

# **Effect of Injection Timing on the Performance and Emission Characteristics of CI Engine Fuelled with Diesel – Compressed Biogas and ROME – Compressed Biogas**

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**ABSTRACT:** In the present study, an experimental work had been carried out to analyze the performance and emission characteristics of diesel engine by varying the injection timing when fuelled with diesel – CBG and ROME – CBG at 80% and 100% load. From the test results it was observed that, maximum brake thermal efficiency and lower emissions were found at 27° bTDC injection timing.

**KEYWORDS:** injection timing, performance, combustion, emission, ROME, compressed biogas.

## **I. INTRODUCTION**

In the present scenario if we observe the effect of fossil fuels on environment, health of the human being, investment on the fuels for importing etc. it is damn clear that Renewable fuels have advantages in terms of renewable, biodegradability, energy security, environmental concerns, foreign exchange savings and socio-economic issues compared to fossil fuels. Therefore renewable fuels can be used predominantly used as fuel for transportation and power generation. Research works have been conducted on biogas production, purification, bottling and usage of bottled or compressed biogas (BIO-METHANE) in vehicles and also utilized in the generation of electricity. Biogas production from waste is not only renewable, also leads to sustainable development of the country. Along with biogas, biodiesel production also carries lot of importance. Biodiesel from non-edible oils have the ability of 100% replacement of the fossil fuels in IC engines without any modification. Vegetable oils have considerable potential to be considered as appropriate alternate fuel as they possess fuel properties similar to that of diesel. Moreover, review of literature revealed that with the use of vegetable oils, as fuel in diesel engines is beneficial because, these are non-toxic, biodegradable, and eco-friendly and renewable in nature and the use of vegetable oils in diesel engine reduces emissions. India has rich and abundant forest resources with wide range of plants and oil seeds. There are more than 300 different species of trees available in India. The oils can be obtained from many oil seeds. Based on the application or use of vegetable oils, the vegetable oils are classified in to two types, namely edible and non-edible oils. Economics of the biodiesel production process can be improved, if non-edible oils are used. Use of edible oils in diesel engines is not encouraged as it is in great demand for human consumption. Therefore only non-edible vegetable oils can be seriously considered as fuel for CI engine. As far as low emission fuels are concerned "gaseous fuels" appears to be capable of performing a prominent role. Various gaseous fuels such as Biogas, Producer Gas, Hydrogen, LPG and CNG are suitable for IC Engines. CBG is considered as a better alternative fuel for CI engines because of availability of raw material (waste) for the production and drastic reduction of exhaust emissions. One of the main motivations to operate engines on gaseous fuel is the fact that exhausts smoke and engine deposits are drastically reduced and they can be adopted for the current fleet of engines with slight modification at relatively low cost. Moreover, engine noise is significantly reduced in gasoline & diesel engine. Lead pollution will not be there with gaseous fuels.

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### II. RELATED WORK

#### Transesterification

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification.

