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PERFORMANCE INVESTIGATION OF COMMON RAIL DIRECT INJECTION ENGINE POWERED WITH BIODIESEL OF USED TEMPLE OIL (BTO)

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Abstract

Any country's growth in terms of economic and social developments depends on energy. The sharp hike in price with emissions released by the petroleum fuels made the scientific community of the world to find alternate fuels to for diesel engine applications. Compression ignition (CI) engines are robust but produce high smoke and oxides of nitrogen (NOx) emissions. Therefore one has to use the alternative fuels as substitute to diesel. Accordingly used temple oil (UTO) and biodiesel of used temple oil (BTO) was a candidate of study to power CI engine. Conventional CI engines have a limited fuel injection pressure (IP) of 300 bar. To address this fuel injection issue, common rail direction injection (CRDI) operates at very high pressures of up to 2500 bar, creating fine fuel droplets that are ideal for highly viscous biodiesel. The performance of the CRDI CI engine running on BTO is covered in the current paper. The variables are the shapes of the combustion chamber (CC) and injection pressure (IP). According to the work, BTO performed better at an IP of 800 bar when using a torriodal re-entrant combustion chamber (TRCC) shape.

Keywords: Used temple oil (UTO),Biodiesel of used temple oil (BTO),Common rail direct injection(CRDI), Combustion chamber (CC), performance

I.Introduction

In addition to social progress, a nation's energy consumption index determines its economic development [1, 2]. Per capita income and energy consumption are used to gauge a nation's level of prosperity. The necessary quantity and at a reasonable price will not be available for petroleum products. As a result, it caused researchers to concentrate on investigating substitute fuels for CI engine applications. Strict regulations imposed by various regulatory bodies on engine emissions not only seriously impact human health but also contribute to global warming. Alternative fuels like compressed natural gas (CNG), biogas, hydrogen, and biodiesel are the answers to the energy crisis [3–7]. Better performance at higher IP was found in experimental trials using CI engines fueled with Honge biodiesel [8]. When compared to diesel, biodiesels from Jatropha, Karanja, and Polanga produced lower smoke and better brake specific fuel consumption (BSFC) [9]. Compared to diesel, biodiesel had a lower ignition delay (ID) [10]. Jatropha biodiesel was used to emulsify the wood pyrolysis oil (WPO), which causes combustion to occur a little later than it does with diesel. A CRDI engine powered with biodiesel yielded higher peak pressure (PP) and heat release rate (HRR) [12, 13]. Higher smoke, lower power, and NOx were reported when CI engines running on biodiesel made from sunflower, cotton seed, and soybean oil [14]. Low engine loads resulted in less smoke [15]. While methyl esters produced slightly more power than ethyl esters, both esters' exhaust emissions were the same [16]. Compared to diesel, soybean methyl ester revealed quicker combustion and decreased PP at the same injection of fuel quantity.[17]The biodiesel yielded lower NOx emission[18,19]. At higher IP levels, biodiesel increased NOx and decreased HC and CO while reducing smoke by 50% [20, 21]. Higher IP shortened ID, higher HRR and PP [22, 23]. Biodiesel combustion starts a little later than the combustion of diesel [24]. Because of the higher temperature, fuel and air mixing are enhanced at higher IP at higher loads [25]. Faster ignition and higher HRR were caused by a higher IP [26]. Droplets with a slightly smaller diameter were produced by the higher IP [27]. Due to oxygen molecular content, the CRDI engine produced lower smoke opacity [28].The study's goal is to demonstrate how BTO can be used to power CRDI diesel engines. In order to determine the optimal IP and CC shape for the best BTE, the performance, emission, and combustion characteristics of a CRDI engine powered by diesel and BTO were examined. Ultimately, the on-going experimental trials on the CRDI engine powered by BTO led to important conclusions.

II. Material and method

2.1 Properties of fuel

The fuel in the study is used temple oil (UTO) and its biodiesel called BTO. Transesterification process was used to produce BTO.T able 1 shows the properties of fuels.

Table 1: Properties of Diesel, UTO and BTO

Property	**Unit**	**ASTM D6751**	**Diesel**	**UTO**	**BTO**
Kinematic viscosity at 40^0C	mm^2/s	1.9-6.0	2.58	26.6	5.1
Density, at 15^0C	kg/m^3	870-890	831	910	870
Flash Point	^{0}C	130 (min)	50	202	164
Calorific value	KJ/kg	37,500	42,500	38,682	39,080

2.2 Experimental plan

The engine speed was kept constant 1500 R.P.M. and load varied during experimental work. Readings were always recorded at stable engine operation. The experimental tests were conducted with diesel and BTO by varying fuel Injection Pressure from 600 bar to 1000 bar in steps of 200 bar. Experimental set up is shown in Fig.1. The experimental setup consists of a Kirloskar TV1, 1- cylinder, 4-stroke diesel engine of 3.75kW @ 1500 R.P.M. and C.R. of 17.5:1.

Fig. 1: Experimental setup of Diesel engine test rig

III. Results and discussions

This section highlights on performance of Common Rail Direct Injection engine with different Injection Pressure and Combustion Chamber shapes in section 3.1 and 3.2 respectively. Experiments trials were repeated three times and averaged out values were used to draw graphs.

