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Experimental of 4S Diesel Engine using Biofuel Blends with Enrichment of C_2H_2 Gas

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Abstract: *In the present scenario owing to the depletion of fossil fuel and at the same time increase in demand averts the researchers towards the alternative fuel. Various investigation are being carried out to find the most suitable alternate for the fossil fuel in IC engine, which satisfies the demand, improves the performance and decreases the emission. This paper deals with the multi fuel mode. Tests were performed at 4S mono cylinder dual fuel diesel engine with blends of acetylene in different proportions (0.199 kg/hr., 0.394 kg/hr. and 0.588 kg/hr.) with 20% waste cooking oil at a rated injection pressure of 200bar.The result shows the increased in BTE and deceased BSFC and exhaust gas temperature, furtherance the decrease in NOx and CO are observed as the amount of acetylene increases. BTE increases due to the lower auto ignition temperature and high calorific value of acetylene. Graphs were obtained based on the performance of the engine and B20 with 0.394 kg/hr. of acetylene is concluded to be optimum, B20 with 0.199 kg/hr. of acetylene shows the result similar to diesel operation, at B20 with 0.588 kg/hr. of acetylene increase in the knocking effect was observed.*

Keywords: *Performance, combustion, emission, acetylene, dual fuel, waste cooking oil blends.*

I. INTRODUCTION

Rudolf diesel who was the first inventor of the diesel engine which runs with the vegetable oil, operated the diesel engine using groundnut oil as bio fuel in 1900. [1] Many researchers are in hunt to render most suitable vegetable oil as an substitute to the diesel fuel .In order to conquer the increasing demand and day by day decreasing quantity of fossil fuel, lowering the hazardous effect of exhaust emission on the environment. A vegetable oil with supreme properties should be used to advance the performance & provide effective utilization of BTE in diesel engine emitting lower emission [2-6]. Transesterifications is the process in which organic acid ester is converted in to another ester and glycerin when rated with alcohol .to improve the reaction rate NaOH can be used as a catalyst [7]. Ramadhas et.al. [8] In his review resolved that the thermal efficiency of vegetable oil was same as diesel oil, but little amount of power loss was observed .the particulate emissions of vegetable oil are more than that of diesel with decline in NOx. Bonaetal et.al [9] in his steady said that vegetable oil and their derivatives in diesel engines provides lower emissions of sulfur oxides, Carbone monoxides (CO), polyromantic hydrocarbon, smoke, PM and noise. Forson et.al. [10].stated that the lower concentration of jatropha oil in the blend in the IC engine renders closer performance and emission characteristics to diesel engine. Karim et.al [11, 12] worked on utilization of gaseous fuel and effect of knock on dual fuel engine. he reveals that the concentration of the gases fuel such as methane ,propane ,acetylene, ethylene and hydrogen effects the ignition delay period of the pilot fuel. And the maximum amount of gases consumption is limited due to onset of knock. Furthermore he stated that the quantity, quality, injection timing intake temperatures are the vital variable factor that effected the performance of dual fuel engine. Wilff et.al. [13] Examined an IC engine utilizing acetylene worked a engine on multi fuel mode utilizing a blend of acetylene and alcohol in a SI engine in a controllable manner. He watched higher productivity than the regular engine. With cleaner consuming petroleum derivative. He included that the life of the motor can be relied upon to increment as the ignition temperature was lower all through the test performed.

Utluz, and kocak. [14] led investigate direct infusion diesel engine they utilized waste fricasseeing oil as bio diesel in their examination and found that the separate normal expires of torque and power estimations of WFOME was 4.3%and 4.5% as a result of the higher thickness and thickness and lower warming worth (8.8%). Senthil et.al [15] stated that the reduction in power and increases in emission can overcome buy dual fuel operation even at all full load for high viscous fuel. He added that dual fuel made offer lower efficiency at part loads due to incomplete combustion of inducted fuel and air their effect can be reduced by the use of wide flammability limits and high flame velocities. Swami Nathan et.al. [16] Tested HCCI engine operates on acetylene. He conducted that the acetylene has lower ignition energy, high flame speed and wide flammability limits compared to the diesel and hydrogen, fuel leading to premature ignition and knock in the acetylene operated engine. Experiment was conducted using LPG in dual fuel mode in a jatropha fueled diesel engine. The result shows reduced NOx and smoke during the test entire load range [17].