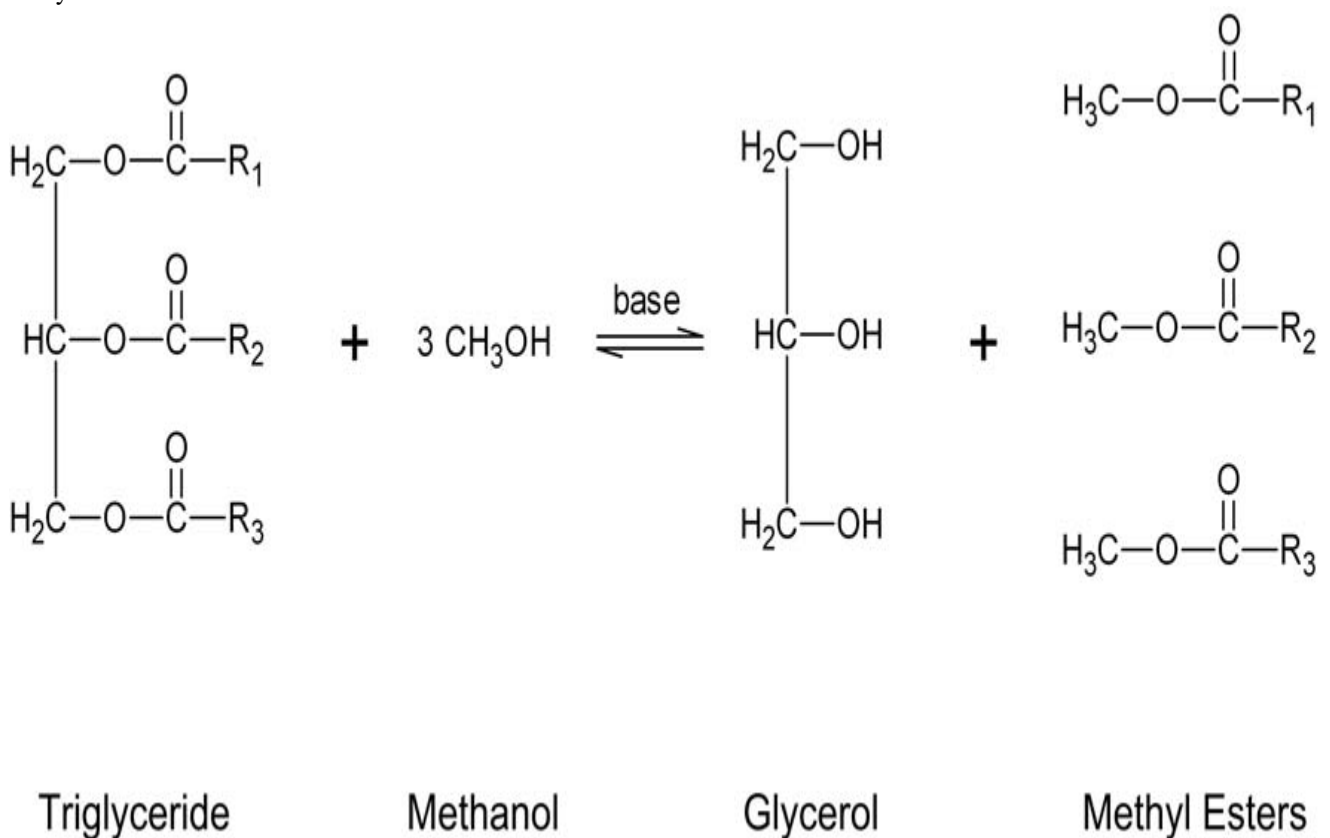


Fig 1: Chemical reaction.

#### Properties of fuels

| Properties                     | Diesel | ROME  | CBG   |
|--------------------------------|--------|-------|-------|
| Viscosity @ 40°C (cSt)         | 4.59   | 5.16  | –     |
| Flash point (°C)               | 56     | 176   | –     |
| Calorific Value (kJ / kg)      | 44146  | 39345 | 36540 |
| Density (kg / m <sup>3</sup> ) | 827    | 860   | 0.68  |

Table 1: Properties of fuels.

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## Composition of CBG

| Composition      | % Volume |
|------------------|----------|
| CH <sub>4</sub>  | 89       |
| H <sub>2</sub> S | 1.5      |
| CO <sub>2</sub>  | 8        |
| N <sub>2</sub>   | 1.5      |

Table 2: Composition of CBG.

## Experimental setup



Fig 2: Computerized diesel engine setup

## Engine specifications

| Engine Parameters | Specifications                                 |
|-------------------|--|
| Machine supplier  | Apex Innovations Pvt Ltd. Sangli, Maharashtra. |
| Type              | TV1 ( Kirloskar make)                          |
| Software used     | Engine soft                                    |
| No of cylinders   | Single cylinder                                |
| No of strokes     | Four stroke                                    |
| Rated power       | 5.2 kW at 1500 RPM                             |
| Bore x Stroke     | 87.5 mm x 110 mm                               |
| Compression ratio | 17.5 : 1                                       |
| Dynamometer       | Eddy current                                   |

Table 3: Engine specifications.

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## III. EXPERIMENTAL RESULTS

