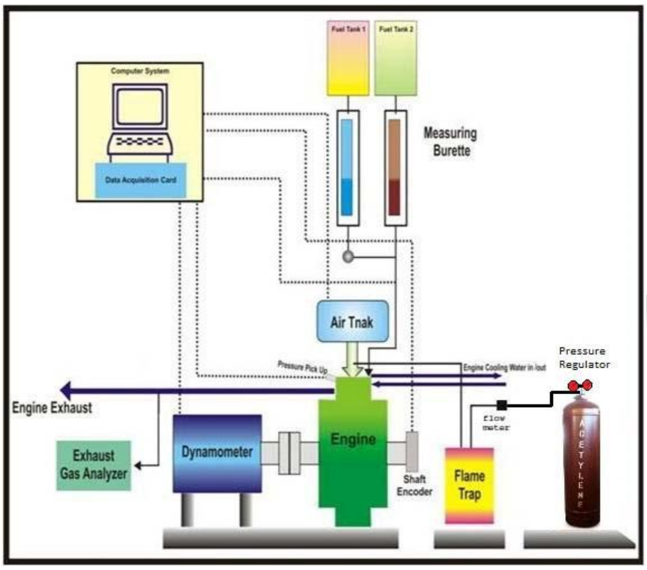

Fig. 1: Schematic of the experimental set up

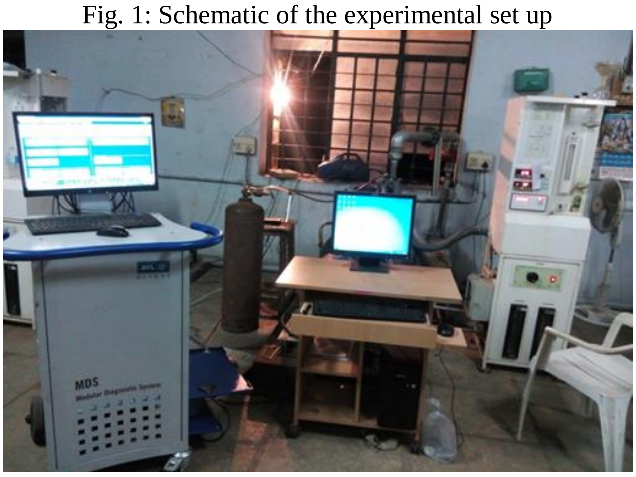

Fig. 2: Photograph of experimental set up

A single cylinder four stroke air cooled naturally aspirated direct injection diesel engine developing 4.4 kW at 1500 rpm, fueled with diesel fuel was utilized for acetylene dual fuel operation. The specifications of the engine are given in table below. The experimental set up is shown in Figure. Acetylene was introduced into intake manifold at a point closer to the intake valve by a non-return valve arrangement through a flame trap. The flow of acetylene was controlled by valve and was measured by a calibrated gas flow meter. Air flow was determined by measuring the pressure drop accurately across a sharp edge orifice of the air surge chamber with the help of a manometer. The diesel flow was measured by noting the time of fixed volume of diesel consumed by the engine. A water-cooled piezoelectric pressure transducer was fixed on the cylinder head to record the pressure variation on the screen of a cathode –ray oscilloscope along with crank angle encoder. Chromel-alumel K-type thermocouple was used for exhaust gas temperature measurement. The exhaust gas constituents CO, CO_2, HC, NOx, and smoke were measured by a Qurotech QRO-401 gas analyzer, and Bosch smoke meter was used for the measurement of smoke.

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV_SR II, naturally aspirated
Engine	Single cylinder, direct injection diesel engine
Bore/stroke/compression	ratio 87.5 mm/110 mm/17.5:1
Rated power	5.2 kW
Speed	1500 rpm, constant
Injection pressure/advance	200bar/23 degree before TDC
Dynamometer	Eddy current
Type of start in Manually	Air flow measurement Air box with 'U' tube
Exhaust gas temperature	RTD thermocouple
Fuel flow measurement	Burette with digital stopwatch
Governor	Mechanical governing (Centrifugal type)
Sensor response	Piezo electric
Time sampling	4 micro seconds
Resolution crank	1 degree crank angle
Angle sensor	360 degree encoder with resolution of 1 degree
Compression ratio	17.5:1

Table 2: Engine Specification

Property	Unit	Diesel
Calorific value	kj/kg	42000
Ash Content	In %	0.07
Cetane number	--	50
Density	kg/m^3	830
Fire point	^{o}C	65
Flash point	^{o}C	57
Specific graivity	--	0.83
Viscosity	cst	5.0

Table 3: Properties of Diesel

V. ENGINE PARAMETER CALCULATION

Calculations related to determination of brake thermal efficiency for blended operation is shown here. BTE for dual fuel engine operation is calculated by using the equation shown below.

