Optimization of Induction Flow Rate of Acetylene in the C.I. Engine Operated on Duel Fuel Mode

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Abstract—In the present study acetylene was used as an alternative fuel blended with Diesel, and its performance in a compression ignition engine was investigated. 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: [i] Gas enter in the engine cylinder along with intake air in the suction stroke. [ii] In the compression stroke the air and acetylene gas gets mixed and compressed. [iii] 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 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. Based on the combustion, performance and emission parameters the flow rate of induction was optimized which was 7lpm.

Keywords—Acetylene, Combustion, Dual fuel mode, Emission, Induction flow rates, Performance

I. INTRODUCTION

Increasing industrialization, growing energy demands, limited reserves of fossil fuel and increasing environmental pollution have necessitated exploration of some alternatives of conventional petroleum fuels. Thermodynamic tests based on engine performance evolution have established the feasibility of using a variety of alternative fuels such as hydrogen, electric battery technologies, compressed natural gas (CNG), liquefied petroleum gas (LPG), acetylene, ethanol, methanol, biodiesel, vegetable oil and other biomass sources in internal combustion engines. Alternative fuel should be easily available, environmentally friendly, renewable, cost effective and techno-economically competitive. Successful fuel should fulfill environmental and energy security needs without sacrificing engine performance. Gaseous fuels are the best suited for IC engines since their combustion delay is almost nil. However, as fuel displaces equivalent amount of air the engines may have poor volumetric efficiency. There are fairly few gaseous fuels that can be used as alternative fuels.

II. LITERATURE REVIEW

Sharma P.K. et al., [1] explained the use of acetylene as an alternative fuel in internal combustion engine. They conducted experiments on SI engine using acetylene as the primary and alcohol as the secondary fuel. Results showed that alcohol to be introduced so as to reduce the temperature inside the combustion chamber. Lakshmanan T. and Nagarajan G. [2, 3] conducted experiments to study the performance and emission distinctiveness of direct injection (DI) diesel engine in dual fuel mode by timed manifold injection to induct acetylene at different flow rates. The results showed that best possible conditions in manifold injection technique is 10° ATDC with the injection interval of 90° crank angle. During experiments a fixed quantity of 3 lpm of acetylene is supplied to the inlet manifold in dual fuel mode with diesel as an ignition source, for various loads. The brake thermal efficiency in dual fuel mode was found lower than diesel operation at full load.

Mahla S.K. et al., [4] conducted experiment to study the performance characteristics of DI diesel engine in dual fuel manner by aspiration of Acetylene at set quantity of 12 lpm in the inlet manifold, with diethyl ether blends (B10, B20, B30) mixed with diesel as an ignition source. From the outcome it was found that Dual fuel operation along with DEE-diesel blend as pilot fuel exhibits fine engine performance as match up to diesel fuel. Sole acetylene fuel in HCCI mode resulted high thermal efficie

III. EXPERIMENTAL SETUP AND PROCEDURE

A single cylinder, direct injection, four stroke, vertical, water cooled engine was used, the specification of which is given in the table 1. Fig 1 illustrates the experimental setup. An acetylene connection was made at the intake air manifold of the engine.
Diesel flow was governed by the governor and the acetylene flow rate was varied manually with the help of gas flow meter.