### Brake thermal efficiency

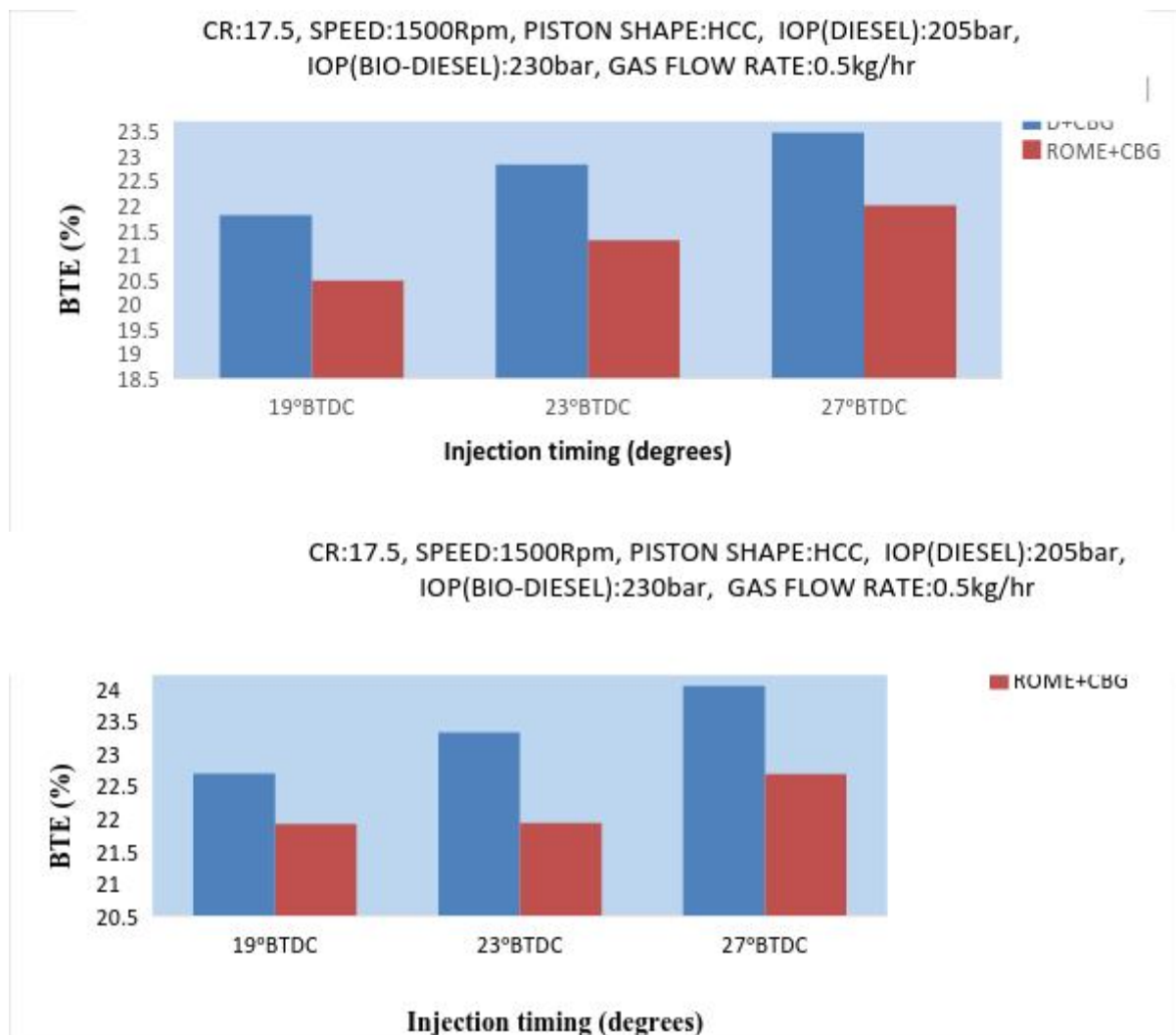


Fig 3 & 4: Variation of BTE with injection timing at constant gas flow rate at 80% and 100% load respectively.

Figure 3 & 4 shows the variation of brake thermal efficiency (BTE) with injection timing for Diesel-CBG and ROME-CBG fuel combinations operated for 80% and 100% load respectively. The results were obtained in the form of increment in the BTE values for both the loads when the injection timing was advanced from 19° bTDC to 27° bTDC. The main reason for this is availability of time for better burning CBG fuel results in better performance and improved brake thermal efficiency BTE values for diesel-CBG and ROME-CBG dual-fuel operation at 27° bTDC injection timing are found to be 23.48 and 21.29 % respectively at 80% load.

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### Brake specific fuel consumption