A. The BTE for diesel fuel is

$$\eta = BP/(M_D * CV_D) * 100 \qquad (3.1)$$

Where: BP= Brake power, kw
M_D = Mass flow rate of diesel, kg/s
CV_D = Calorific value of diesel

B. BTE for dual fuel engine operation

$$\eta = BP/(M_A * CV_A + M_{KOME} * CV_{KOME}) * 100 \qquad (3.2)$$

M_A= Mass flow rate of Acetylene, kg/s
M_{KOME}= Mass flow rate of Karanja oil methyl ester, kg/s
CV_A= Calorific value of acetylene, kj/kg
CV_{KOME}= Calorific value of Karanja oil methyl ester, kj/kg

Sl. No.	BP(kw)	T(sec)	Q_s(kw)	η_{Bth}(%)	BSEC
1	0	49	7.09	0	∞
2	1.01	41	8.48	11.91	30225.74
3	2.07	33	10.54	19.63	18330.43
4	3.0	27	12.89	23.27	15468
5	4.01	22	15.83	25.33	14211.47
6	5.07	14	24.86	20.39	17652.07

Table 3: Results for Diesel100

C. Notations

- T: time taken for 10ml of fuel consumption in sec
- Q_S: Heat Supplied in kw
- BSEC: Brake Specific Energy Consumption in (kj/kw.hr)
- BP: Brake power in kw
- η_{Bth}: Brake thermal efficiency

D. Calculation for Diesel100 at full load

1) *Mass Flow Rate of D100*

M_f = oil consumption × specific gravity/ time
$M_f = 0.01\times 0.83/14 = 5.92\times10^{-4}$ Kg/sec

2) *Heat Supplied (Q_S)*

$$Q_S = (M_f \times CV_f)$$
$$= 5.92\times10^{-4} * 42000 = 24.86 \text{ kw}$$

3) *Brake thermal efficiency*

$$\eta_{Bth} = (BP/Q_{sup}) \times 100$$
$$= (5.07/24.86) \times 100 = 20.39\%$$

4) *Brake Specefic Energy Consumption(kj/kw.hr)*

$$BSEC= Q_{sup}\times3600/BP$$
$$= 24.86\times3600/5.07$$
$$= 17652.07 \text{ kj/kw.hr}$$

The above calculation is carried out in similar fashion to 1^{st} to 5^{th} readings.

Sl. No.	BP	V(m/s)	T(s)	Q_s(kw)	η_{Bth}(%)	BSEC
1	0	1.8	84	9.35	0	∞
2	1.02	1.7	66	10.16	10.03	35858.82
3	2.06	1.6	45	12.39	16.62	21652.42
4	3.05	1.5	37	13.78	22.13	16264.91
5	4.02	1.5	29	16.39	24.52	14677.61
6	5.21	1.5	18	23.74	21.94	16403.83

Table 4: Results for Diesel-0.5bar blend

E. Notations

- V: velocity of gas flowrate in m/s
- T: time taken for 10ml of fuel consumption in sec

F. Calculation for Diesel-0.5bar blend at full load

Diameter of Fuel Pipe =12.4 mm (0.0124 m)

1) *Area of Fuel Pipe = $(\pi/4)d^2$*

$= (\pi/4)(0.0124)^2 = 1.208\times10^{-4}$ m^2

2) *Discharge (v_1) = AV (m^3/sec)*

For BP at full load, V =1.5 m/sec
$V_1= 1.20\times10^{-4}\times1.5 = 1.8\times10^{-4}$ m^3/sec

