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Influence of injection timing on combustion and heat release parameters using biodiesel of Neem, Rice bran and Pongamia in a direct injection compression ignition engine

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Abstract: *In the present study, the effect of injection timing on combustion and heat release characteristics were analyzed in a single cylinder direct injection compression ignition engine using Neem, Rice bran and Pongamia biodiesels. The biodiesel of Neem, Rice bran and Pongamia was prepared by transesterification process using 2.5 gms of Sodium hydroxide and 400 ml of methanol between 70°C and 100°C. All the three biodiesel were blended in 5%, 10% and 15% ratios. The results showed that at 6 CAD advancement of injection timing, the maximum rise in combustion pressure was 2% to 4% and the rate of heat release was also improved with higher blends of Pongamia biodiesel. Blends of Neem and Rice bran also showed positive improvement but lower that Pongamia.*

I. INTRODUCTION

Biodiesel form vegetable oil has been a promising alternative for petro-diesel for the near future. A wide research studies has been reported on the use of vegetable oil as straight fuel and transesterified esters blends on compression ignition engine and found to be suitable with minor or no modification in the existing engine setup. Admittance of straight vegetable oil in compression ignition engine causes several problems like carbon deposition in cylinder walls and valve seating, higher viscosity, poor atomization and ultimately leads to incomplete combustion. To overcome these disadvantages, transesterification process can be carried out on neat vegetable oil to replace the triglycerides with mono esters of alcohol and vegetable oil to form biodiesel which reduces the viscosity and favors its admittance in the compression ignition engine. Biodiesel derived from vegetable oil is one of the successful and best resources available to meet the energy demand of the country. It is also gaining more and more importance as second generation biofuels like Soyabean, Neem, Rice bran and third generation biodiesels like Algal biodiesel, Bio-ethanol and many more [1,2].

An intense comparative study was reported with Jatropha, Karanja and Polanga biodiesel to analyze its combustion characteristic in compression ignition engine [16]. The biodiesels were blended with diesel in 20% and 50% ratios by weight and used in compression ignition engine and found that neat Polanga biodiesel showed maximum in-cylinder pressure. They also noticed that the ignition delay for Jatropha biodiesel was periodically shortened with increasing load and the same trend was seen in Karanja and Polanga biodiesel. Another study has been conducted by analyzing the effect of EGR and injection timing on combustion and emission characteristics using neat Soyabean biodiesel in direct injection compression ignition engine [10]. The results revealed that higher EGR rate showed increased BSFC and soot formation with reduced NO_x. Biodiesel from Hazel nut kernel oil was derived through transesterification process and experiments were conducted to study the combustion and heat release rate of a direct injection compression ignition engine [12]. He suggested that the combustion characteristics were almost similar to diesel and minor modifications in input parameters like injection timing, injection pressure and compression ratio proved significant improvement in combustion. More and more research studies have been reported in the literature in relation with combustion characteristics and rate of heat release of biodiesel blends. The researchers have analyzed by varying the test parameters like engine load, engine speed, injection timing, injection pressure, compression ratio and generally noticed that with an increase in biodiesel blends, combustion peak pressure has been reduced with reduction in ignition delay. The HRR and rate of pressure rise also showed negative improvement with increase in biodiesel blends [14].

In the present study, biodiesels were derived from Neem, Rice bran and Pongamia oil by transesterification process using alcohol and Sodium hydroxide. Blending ratio of 5%, 10% and 15% was made with all biodiesel and the combustion & heat release analysis was conducted. The test was intensified by varying the injection timing (i.e Advancement and Retardment) by 6 CAD across all blends of fuel and results showed that Pongamia biodiesel with higher blend ratio was more suitable when compared with Neem and Rice bran at advanced injection timing. The main aim of this study was to analyze a suitable biodiesel with favorable blend ratio with variable injection timing.

II. MATERIALS AND METHODS

Biodiesel were derived from Neem, Rice bran and Pongamia oil through transesterification process in which primary alcohol replaces the triglyceride into glycerol and three esters of vegetable oil. The vegetable oils were collected in separate conical flask and maintained at 60°C, 70°C and 85°C. 2.5 gms of Sodium hydroxide and 400 ml methanol was mixed thoroughly to form Sodium methoxide solution and mixed with Neem, Rice bran and Pongamia oil in separate conical flask. The mixtures were maintained at 70°C, 80°C and 100°C respectively to initiate transesterification reaction in a rotating agitator for 8 hrs and transferred into a inverted separator. Settling period of 24 hrs was allowed and glycerol formation was removed. The biodiesel thus obtained was washed with 5% distilled water to remove the impurities [4-7]. By this extraction method 92% of biodiesel was obtained. The properties of Neem, Rice bran and Pongamia biodiesel are given in table (1) and the various fatty acids present in Neem, Rice bran and Pongamia biodiesel are listed in table (2) which was identified using GC/MS JOEL Mate II..