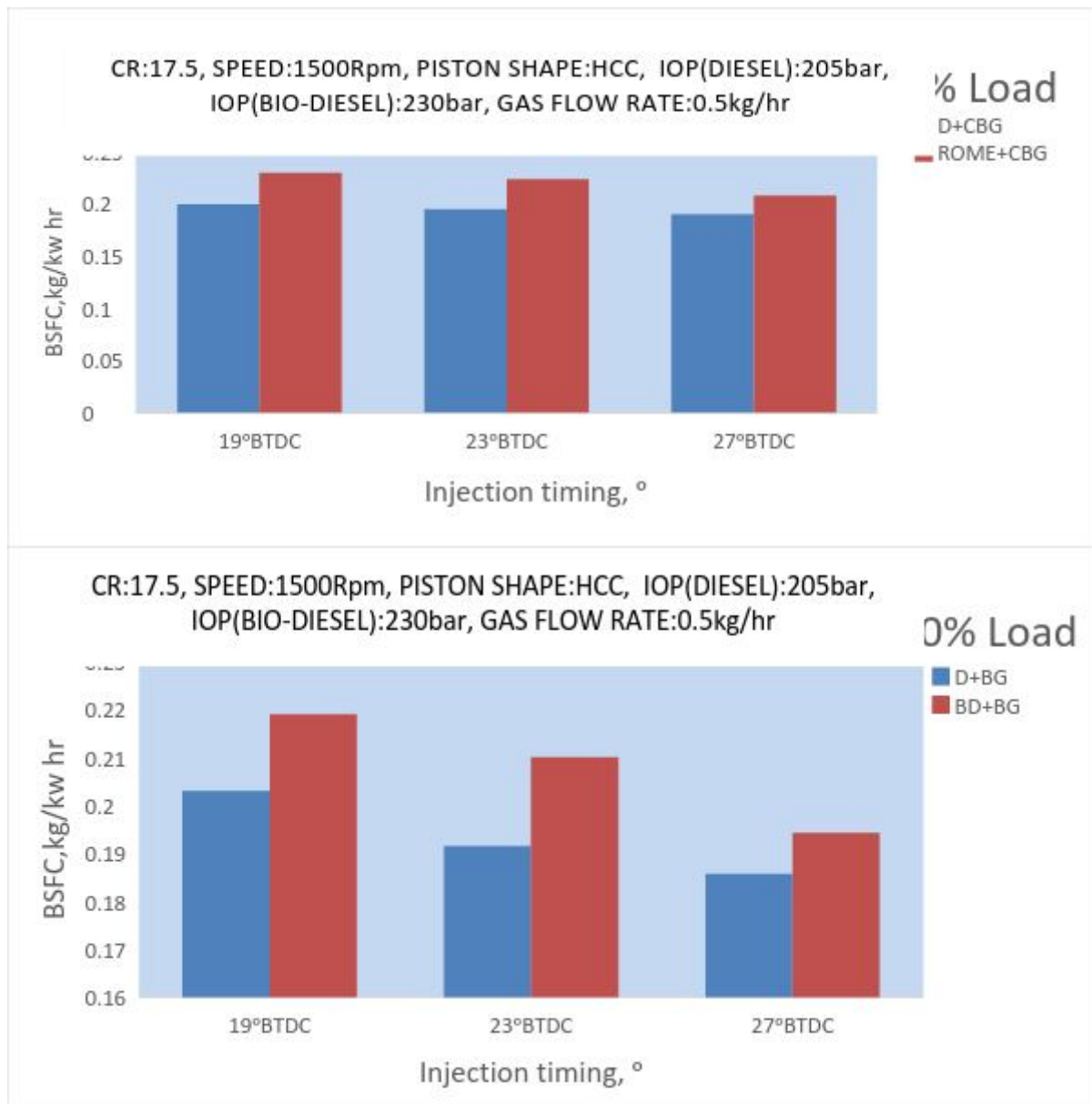
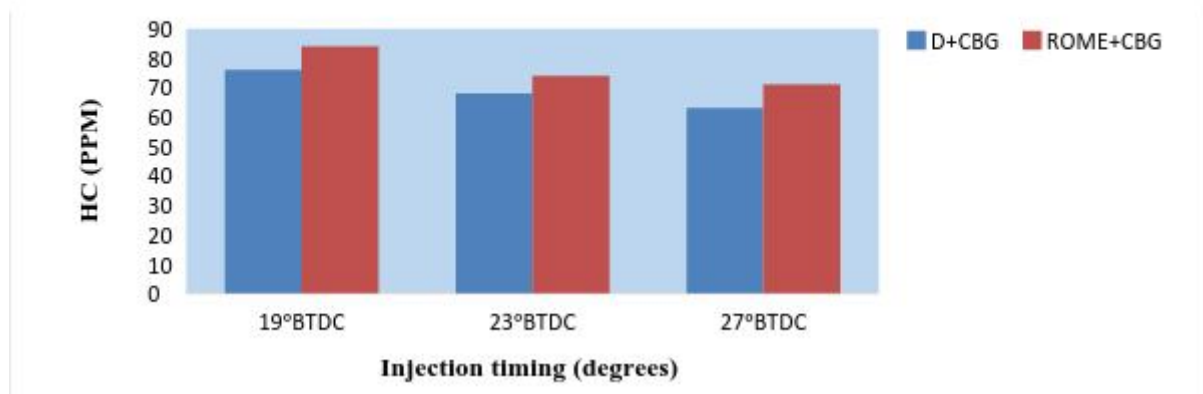


Fig 5 & 6: Variation of BSFC with injection timing at constant gas flow rate at 80% and 100% load respectively.