3.1 CRDI engine performance with IP

The purpose of the tests was to assess the CRDI engine's performance using IP. The speed was maintained at 1500 rpm and the IP was the variable parameter. Fuel IT was kept at -10^0BTDC.

Brake thermal efficiency

The impact of IP on the BTE of a CI engine converted to run in a CRDI with BTO is depicted in Figure 2. Because of the effective fuel and air mixture formation at higher IP, BTE increased [29]. Increased IP caused the BTO spray to vaporize quickly, increasing the rate of combustion. The resultant highest BTE was 800 bar IP. Engine performance was marginally lower than diesel. This could be because BTO has less volatility and a higher viscosity.

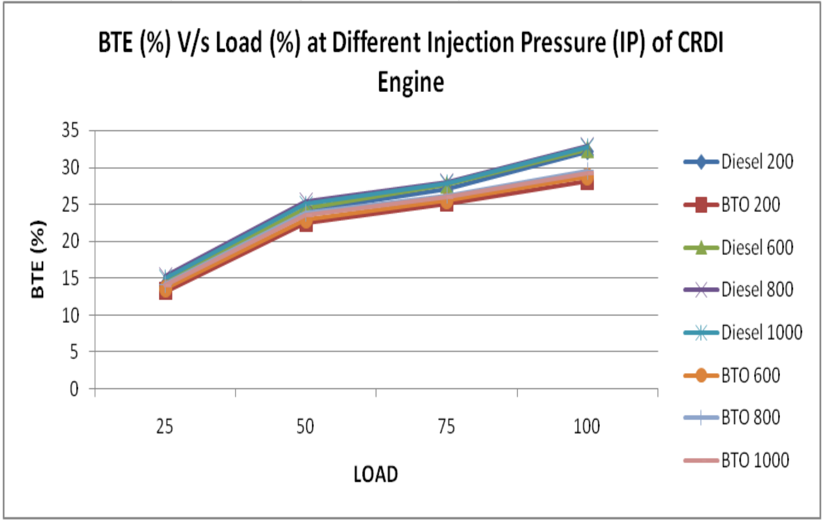

Fig. 2: Effect of IP on BTE

Brake specific fuel consumption

The impact of IP on the BSFC of CRDI with BTO is shown in Figure 3. Because of improved combustion and higher BTE, BSFC was lower at a higher IP [29]. Increased IP caused the BTO spray to vaporize quickly, increasing the rate of combustion. Lower BSFC was attained at 800 bar IP, where the highest BTE was attained. With BTO, the CRDI engine produced better BSFC, but slightly less than diesel. This could be because BTO has a higher viscosity.

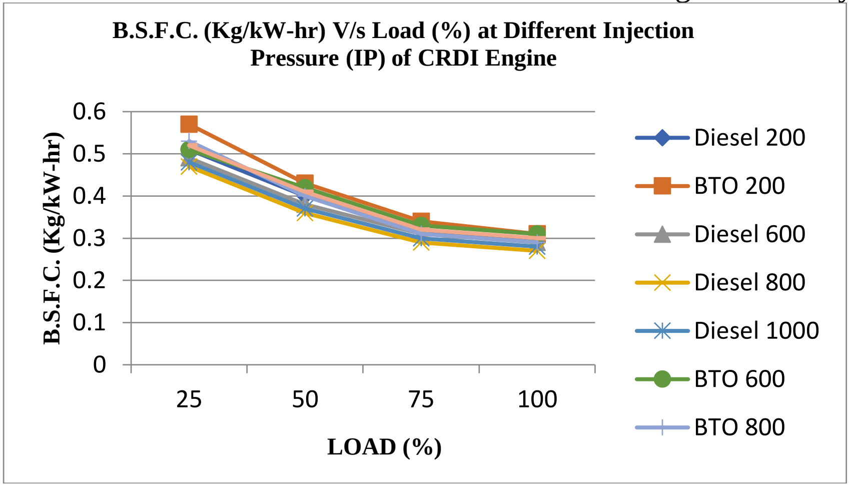

Fig. 3: Effect of I.P.on B.S.F.C.

HC and CO emissions

The impact of IP on HC and CO is shown in Figures 4 and 5. Because a better air-fuel mixture was formed in the CC, there may have been better fuel burning at higher IP, resulting in lower HC and CO levels. Because of the reported lower BTE trends, BTO with similar ignition qualities and higher oxygen content produced slightly higher emissions than diesel. When compared to other IPs, the 800 IP performed better. It could be because there is less ignition delay (ID), which causes more fuel to burn during the diffusion phase.