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Table 1: Physical and combustion properties of fuel

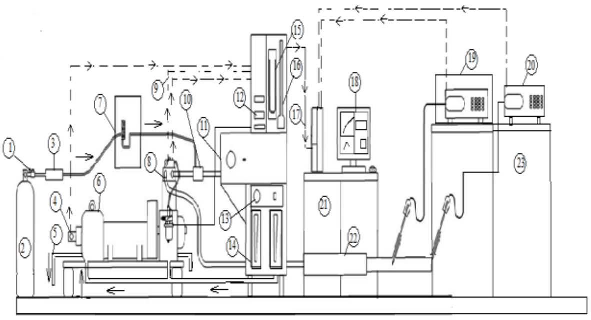
Properties	C_2H_2	Hydrogen	Diesel	Waste cocking oil
Density at 1.0132 bar and 293K(kg/m^3)	1.092	0.08	815	878
Calorific value (kj/kg)	48,22 5	1,20,000	43,350	38,650
Viscosity at 300 K (mm^2/s)	-	-	4.3	10.3
Cetane number	-	-	47	45
Auto ignition temperature(K)	578	572	527	-
Flame speed(m/s)	1.5	3.5	0.3	3.9
Flammability limits (volume %)	2.5-81	4-74.5	0.6-5.5	-
Ignition energy(MJ)	0.019	0.02	-	-

II. EXPERIMENTAL SETUP AND METHODOLOGY.

The Exercise were performed on computer attached 4S, mono cylinder duel fuel, water cooled engine with eddy current loading as explained in below in Table 2. The exercise were performed on maximum load condition and speed of 1500 rpm. Piezoelectric sensor were used to sense the inside cylinder pressure and the equipment were attached with other sensors like thermocouple, crank encoder etc. In the startup of engine initial fuel used to run is diesel and later on experiment carried by biofuel with gases. The acetylene gas enriched with low concentration like 0.199kg/hr, 0.394kg/hr, & 0.588kg/hr respectively. And the emission were captured by using of equipment multigas analyzer model of MN-05.

Table 2: Engine Specifications

Make	Kirloskar
Model	TV-1
Type	VCR engine
Bore ×stroke(mm)	87.5×110
Rated power(kW)	3.5
Rated speed (rpm)	1500
Injector operating pressure(bar)	200
Cubic capacity (cc)	661
Compression ratio	17.5
Crank Timing (degree BTDC)	23
Arm length (m)	0.18
Fuel Injection	Direct Injection
Type Of Ignition	Compression Ignition
Piston Bowl	Hemispherical
Connecting rod length (m)	0.234



1.Regulater 2.Cylinder 3.Fire Resistor 4.CA Encoder 5.Water Outlet 6.Eddy Current Dynamometer7. Flow meter 8.Engine 9.Fuel Line Pressure sensor line 10.Gases mixed chamber 11.Orifice Meter 12.RPM Indicator 13.Loading unit 14.Rota meter 15.U-Tube Manometer 16.burette 17.NI-6210 USB Multi function line 18.Computer 19.Exhaust gas analyzer 20.Smoke meter 21.Computer Table 22.Exhaust Gas Calorimeter 23.Analyser Table

Figure 1. Schematic diagram of experimental set up

III. ERROR ANALYSIS

Energy share is defined as ratio of energy given as a primary fuel to the total energy given to the engine.

$$\text{Energy Equivalent to B20} = \dot{m}_{B20} \times LHV_{B20}$$

$$\text{Energy Equivalent to } C_2H_2 = \dot{m}_{C2H2} \times LHV_{C2H2}$$

$$\text{Energy share by B20} = \frac{\text{Energy Equivalent to B20}}{\text{Energy Equivalent to B20} + \text{Energy Equivalent to } H_2}$$

$$\text{Energy share by } C_2H_2 = \frac{\text{Energy Equivalent to C2H2}}{\text{Energy Equivalent to B20} + \text{Energy Equivalent to C2H2}}$$

$\dot{m}_{B20}$ $\dot{m}_{C_{2H_2}}$ are the mass flow rates of B20 and Acetylene, and LHV is the lower heating value of the fuel used. The energy shares of B20 and Acetylene with the Acetylene induction rate of 0.199 kg/hr, 0.394 kg/hr and 0.588 kg/hr. are given in table 3.