Figure 5 & 6 shows the variation of brake specific fuel consumption (BSFC) with injection timing for Diesel-CBG and ROME-CBG fuel combinations operated for 80% and 100% load. The experimental values show that, increase in injection timing from 19° bTDC to 27° bTDC, it was found decrement in the BSFC value. The reason for this may be due to sufficient time availability for evaporation and mixing of fuel and air with increased premixed combustion and lower diffusion combustion. On the other hand, retarding the injection timing resulted in increased the specific fuel consumption due to late combustion. BSFC values for diesel-CBG and ROME-CBG dual-fuel operation at 27° bTDC injection timing are found to be 0.1903 and 0.2082 % respectively at 80% load.

**HC Emissions**

CR:17.5, SPEED:1500Rpm, PISTON SHAPE:HCC, IOP(DIESEL):205bar,  
IOP(BIO-DIESEL):230bar, GAS FLOW RATE:0.5kg/hr



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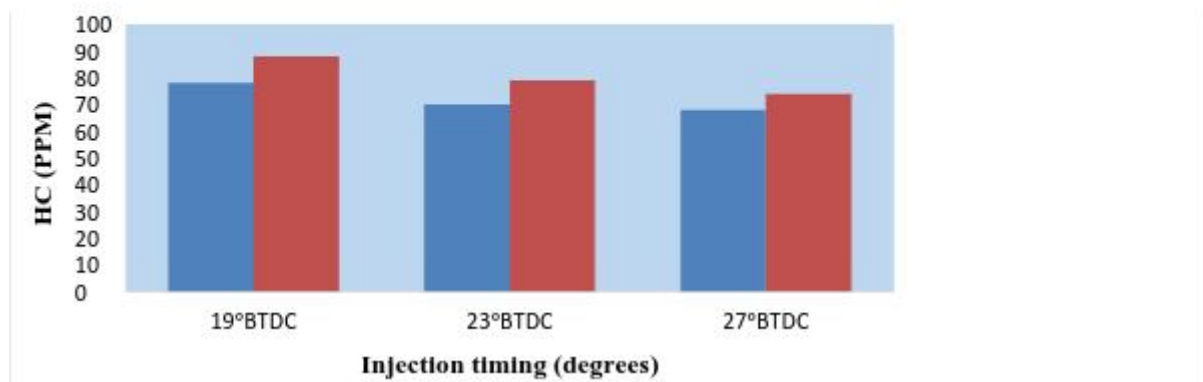


Fig 7 & 8: Variation of HC with injection timing at constant gas flow rate at 80% and 100% load respectively.

Figure 7 & 8 shows variation of HC emissions with injection timings for Diesel-CBG and ROME-CBG operated dual fuel engine for 80% and 100% load respectively. As the injection timing increases the HC emission decreased considerably as seen in the figure for both loads. The reason for this is, as the injection timing advances there will be a longer ignition delay which allows a fuller spray penetration and development, creating a larger amount of the pilot fuel-air-gaseous fuel mixture (or flame propagation region) prior to ignition which leads to better combustion of mixture.. The higher combustion rates of this larger premixed regions yields higher combustion temperatures and thus, lowers the UBHC emissions. HC emission levels for diesel-CBG and ROME-CBG dual-fuel operation at 19, 23 and 27°bTDC injection timing, at 80% load are found to be 76, 68 and 63 and 84,74 and 71ppm respectively.