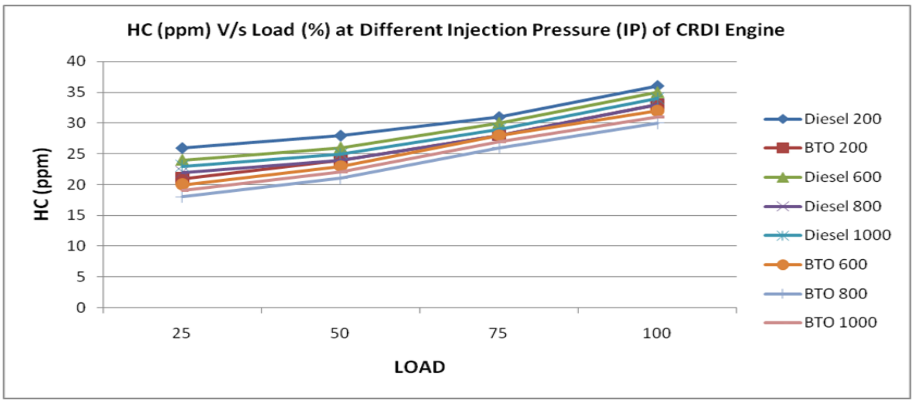

Fig. 4: Effect of IP on HC

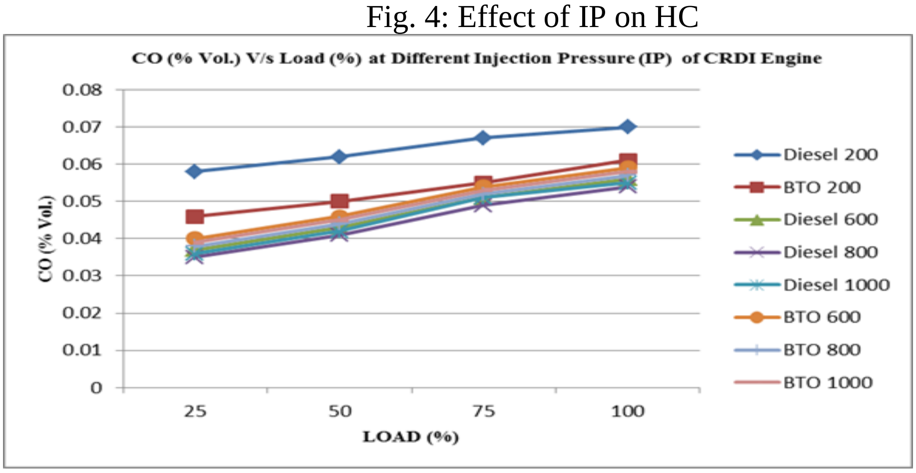

Fig. 5: Effect of IP on CO emission

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NO_x emissions

As shown in Fig. 6, an increasing trend in NOx emissions was noted with an increase in IP due to the gas's quick burning and higher temperature. Because of the delayed combustion and resulting lower gas temperature, NOx formation in the CRDI mode of engine operation is slightly lower than in the CI mode. In addition to decreasing droplet size at higher IP, it also increased fuel droplet velocity [30], which reduced ignition delay and lengthened the gas's residence time, increasing NOx [31]. Because there was less premixed combustion in BTO, it produced fewer NOx emissions than diesel. Because of its higher viscosity and lower calorific value, BTO caused a lower flame temperature, which in turn reduced BTE and NOx.

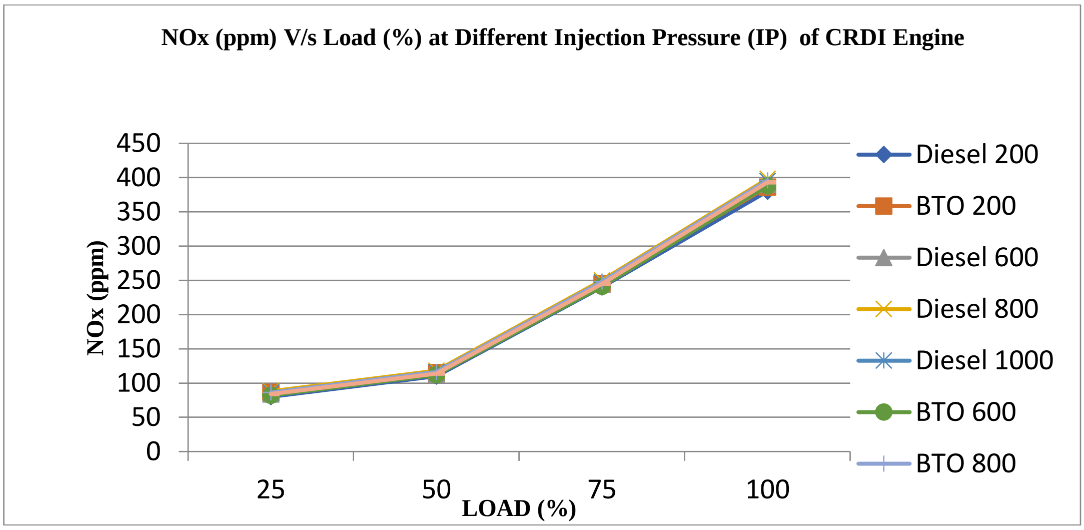

Fig. 6: Effect IP on NO_x Emission

Smoke emissions:

Figure 7 depicts how IP affects smoke. The reason for the lower smoke yield at higher IP could be attributed to smaller droplets that improved fuel-air mixing, ultimately resulting in full combustion [32]. In comparison to diesel, the heavier molecular weight of BTO's, increased viscosity caused larger fuel droplets, which in turn produced more smoke at the same IP. Smoke at 800 bar IP was at a minimum.