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Table 3: Energy share ratio of diesel acetylene and waste cooking oil

Made of operation full load	Mass of diesel (kg/hr.)	Mass of WCO (kg/hr.)	Mass of C_2H_2 (kg/hr.)	Energy Equivalent to diesel (kW)	Energy Equivalent to WCO (kW)	Energy Equivalent to C_2H_2 (kW)	Energy Shearing to Diesel (%)	Energy Shearing to WCO (%)	Energy Shearing to C_2H_2 (%)
Pure diesel	0.95	-	-	11.084	-	-	100	-	-
80% D+20% WCO	0.92	0.2479	-	10.7341	2.661	-	80.1	19.86	-
80% D+20% WCO+ 0.199 kg/hr. of C_2H_2	0.809	0.2023	0.0288	9.439	2.172	0.3811	78.7	18.11	3.178
80% D+20% WCO+ 0.394 kg/hr. of C_2H_2	0.586	0.1467	0.0576	6.8372	1.5751	0.784	74.34	17.127	8.52
80% D+20% WCO +0.588 kg/hr. of C_2H_2	0.422	0.1057	0.0864	4.9342	1.1348	1.176	68.103	15.664	16.322

IV. RESULTS AND DISCUSSION

4.1 COMBUSTION

4.1.1 Pressure crank angle diagram

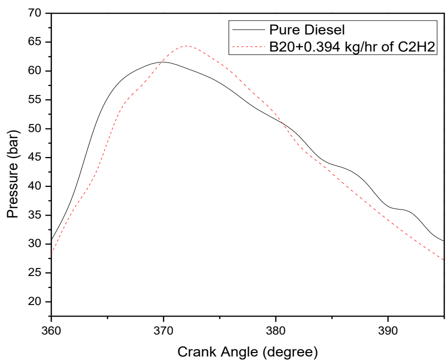

Figure 2. Variation of cylinder pressure with crank angle

The Fig.2 shows the variation of pressure with the crank angle for B20+0.394 kg/hr. of acetylene and pure diesel at a rated speed of 1800 rpm. The values of peak pressure for pure diesel and B_{20}+0.394 kg/hr. of C_2H_2 were obtained as 60.47 bar and 64.12 bar. This is due to the high calorific value of acetylene and wide flammability limits.

4.1.2 Heat releases rate

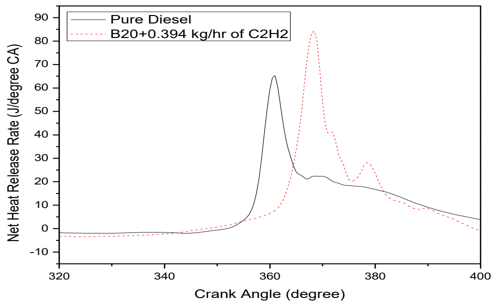

Figure 3. Variation of net heat release rate with crank angle

The analysis of the heat release rate depends upon the concept of first law of thermodynamics which involves the ratio of specific heat of fuel and air, average pressure of the combustion chamber taken for 100 cycles and volume of the combustion chamber. Fig (3) shows the relation between the heat release rate and crank angle.

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The net heat release rate at 360^0 CA was 66 J/^{0} CA for pure diesel and for B20+0.394 kg/hr. of acetylene at 364^0 CA the net heat release was 80 J/^{0} CA which is the maximum heat release rate and assumed to be optimum. This is because in dual fuel mode slight time is taken for burning the charge due to the phase change and high viscosity of the pilot fuel.