**CO Emissions**

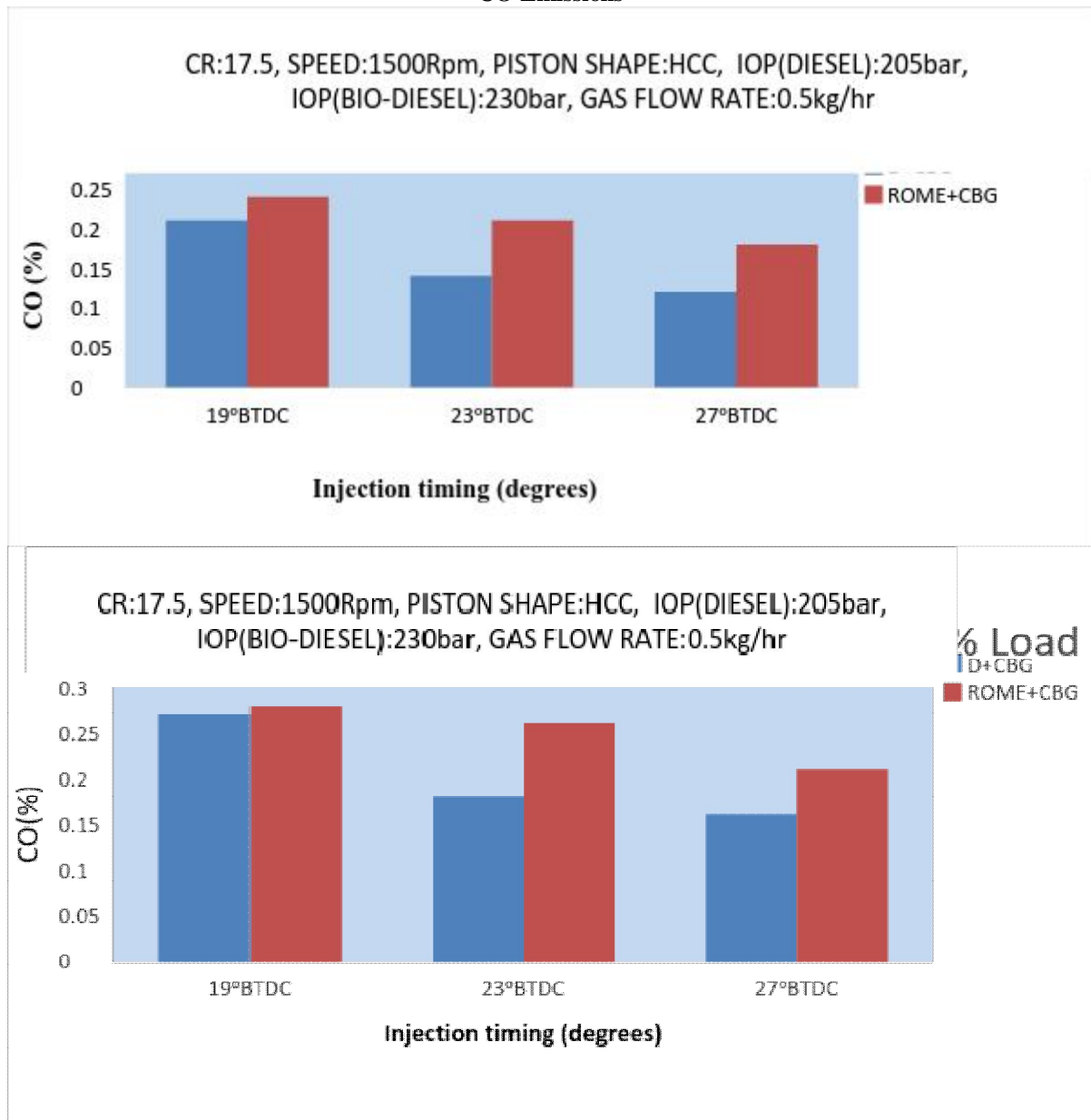


Fig 9 & 10: Variation of CO with injection timing at constant gas flow rate at 80% and 100% load respectively.

Figure 9 & 10 shows the variation of CO emissions with respect to injection timing for diesel-CBG and Rome-CBG dual fuel operation at 80 and 100% loading respectively. Main reason for CO emission is incomplete combustion of HC fuel and also it depends on the air-fuel ratio relative to stoichiometric proportions. As the injection timing advances from 19°bTDC to 27°bTDC the CO emission decreased considerably as seen in the figure. Because of overall better combustion and the activity of the partial oxidation reactions.CO emission levels for diesel-CBG and ROME-CBG dual-fuel operation at 19, 23 and 27°bTDC injection timing, at 80% load are found to be 0.21, 0.14 and 0.12% and 0.24,0.21 and 0.18% respectively.

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### NO<sub>x</sub> Emissions