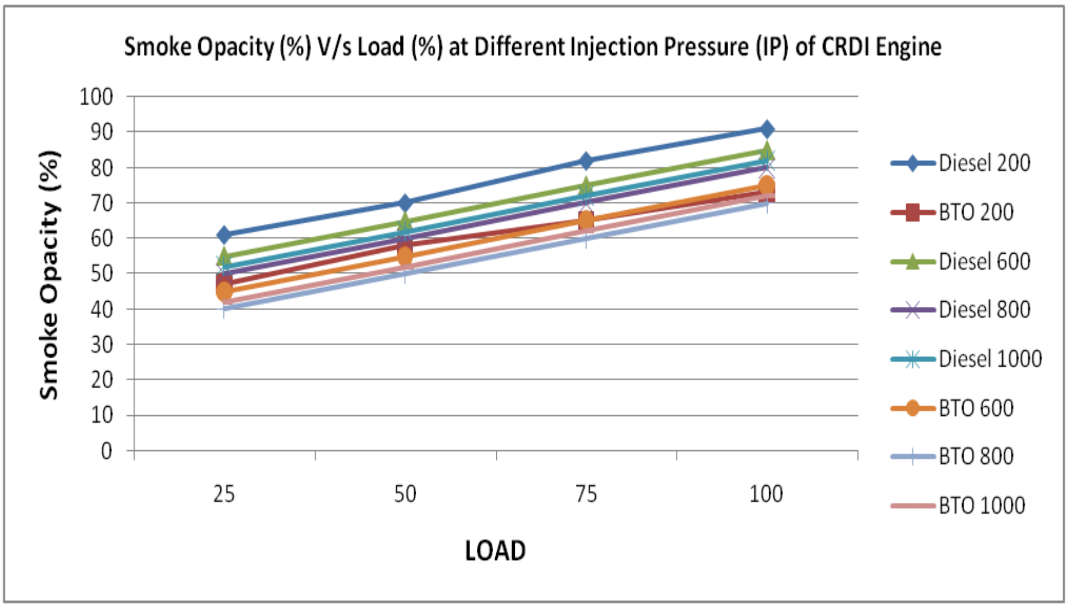

Fig. 7**:** Effect of I.P. on Smoke

3.2 CRDI engine performance with different CC shapes

Brake thermal efficiency

Figure 8 illustrates how the CC shapes affect the CRDI engine's BTE with BTO. Higher BTE was the outcome of combustion that happened close to TDC because the fuel and air mixed more effectively [33]. Fuels used at 800 bar IP had higher BTE when using TRCC; this could be because the swirl generated improved the fuel's mixing and combustion. However, due to its higher viscosity, BTO performed poorly when compared to diesel.

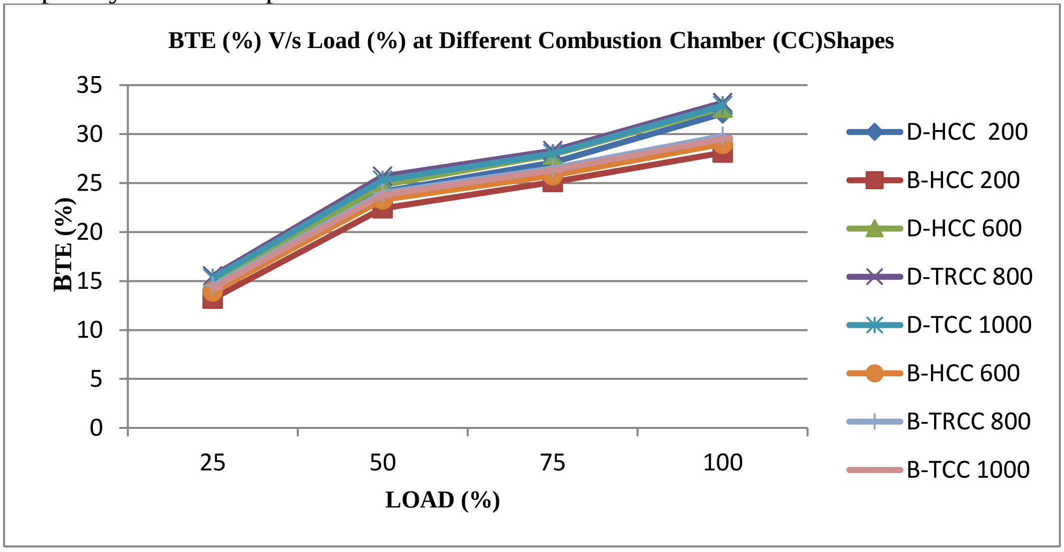

Fig. 8**:** Effect of CC shape on BTE

Brake specific fuel consumption

Fig. 9 shows the impact of CC shapes on the BSFC of the CRDI engine with BTO. Lower BSFC was the outcome of homogenous fuel and air mixing at higher loads, which led to higher BTE. The CRDI engine's BSFC at 800 bar IP was lower with TRCC than with other CC shapes because of improved combustion and enhanced mixing. As expected, BSFC with BTO was marginally higher than engine run on diesel. The cause could be slightly larger droplets because of the increased viscosity.