Table 1. Properties of Neem, Rice bran and Pongamia blends

S.No	Properties	Density (g cm^{-3})	Flash Point	Kinematic Viscosity	Cetane No	Heat of combustion
1	Diesel	0.834	60-80	1.91-4.1	45	42000
2	Neem 5% Blend	0.8079	68	2.10	56	41580
3	Neem 10% Blend	0.8124	71	2.14	54	40950
4	Neem 15% Blend	0.8278	73	2.20	51	39950
5	Rice bran 5% blend	0.8127	68	2.20	56	41640
6	Rice bran 10 % blend	0.8195	70	2.14	55	40530
7	Rice bran 15% blend	0.8249	73	2.21	52	39500
8	Pongamia 5% Blend	0.8043	69	2.00	54	41540
9	Pongamia 10% Blend	0.8144	71	2.02	56	40370
10	Pongamia 15% Blend	0.8279	73	2.15	57	39270

Table 2. Fatty acids in Neem, Rice bran and Pongamia biodiesel

S.No	Name of the	Palmitic acid	Palmitoleic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Arachidic acid
1	Neem	18.2	-	18.8	44.9	18.1	0.3	0.9
2	Rice bran	17.9	0.25	2.4	40.9	1.9	36.2	-
3	Pongamia	11.62	-	7.59	52.68	16.84	-	-

III. EXPERIMENTAL SETUP

Kirloskar DM10 single cylinder naturally aspirated direct injection compression ignition engine was used in this study with the following specifications as given in table (3) and the schematic diagram is shown in fig (1).

Table 3. Specification of the test engine

Model & Make	Kirloskar DM10
Bore & Stroke	102 x 118 mm
Capacity	984 CC
Maximum power	10 BHP
Compression ratio	17.5 : 1
Injection timing	26°bTDC
Injection pressure	190-200 bars
Rated speed	1500 rpm

Nine different blends of Neem, Rice bran and Pongamia biodiesel with diesel as a base were tested in the test engine which was coupled with DC electrical dynamometer. The load was varied between 0% load and 80% load broadly classified as part load and full load conditions. Time taken for 10cc fuel consumption was noted to calculate the specific fuel consumption. The mass flow rate of air was measured using an orifice coupled to a manometer. Kistler 701A type of transducer was employed to analyze the pressure variations in the cylinder during combustion which was amplified using a multipurpose charge amplifier into the data acquisition system.

20 mins of Warm-up time was given before testing the all the blend of fuel. Variation of injection was achieved by Spill method in which the number of teethes in the timing gear was used to advance and retard.

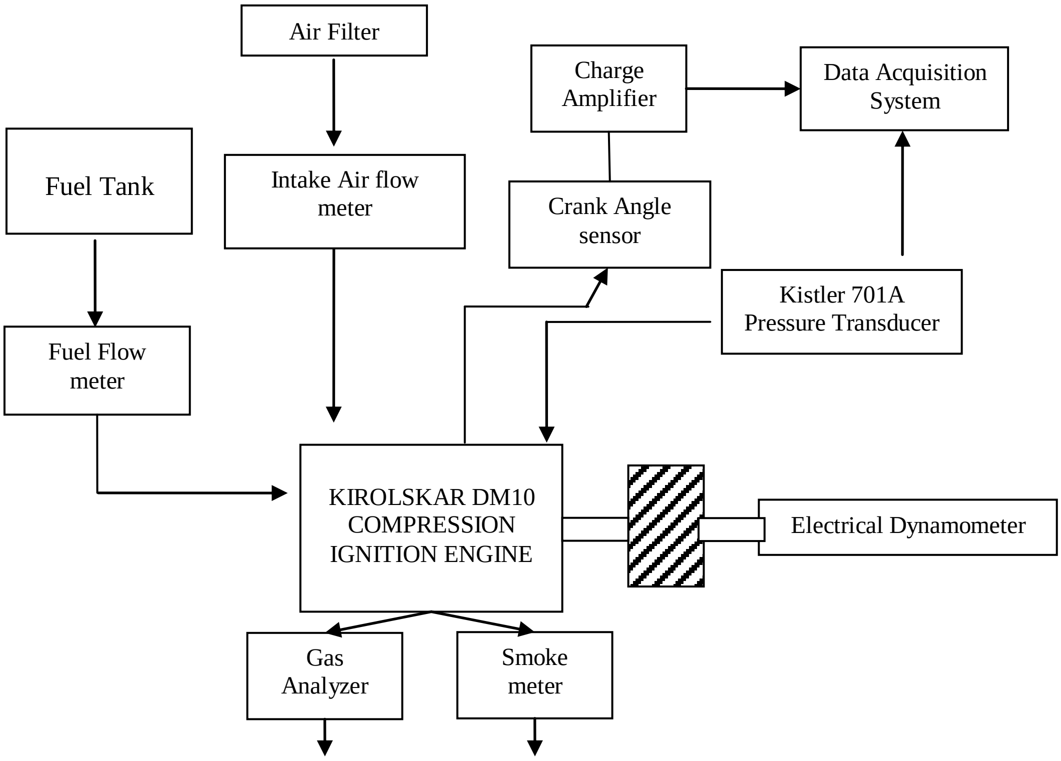

Figure 1. Schematic diagram of experimental setup

IV. RESULT AND DISCUSSION

4.1Effect of In-Cylinder combustion pressure

Fig (2) to Fig (7) shows the comparison of In-Cylinder pressure at advanced, standard and retarded injection timing for the blends of Neem, Rice bran and Pongamia biodiesel at part load and full load condition.