**TABLE 1**

<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Single Cylinder, Direct Injection, Four-Stroke, Vertical, Water-Cooled, Naturally Aspirated Variable Compression Ratio Multi-Fuel Diesel Engine</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>3 to 5 HP</td>
</tr>
<tr>
<td><strong>Rated Speed</strong></td>
<td>1450 to 1600 rev/min (Governed Speed)</td>
</tr>
<tr>
<td><strong>Number of Cylinders</strong></td>
<td>One</td>
</tr>
<tr>
<td><strong>Bore</strong></td>
<td>80 mm</td>
</tr>
<tr>
<td><strong>Stroke</strong></td>
<td>110 mm</td>
</tr>
<tr>
<td><strong>Injector Pressure</strong></td>
<td>203 bar</td>
</tr>
<tr>
<td><strong>Injection Timing by Spill</strong></td>
<td>23° CA BTDC</td>
</tr>
<tr>
<td><strong>Method of Loading</strong></td>
<td>Eddy Current Dynamometer</td>
</tr>
<tr>
<td><strong>Method of Starting</strong></td>
<td>Manual Crank Start</td>
</tr>
<tr>
<td><strong>Method of Cooling</strong></td>
<td>Water Cooled</td>
</tr>
<tr>
<td><strong>Over all Dimensions</strong></td>
<td>1400 x 1300 x 1100 mm</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>225 kg</td>
</tr>
<tr>
<td><strong>Air Tank Size (mm)</strong></td>
<td>400 x 400 x 400 mm</td>
</tr>
<tr>
<td><strong>Orifice Size (mm)</strong></td>
<td>20 mm</td>
</tr>
<tr>
<td><strong>Valve Timings</strong></td>
<td></td>
</tr>
<tr>
<td>Inlet Valve Opens</td>
<td>4.5° CA BTDC</td>
</tr>
<tr>
<td>Inlet Valve Closes</td>
<td>35.5° CA ABDC</td>
</tr>
<tr>
<td>Exhaust Valve Opens</td>
<td>35.5° CA BTDC</td>
</tr>
<tr>
<td>Exhaust Valve Closes</td>
<td>4.5° CA ATDC</td>
</tr>
</tbody>
</table>

**Fig. 1 Experimental Setup**

Cylinder pressure signals, obtained from a flush mounted quartz pressure pickup were recorded on a computer system. The heat release rate and other combustion parameters were calculated using software developed for the reason after obtaining the pressure signals 100 successive engine cycles. The combustion, performance, and emission distinctiveness of the diesel engine were calculated, compared with diesel fuel process.

**IV. RESULTS AND DISCUSSIONS**

**A. Combustion Parameters**

**Pressure Crank Angle Diagram:**

Fig. 2 shows the measured cylinder pressure versus crank angle variation at full load for diesel operation and acetylene flow rates of 5 lpm, 6 lpm, 7 lpm and 8 lpm at compression ratio 18:1 of the engine. The maximum cylinder pressure for diesel operation at full load is 61.27 bar and for acetylene at different flow rates, it is 62.75 bar, 63.23 bar, 63.96 bar and 62.34 bar. The cylinder pressure is raised by acetylene induction due to increase in ignition delay and high heat release by acetylene. The peak cylinder pressure for acetylene induction at 7 lpm is 63.96 bar and it is higher among that of all other flow rates.
Heat Release Rate:

The graph drawn for the heat release rate for diesel operation and acetylene inducted at different flow with crank angle for compression ratio 18:1 is shown in fig. 3. The maximum heat release rate for diesel operation at full load is 24.81 J/deg CA and for acetylene induction at 7lpm the rate of heat release is marginally increased to 27.81 J/deg CA.

Mass Fraction Burnt:

The graph shown in the fig. 4 is drawn between MFB and Crank Angle for compression ratio 18:1. The graph is drawn for base line diesel fuel and acetylene induction at various flow-rates. It is observed from the curve that combustion duration is short for all induction flow rates of acetylene compared to diesel.

B. Performance Parameters

Brake Thermal Efficiency:

The graph shown in fig 5 is drawn between brake thermal efficiency and percentage of load for diesel engine when acetylene is induced at different flow rates at compression ratio of 18:1. The brake thermal efficiency is decreasing while acetylene is induced as supplementary fuel. The brake thermal efficiency is marginally decreasing with induction of acetylene irrespective of flow rates due to high combustion rate and rapid energy release. Brake thermal efficiency for acetylene inducted at 7 lpm is higher than other flow rates at full load operation.

Exhaust Gas Temperature:

The exhaust gas temperature is increasing with acetylene induction when compared to diesel operation may be due to more energy input with acetylene gas. The graph shown in fig 6 is drawn between exhaust gas temperature and % load.
The EGT is in the range of 261°C to 618°C for neat diesel operation and 264°C to 638°C for acetylene at various flow rates at compression ratio 18:1. The EGT reached to 638°C while acetylene was inducted at 7lpm and it is more when compared with other flow rates at full load. So EGT graph is useful for optimizing the flow rate at which acetylene gas can be inducted in the in air manifold along with air.