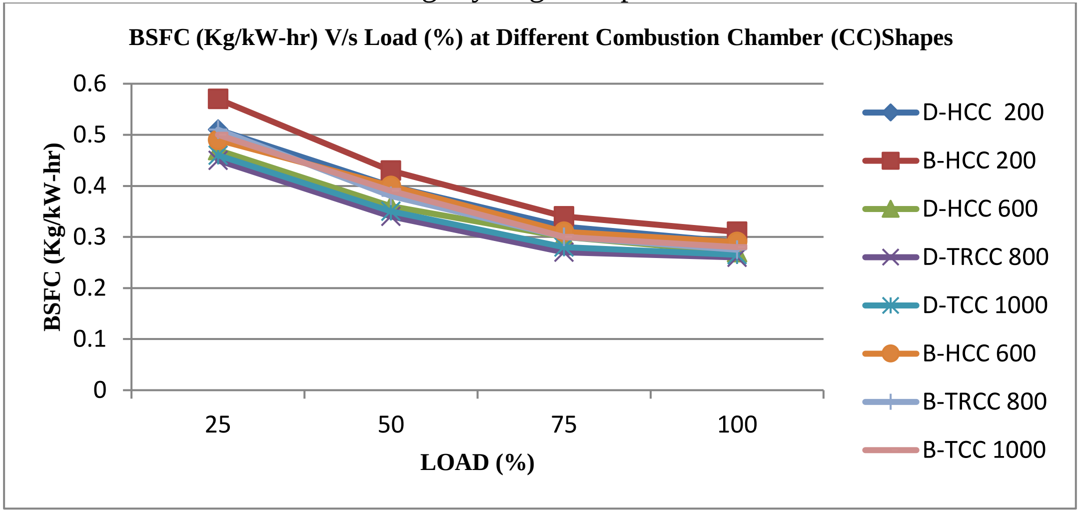

Fig. 9: Effect of CC shape on BSFC

HC and CO emission

The impact of IP on the HC and CO emissions of the CRDI engine with various CC shapes is depicted in Figures 10 and 11, respectively. The engine produced reduced levels of CO and HC with TRCC due to nearly full fuel combustion. In addition to having a higher oxygen content than diesel, BTO had comparable ignition qualities but slightly higher emissions due to reported lower BTE trends. When compared to other IPs, the 800 IP performed better. It might be because of a smaller ignition delay (ID), which causes more fuel to burn during the diffusion phase.