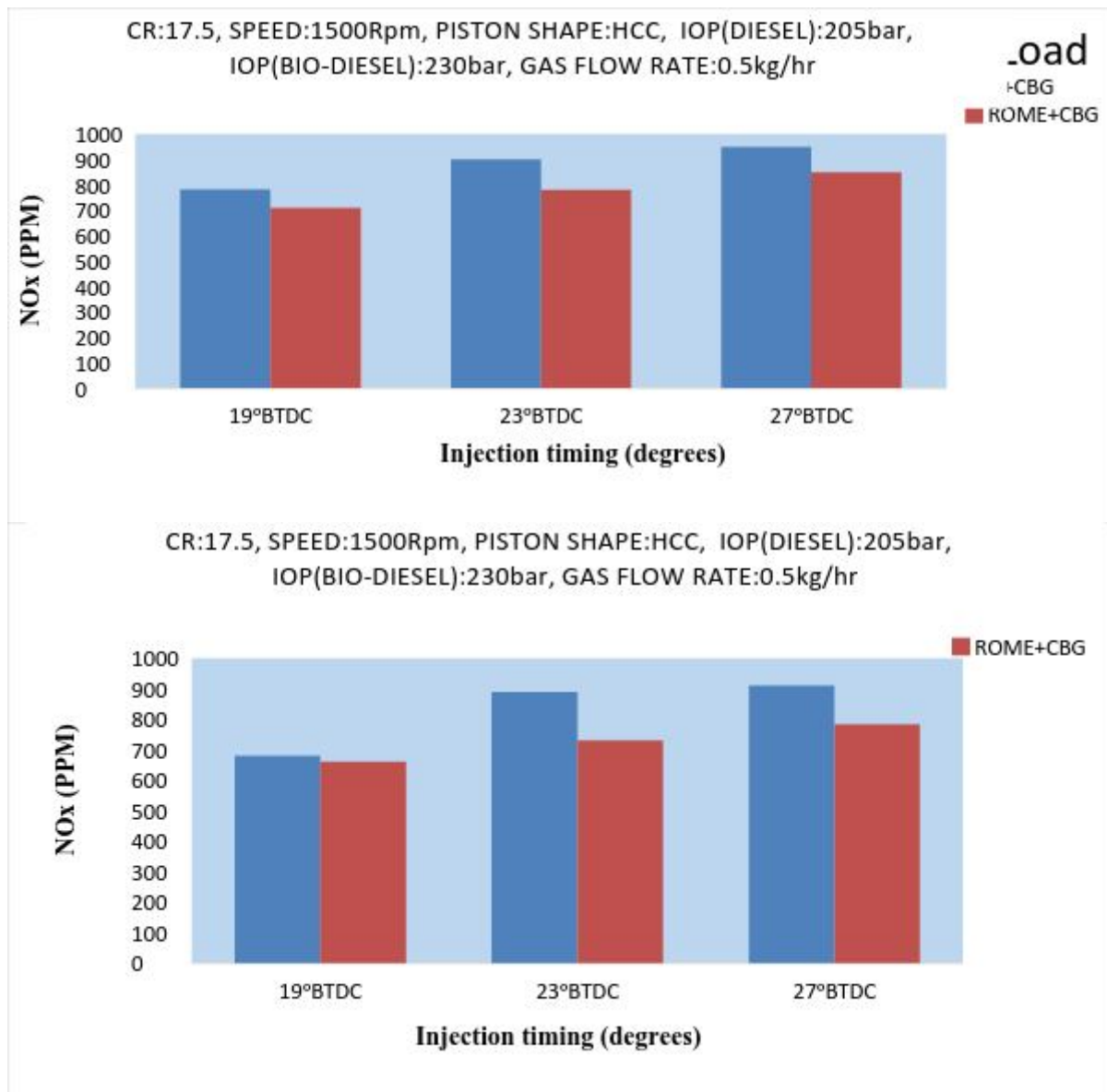


Fig 11 & 12: Variation of NO<sub>x</sub> with injection timing at constant gas flow rate at 80% and 100% load respectively.

Figure 11 & 12 shows variation of NO<sub>x</sub> emissions with injection timings for Diesel-CBG and ROME-CBG operated dual fuel combinations for 80% and 100% load respectively. The value of NO<sub>x</sub> is going to rise as the injection timing increases because of better combustion occurrence inside the engine cylinder which results in more heat release rate and leads to increase in combustion chamber temperature and this high temperature is the main reason for high NO<sub>x</sub> emissions. NO<sub>x</sub> emission levels for diesel-CBG and ROME-CBG dual-fuel operation at 19, 23 and 27°BTDC injection timing are found to be 680, 890 and 910 and 660, 730 and 784ppm respectively.