![Fig. 6 Changes in EGT with %load](image)

**Brake Specific Energy Consumption:**

The graph shown in fig. 7 drawn between brake specific energy consumption and % load applied for diesel and different flow rates of acetylene. Addition of acetylene gas provides more energy share compare to that of diesel so that the brake specific energy consumption increase. BSFC for neat diesel is 13.68 MJ/kWh and for acetylene at 7 lpm it is 18 MJ/kWh.

![Fig. 7 Changes in BSEC with % load](image)

**Volumetric Efficiency:**

The ratio of actual air capacity to the ideal air capacity which means breathing ability of the engine is known as volumetric efficiency of an engine. When the acetylene supplied to the air intake pipe, it displaces some of the air inducted.

Because of this reason as some amount of air replaced by acetylene gas, there is reduction in volumetric efficiency for all flow rates irrespective of load when compared to neat diesel operation. The change in volumetric efficiency with % load is shown in the fig. 8.

![Fig. 8 Changes in Volumetric Efficiency with % load](image)

**C. Emission Parameters**

The main pollutants contributed by automobiles are carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NOx) during combustion process. Some emissions exhausted from the engine are discussed below. The results were compared between diesel and acetylene induction at compression ratio 18:1.

**Carbon Monoxide:**

Carbon monoxide emission is due to unavailability of oxygen during the combustion process. Poor mixing and incomplete combustion are also responsible for CO emissions. The graph shown in fig 9 is drawn between CO emission (% Vol.) and % load applied. By induction of acetylene, results show less CO emissions at all loads when compared to neat diesel operation, may be due to operation of dual fuel engine in lean range than base line diesel fuel.

![Fig. 9 Changes in CO emission with % load](image)
Unburnt Hydrocarbons:

There is an increase in unburnt hydrocarbon emissions with the addition of acetylene because of decrease of oxygen % inhaled. Due to less oxygen present in the charge intake it leads to improper combustion. The HC value for diesel operation at full load is 23ppm and for 5 lpm, 6 lpm, 7 lpm and 8 lpm of acetylene flow rates are 22ppm, 25ppm, 23ppm and 30ppm respectively. The change in HC emission with % of load is shown in the fig. 10.

Oxides of Nitrogen (NO\textsubscript{x}):

NO\textsubscript{x} values in emission depend upon reaction temperatures and peak cylinder pressures. The graph showed in fig 11 is in between NO\textsubscript{x} emission and % load for neat diesel and all acetylene flow rates. As the flow rate of acetylene gas increases the reaction temperatures and peak cylinder pressures are increases accordingly that results higher NO\textsubscript{x} emissions. NO\textsubscript{x} emission for the diesel operation at full load is 437 ppm and for different flow rates of acetylene induction 5 lpm, 6 lpm, 7 lpm and 8 lpm are 466ppm, 475ppm, 465ppm and 541ppm respectively.

V. CONCLUSION

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. The heat release rate obtained with acetylene induction of 7 lpm is 27.81 J/deg CA, which is uppermost among all other induction flow rates and neat diesel operation. The brake thermal efficiency is marginally decreasing with induction of acetylene irrespective of different flow rates due to high combustion rate and fast energy release when compare to base line diesel operation. Brake thermal efficiency for acetylene inducted at 7 lpm is higher than other flow rates at full load operation.

The EGT reached to 638°C while acetylene inducted at 7 lpm and it is more when compared with other flow rates at full load. Induction of acetylene provides more energy share compare to that of diesel so that the brake specific energy consumption increase. BSFC for neat diesel is 13.68 MJ/kWh and for acetylene at 7 lpm it is 18 MJ/kWh. By induction of acetylene results show less CO emissions at all loads when compared to base line diesel operation, may be due to operation of dual fuel engine in lean range than base line diesel fuel.

As the flow rate of acetylene gas increases the reaction temperatures, peak cylinder pressures also increases accordingly that results higher NO\textsubscript{x} emissions. NO\textsubscript{x} emission for acetylene induction at 7 lpm is measured as 465 ppm. Based on the combustion, performance and emission parameters, the acetylene induction of 7 lpm is taken as optimum.
REFERENCES