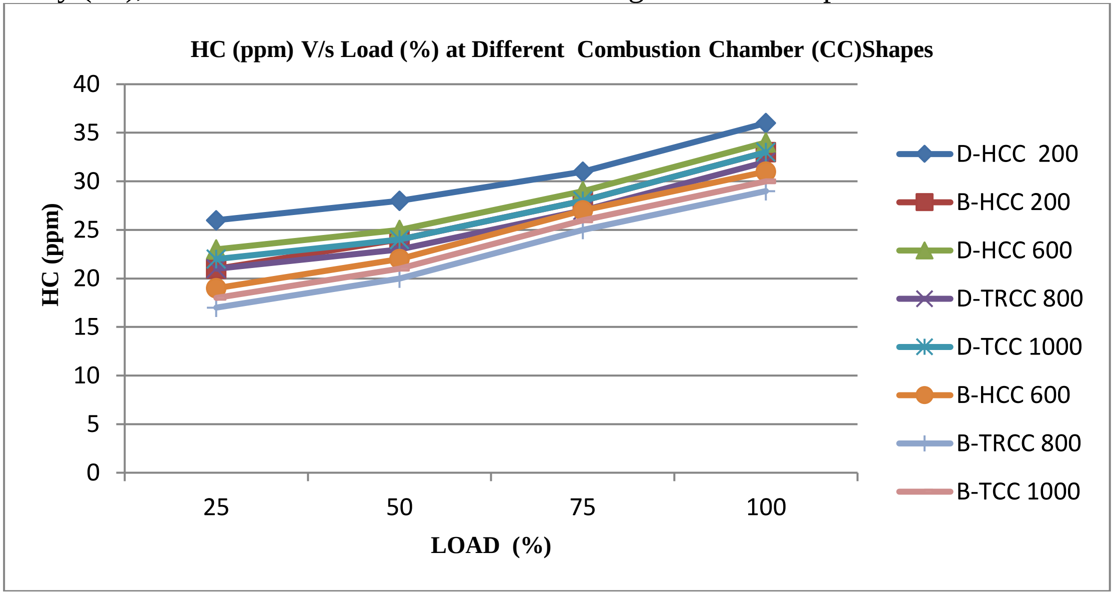

Fig. 10: Effect of CC shape in HC emissions

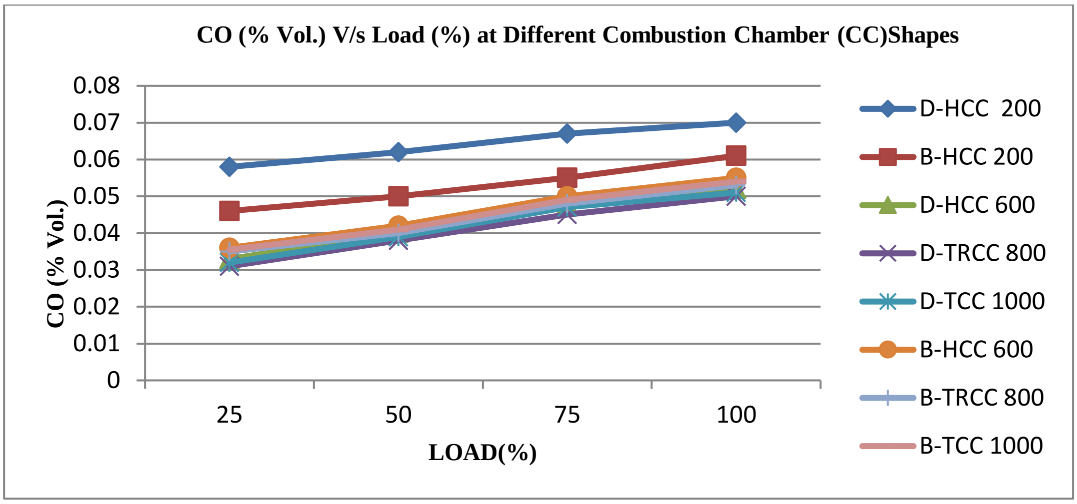

Fig. 11: Effect of CC shape on CO emissions

NO$_x$ emission

Fig. 12 shows the impact of the CC shape on NOx in the CRDI system operating with diesel and BTO. Because they provide a lower temperature than diesel, BTO operations produce less NOx. Additional factors that led to reduced NOx emissions could include late burning and a decrease in ignition delay.

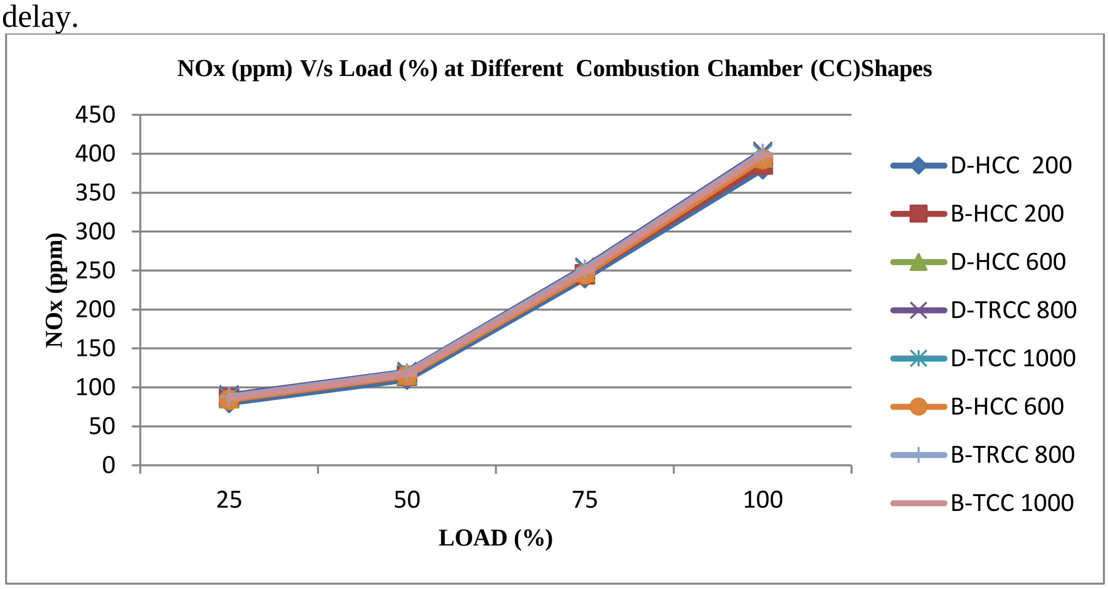

Fig. 12: Effect of CC shape on NOx emission

Smoke opacity

Fig. 13 shows how the CC shape affects the CRDI engine's smoke at different loads. As HC fuel molecules transform into soot particles, smoke is produced. Because of better combustion brought about by smaller droplets formed at higher IP and a homogenous mixture formed, the BTO run CRDI engine produces less smoke. Under all operating conditions, the BTO's smoke output was marginally higher than that of diesel; this could be because the BTO contains free fatty acids (FFA). Higher IP in the TRCC shape resulted in faster combustion, a higher HRR, and a higher peak pressure. At all loads, the BTO's smoke little more than the diesel.