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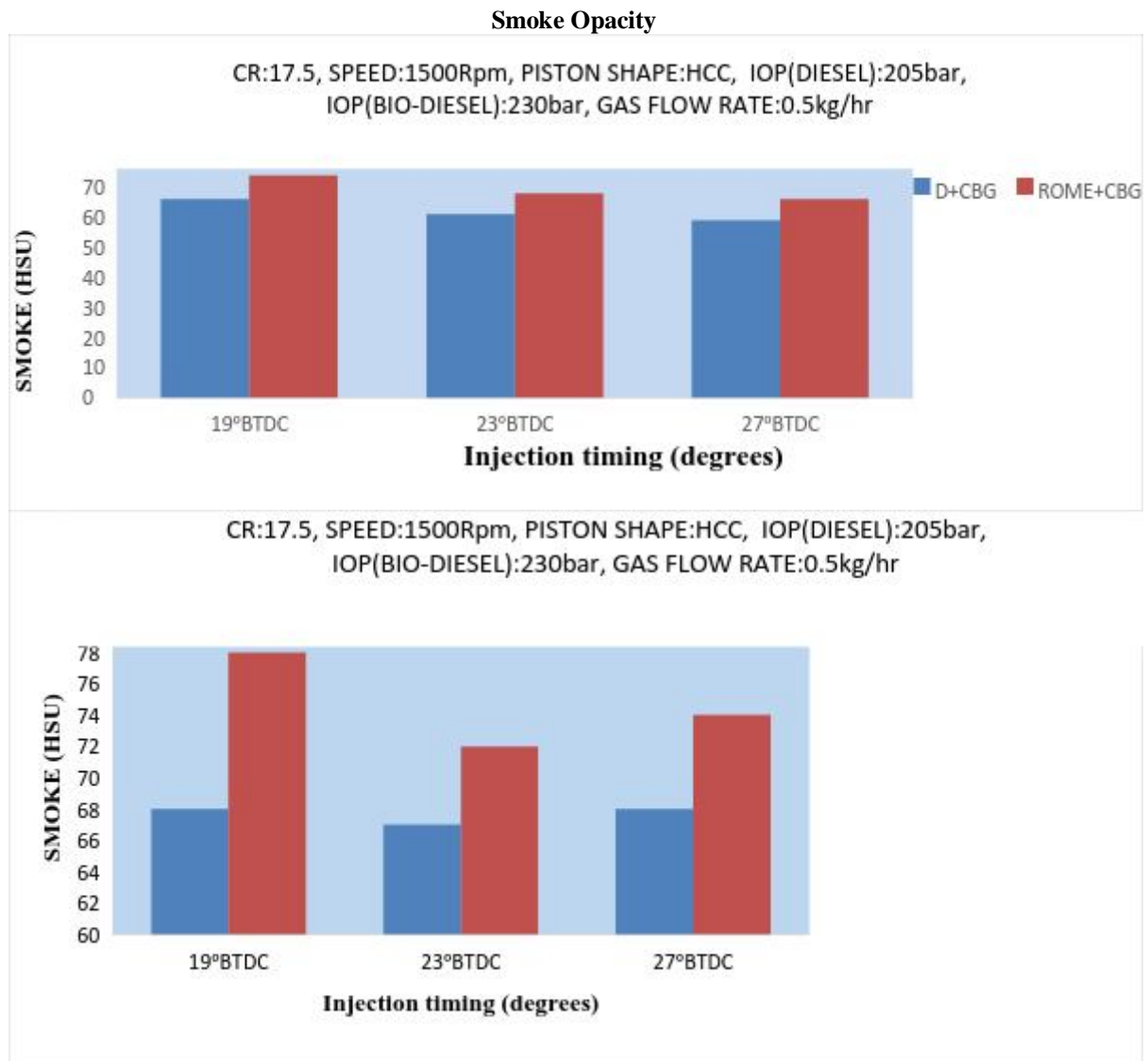


Fig 13 & 14: Variation of Smoke with injection timing at constant gas flow rate at 80% and 100% load respectively.

Figure 13 & 14 shows the variation of smoke opacity with injection timing for 80% and 100% load respectively. Experimental results show that the smoke opacity reduced when injection timing was increased due to better combustion taking place inside the engine cylinder. Smoke levels for diesel-CBG and ROME-CBG dual-fuel operation at 19, 23 and 27°bTDC injection timing are found to be 66, 61 and 64 and 74, 68 and 71 HSU respectively At 80% load.

#### IV. CONCLUSION

It is concluded from experimental results that the increase in injection timing from 19° bTDC to 27° bTDC, leads to better values of brake thermal efficiency, brake specific fuel consumption and emissions. At 80% load and 27° bTDC, BTE value was found to be 23.48 & 21.29%, BSFC found to be 0.1903 & 0.2082 kg/kW-hr for diesel – CBG and ROME- CBG combinations respectively. Among emissions it was found that percentage decrement in CO by 42.8, HC by 17.10, Smoke by 3.03 and percentage increase in the NO<sub>x</sub> by 33.82 at 80% load, 27° bTDC when diesel – CBG fuel were used.

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