4.1.3 Mass fraction

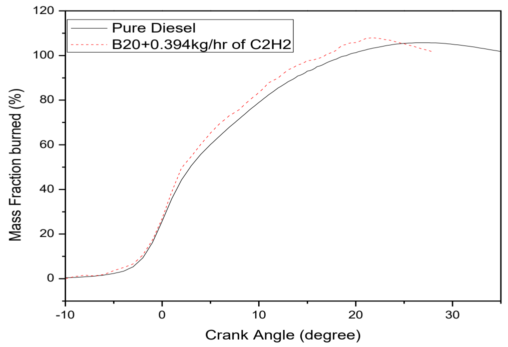

Figure 4. Variation of mass fraction burned with crank angle

It was determine from the measured cylinder pressure. It is an assessment of the portion of vitality discharged from the fuel ignition to the complete vitality delivered toward the finish of burning. At the beginning of combustion, acetylene has wide flammability and less auto ignition temperature it gives complete combustion of acetylene it helps to give a complete combustion of B20+0.394 Kg/hr. of C_2H_2 From Fig. B20+0.394 kg/hr. of C_2H_2 is 10%, 50% and 90% mass fraction burned was observed at crank angle $1.2^{0,}$ 4.5^0 and 14.3^0.

4.2 PERFORMANCE

4.2.1 Brake thermal efficiency

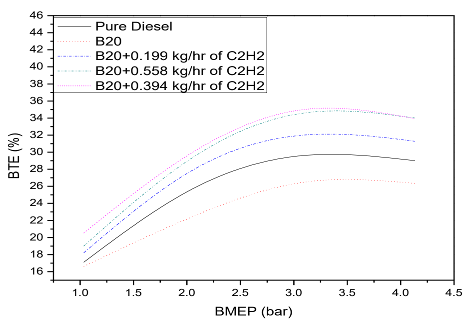

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Figure 5. Variation of Brake Thermal Efficiency with Break Mean Effective Pressure

The fig.5 shows the variation of Brake Thermal Efficiency with Break Mean Effective Pressure Different flow rates were taken and plotted on graph and compared with the standard pure diesel values. The fuel B20 was compared with the standard pure diesel and it was found out that the Brake Thermal Efficiency of B20 is low the reason is that the viscosity of B20 is high compared to pure diesel and also when combustion takes place inside the cylinder the carbon gets deposited on the walls of the cylinder which changes the fuel Cetane value and this effect the calorific value of the fuel which relatively decreases the Break Thermal Efficiency. Then along with B20 acetylene was induced i.e. B20+0.199 kg/hr. of C_2H_2 and the Break Thermal Efficiency is 30.2 for B20+0.394kg/hr. of C_2H_2 the Brake Thermal Efficiency is 35.4 and for B20+0.558 kg/hr. of C_2H_2 Break Thermal Efficiency is 35.6 and on comparison of these three fuel values it was found out that the Brake Thermal Efficiency increases with increase in flow of acetylene and the optimum value occurs at B20+0.394 kg/hr. of C_2H_2 due to the reason that acetylene increases combustion points in combustion chamber

4.2.2 Exhaust gas temperature

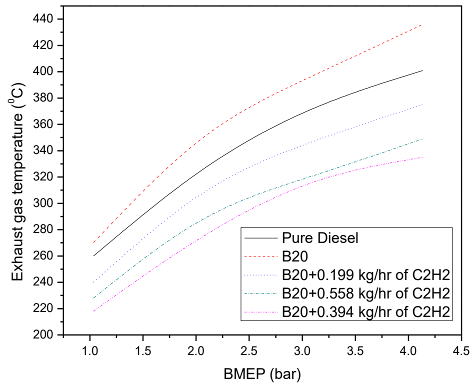

Figure 6. Variation of exhaust gas temperature with break mean effective pressure