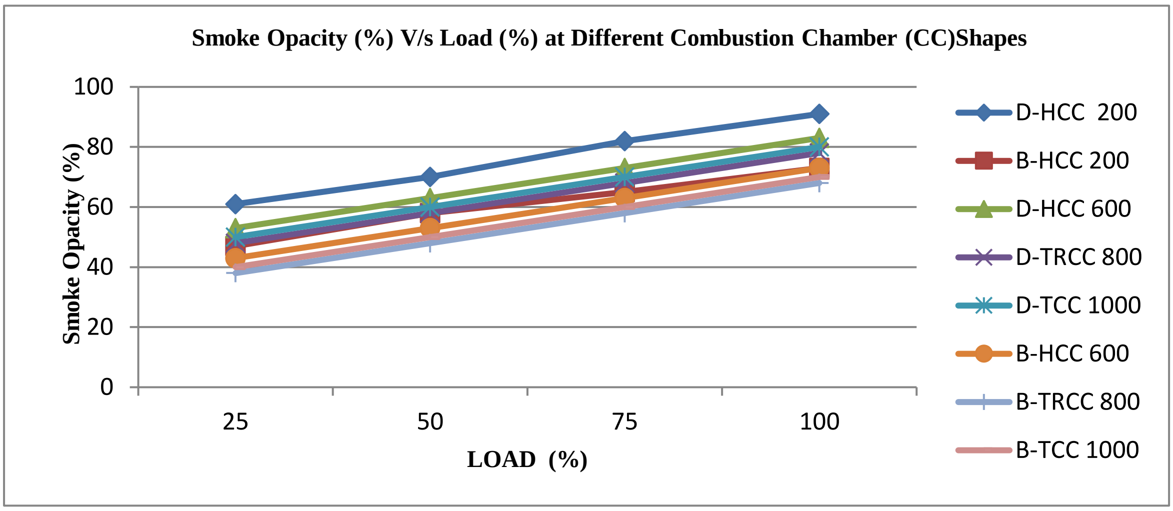

Fig. 13: Effect CC shape on Smoke emission

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Combustion Characteristics

ID, CD, PP and HRR Figures 14 to 17 display the variation of ID, CD, PP, and HRR with various CC shapes. It was found that ID decreased with load while CD, PP, and HRR increased. This might be the result of the air-fuel mixture burning quickly, producing more HRR and PP. Lower ID and CD, higher PP, and HRR were reported for TRCC. Better combustion and a homogenous mixture are the causes of this. When compared to diesel fuel, BTO performed comparably poorly for all CC shapes.