3) *P_1=0.5 kg/cm^2 or 0.5 bar*
4) *T_1=38.5 ℃ or 311.5 K*
5) *P_N= 1 kg/cm^2 or 1 bar*
6) *T_N=15℃ or 288 K*
7) *Discharge (v_N), $P_1V_1/T_1= P_NV_N/T_N$*

$$0.5\times1.8\times10^{-4}/311.5 = 1\times V_N/288$$
$$\therefore V_N = 8.32\times 10^{-5} \text{ m}^3/\text{sec}$$

8) *Mass Flow Rate of Acetylene*

$$M_g = V_N\times \rho_g$$
$$M_g = 8.32\times 10^{-5}\times1.092 = 9.08\times10^{-5} \text{ Kg/sec}$$

9) *Mass Flow Rate of KOME*

$$M_f = \text{oil consumption} \times \text{specific gravity/ time}$$
$$M_f = 0.01\times 0.9/18$$
$$= 4.61\times10^{-4} \text{ Kg/sec}$$

10) *Heat Supplied (Q_S) = [$Q_s(g)+Q_s(f)$]*

$$Q_S = (M_g\times CV_g) + (M_f\times CV_f)$$
$$Q_S = (9.08\times10^{-5}\times48225) + (4.61\times10^{-4}\times 42000)$$
$$Q_S = 23.74 \text{ kw}$$

11) *Brake Thermal Efficiency (%)*

$$\eta_{Bth} = (BP/Q_{sup}) \times100$$
$$\eta_{Bth} = (5.21/23.74)*100 = 21.94 \%$$

12) *Brake Specefic Energy Consumption (kj/kw.hr)*

$$BSEC= Q_{sup}\times3600/BP$$
$$BSEC= 23.74\times3600/5.21$$
$$= 16403.83 \text{ kj/kw.hr}$$

The above calculation is carried out in similar fashion to 1^{st} to 5^{th} readings.

Sl. No.	BP (kw)	V	T	Q_s (kw)	η_{Bth} (%)	BSEC
1	0	3.1	144	16.88	0	∞
2	1.05	3.2	126	20.95	5.92	60720
3	2.04	3.2	87	18.95	10.76	33441.17
4	2.99	3.2	58	17.71	14.27	25224.08
5	4.04	2.5	34	21.87	18.47	19488.11
6	5.19	2.4	22	27.02	19.20	18742.19

Table 5: Results for Diesel-0.8bar blend

VI. Result and Discussion

A. Variation of Brake Thermal Efficiency with brake power

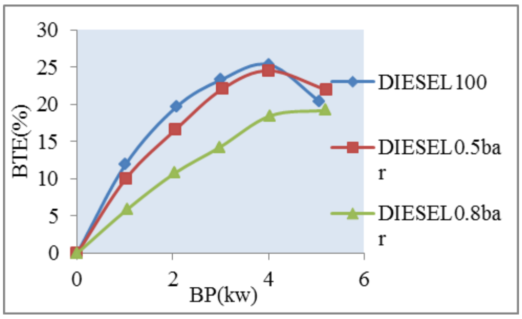

Fig. 3: Variation of Brake Thermal Efficiency with brake power

The graph is drawn at different flow rate of Acetylene between the brake power & brake thermal efficiency from the results obtained it shows Brake thermal efficiency is slightly nearer to diesel when the acetylene is inducted as secondary fuel. The brake thermal efficiency for diesel is 25.33 at 4kw load. In dual fuel mode for diesel at different acetylene flow rates of pressure 0.5bar & 0.8bar the maximum thermal efficiency obtained is 24.52% at 4kw & 19.20% at full load. Due to wide flammability limit and high combustion rate of acetylene, with high loads & at different flow rate the brake thermal efficiency falls because of faster heat release and high diffusion rate. Dual fuel operation normally encounters the problem of low efficiency at part loads. This is because of the incomplete combustion of the inducted fuel and air. The use of fuels with wide flammability limits and high flame velocity can reduce this effect. From the results the flow rate of 0.5bar of pressure is slightly nearer in thermal efficiency & for 0.8bar of pressure the thermal efficiency is very poor, since 0.5bar of acetylene flow rate is optimum.