The graph shows exhaust gas temperature and break mean effective pressure B20 fuel exhaust temperature is high the reason is high boiling point constituents i.e. the diesel, the ignition delay and high viscosity, incomplete combustion(ch-10,41).In dual fuel case the exhaust gas temperature is lower than 0.199 kg/hr. of C_2H_2 value and is near to the standard diesel value. It happen in the combustion chamber acetylene reduces the ignition delay and high thermal efficiency. The various acetylene flow rates 0.199 kg/hr. of C_2H_2, 0.394 kg/hr. of C_2H_2 and 0.584 kg/hr. of C_2H_2 the exhaust gas temperatures are 370,338 and 309 degree C respectively. This is due to higher flame speed and faster energy released in cycle (ch-6,6).the pressure diagram indicates high pressure that occurs when acetylene was introduced and heat loss will happen gases to the wall increased due to higher thermal conductivity (ch-6,22)

4.3 EMISSIONS

4.3.1 Oxides of Nitrogen

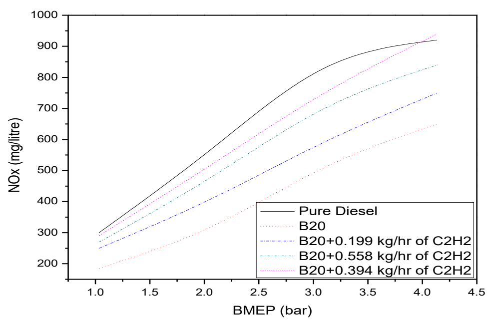

Figure 7. Variation of NOx with break mean effective pressure

The NOx formation depends on the oxygen availability in combustion chamber, high peak pressure and combustion temperature. the graph shows the relation between BMEP and NOx,

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The NOx value decreases compared to pure diesel due to low cylinder gas temperature and higher cetane number than diesel this effect reduces the ignition delay. As on increasing the acetylene flow rates the NOx increases at 0.199 kg/hr. of C_2H_2,0.394 kg/hr. of C_2H_2 and 0.588 kg/hr. of C_2H_2 the NOx value is 662,778,and 887 respectively, the B20+ 0.588 Kg/hr. of C_2H_2 value is closer to the pure diesel . This is due to the higher pressure rate in combustion chamber which indicate faster combustion and higher NOx formation (ch-10).

4.3.2 Carbon monoxide

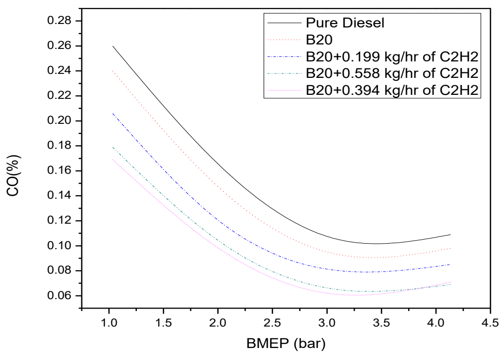

Figure 8. Variation of CO with break mean effective pressure

This graph Indicates the variation of carbon monoxide and break mean effective pressure the value of B20 decreases, this fuel value is near to the diesel value. As the amount of acetylene increases the CO value decreases this is due to oxygen content that provide complete combustion (ch-10, 47).The emission of the CO depends on the air fuel ratio and stoichiometric quantities. Due to the lean mixture of fuels in CI engine the CO value will be minimum (ch-5, 1).

V. CONCLUSIONS

The duel fuel operation is conducted on single cylinder water cooled four stroke CI engine, the test was carried on varies flow rates (B20,B20+0.199 kg/hr. of C_2H_2,B20+0.394 kg/hr. of C_2H_2,B20+0.588 kg/hr. of C_2H_2) in dual fuel mode.

- Break thermal efficiency is increased as compared to standard values of diesel. It is increased by 32.91%, 37.5%, and 42.43% with 0.199 kg/hr. of C_2H_2, 0.394 kg/hr. of C_2H_2 and 0.588 kg/hr. of C_2H_2 respectively, the value of B20+0.199 kg/hr. is near to diesel values.
- Break specific fuel consumption is decreased.
- In duel fuel mode the NOx value also decreases as compare to the diesel value.
- Lower CO emissions due to the complete combustion of charge in dual mode as CO being converted to CO_2.
- Exhaust temperature is also low in duel fuel mode as compared to the standard value of diesel.

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