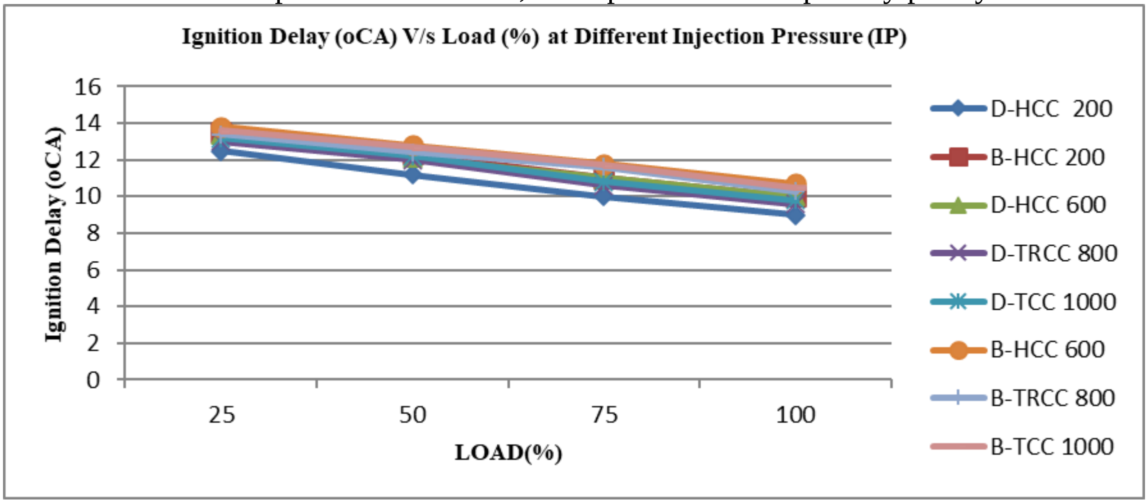

Fig. 13: Effect CC shape on Ignition Delay

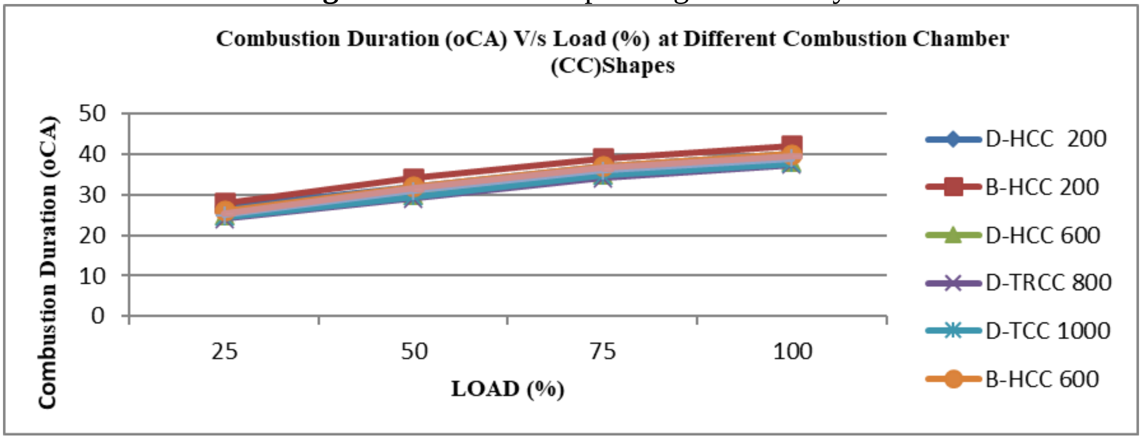

Fig. 14: Effect CC shape on Combustion Duration

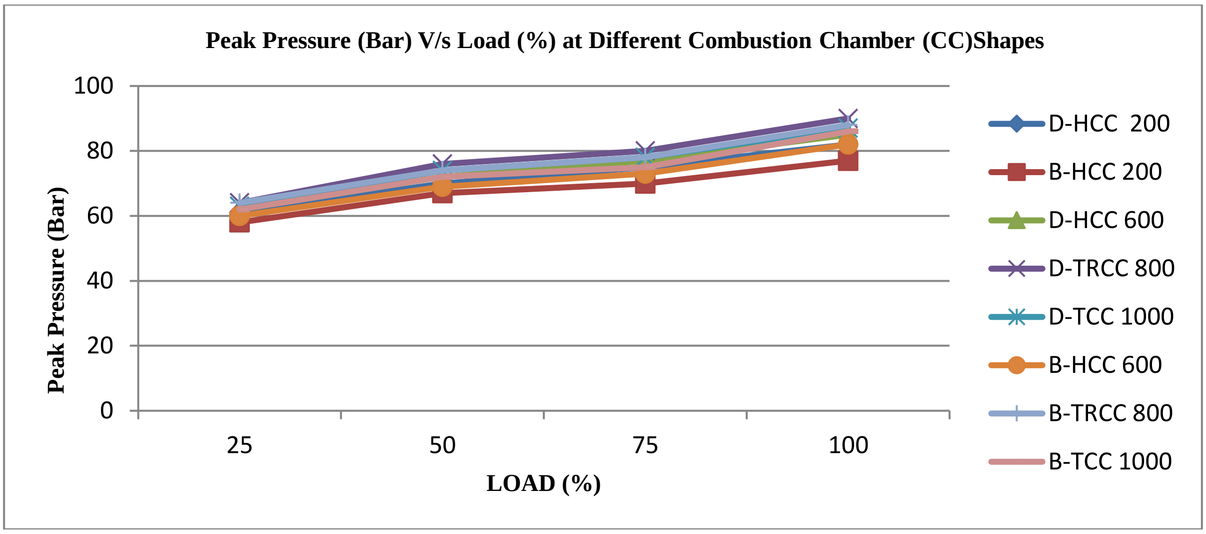

Fig. 15: Effect CC shape on Peak Pressure

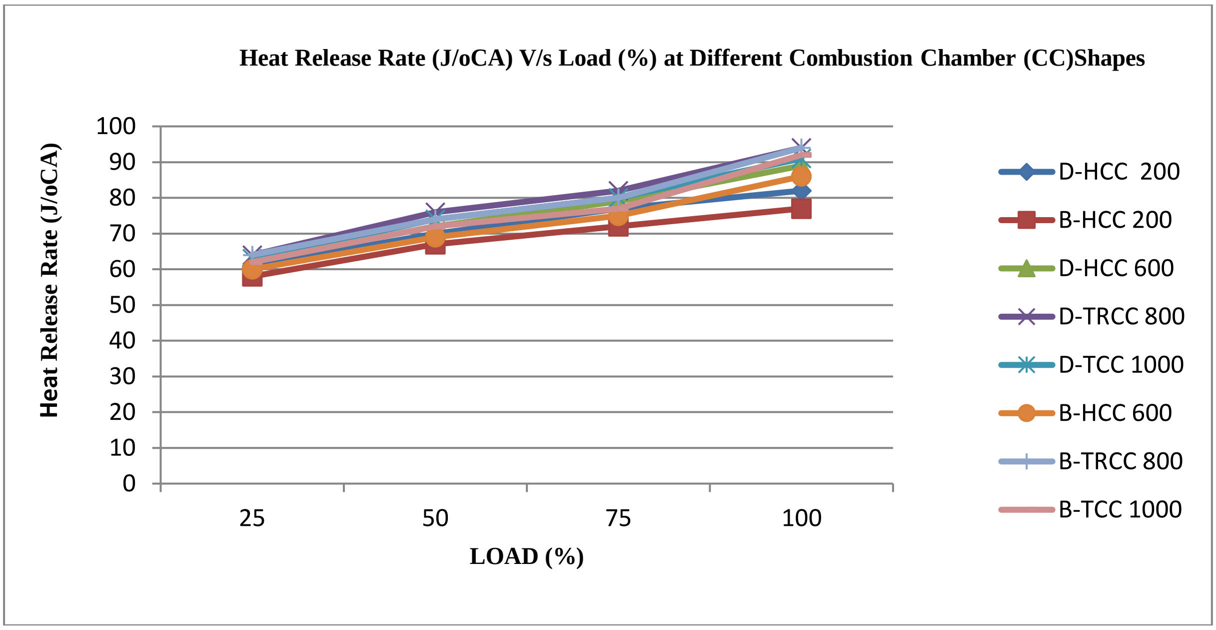

Fig. 16: Effect CC shape on Heat Release Rate

IV.Conclusions:

For the current study, the CI was modified to operate in CRDI mode. This arrangement was used for the experiment trials, where different loads were applied to the IP and CC shapes. The research led to the following conclusions being drawn:

- When the CRDI engine was operated by BTO, the BTE increased with load and peaked at 800 bar IP. BTO performed poorly in comparison to diesel because of its inadequate ignition characteristics. At 800 bar fuel IP, the BSFC was lower.
- Compared to BTO, there were fewer emissions of HC and CO because of the higher oxygen content and lower combustion quality.
- On the other hand, NOx emissions rose with IP, reaching a maximum at 800 bar. Due to its superior burning over diesel, BTO produced less smoke. When compared to other CCs used, the TRCC shape performed better.

- All things considered, the modified CRDI single cylinder engine running on BTO performed admirably, reaching its peak performance at 800 bar IP and TRCC shape.

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