B. Variation of Brake specific Energy consumption with Brake power

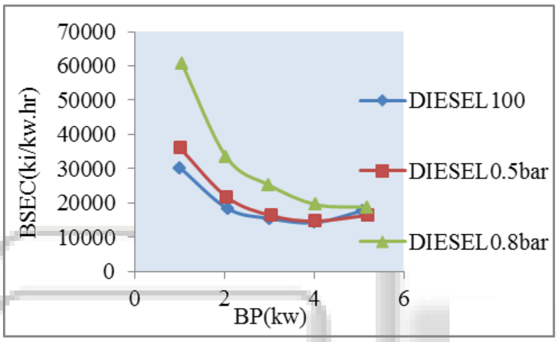

Fig. 4: Variation of Brake specific Energy consumption with Brake power

Fig. represents brake specific energy consumption with brake power at different flow rates of acetylene. The BSEC. is more reliable parameter when using different fuels in the same engine. The BSEC decreases with increase in engine loads. The BSEC depends on fuel specific gravity, viscosity and calorific value. if the specific gravity increases and calorific value decreases and more amount of fuel is needed to produce the same amount of energy. This may due to improved utilization of fuels with increase in engine load. The dual fuel operation of diesel along with acetylene blend at flow rate of 0.5bar shows slightly lesser fuel utilization for higher loads and high fuel for low, medium loads compared to diesel. For dual fuel at 0.8bar energy utilization is far up from diesel, this may results in slightly lower brake thermal efficiency as compared to diesel.

VII. Conclusion

The performance, combustion and emission characteristics of a single cylinder, four stroke, air-cooled, direct injection diesel engine having a power output of 5.2 kW, at compression ratio17.5:1, at a constant speed of 1500 rpm, fueled with diesel & acetylene at different flow rate were analysed and compared with diesel operation of the same engine.

The conclusions are given below.

- Brake thermal efficiency in dual fuel mode is slightly nearer to diesel operation for DIESEL-0.5bar and for DIESEL-0.8bar it is lesser than diesel at 4kw load, as a result of continuous induction of acetylene in the intake.
- BSEC is decreases with increase in engine load, for DIESEL-0.5bar the energy consumption is less than diesel (i.e diesel at 5.07kw is 17652kj/kw.hr, DIESEL-0.5bar at 5.21kw is 16403kj/kw.hr) and for DIESEL-0.8bar at 5.19kw is 18742kj/kw.hr it is nearer to diesel.

Reference

[1] Nakul agggarwal, “Analysis of engine performance by using acetylene in CI engine operated on dual fuel mode” International Journal of Enhanced Research in Science, Technology & Engineering, volume-4, pp. 95-104 July-2015.

[2] T. Lakshmanan, G. Nagarajan, “Performance and Emission of Acetylene-Aspirated Diesel Engine”, JJMIE, Volume-3, pp. 125-130, June 2009.

[3] S.K. Mahla, S. Kumar, H. Shergill and A. Kumar, ”Study the Performance Characteristics of Acetylene Gas in Dual Fuel Engine with Diethyl Ether Blends”, “International Journal on Emerging Technologies 3(1)”, pp. 80-83, April 2012.

[4] Kapil Dev Choudhary, Ashish Nayyar, “optimization of induction flow rate acetylene in CI engine operated on duel fuel mode” IJETAC, volume-3, pp. 297-302 december 2013.

[5] Pritinika behera, Abhishekh kumar Jha & S. Murugan [5] “Dual Fuel Operation Of Used Transformer Oil With Acetylene In A DI Diesel Engine” IJTARME, volume-2, pp. 126-132, 2013.

[6] S. Swami Nathan, J.M. Mallikarjuna, A. Ramesh, “Effect of Charge temperature and Exhaust gas re-circulation on Combustion and Emission Characteristics of Acetylene fuelled HCCI Engine”, “Fuel 89”, pp. 515-521, 2010.

[7] G.A. Karim, N.P.W. Moore, “The knock in dual-fuel engines”. Proc Instn Mech Engrs, Vol. 181, 1966-67, 453-466.

[8] V.M.S. Ashok, N.I. Khan, “Experimental investigation on use of welding gas (Acetylene) on SI Engine”. Proceedings of AER Conference, IIT, 2006. [6] Ganesan V. Internal combustion engine. 3rd ed. Singapore: McGraw Hill Book Company; 2007.

[9] J. Wulff, W.Hulett, L. Sunggyu, “Internal combustion system using acetylene fuel”. United States Patent No 6076487.