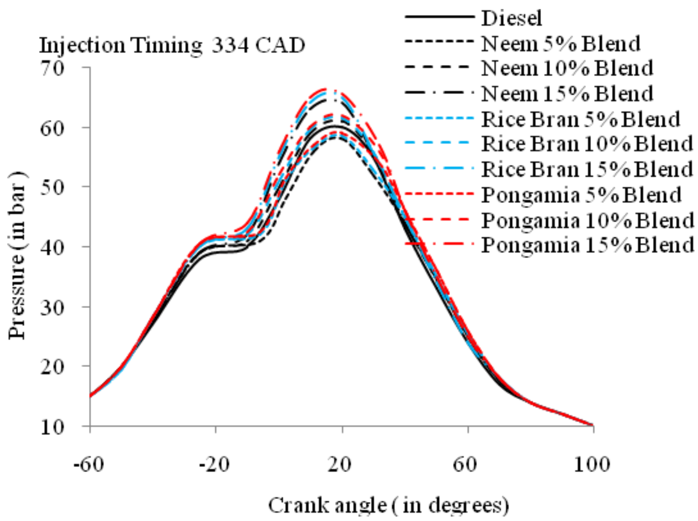

Fig 2. Comparison of cylinder pressure at part load condition for blends of Neem, Rice bran and Pongamia with standards injection timing

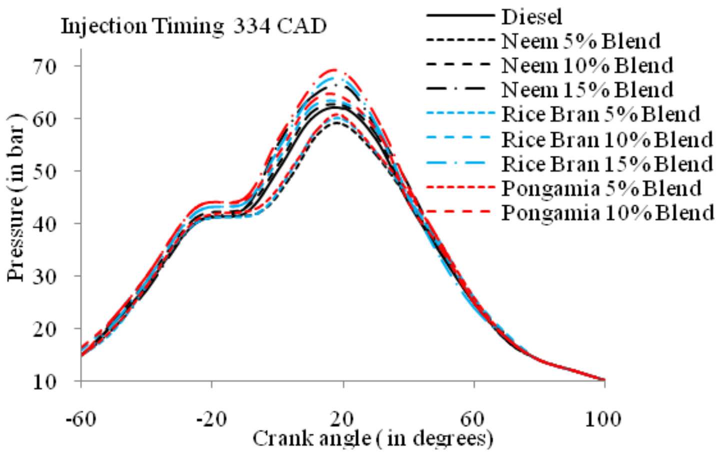

Fig 3. Comparison of cylinder pressure at full load condition for blends of Neem, Rice bran and Pongamia with standards injection timing

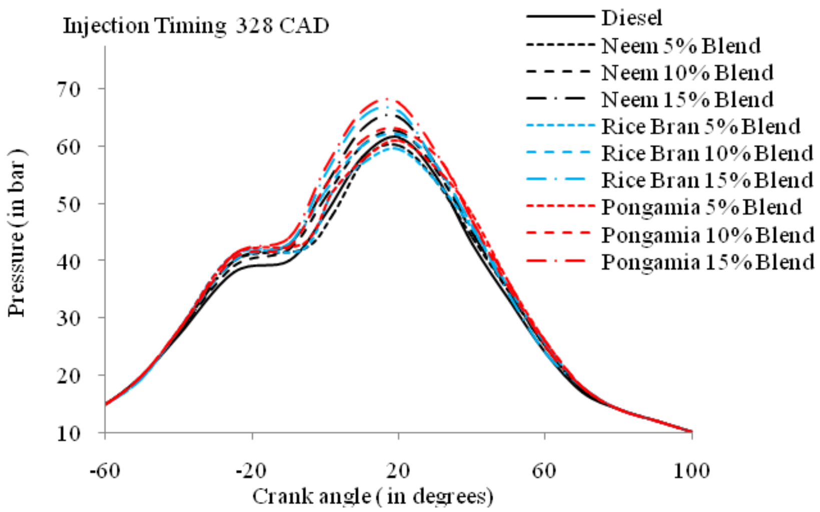

Fig 4. Comparison of cylinder pressure at Part load condition for blends of Neem, Rice bran and Pongamia with Advanced injection timing

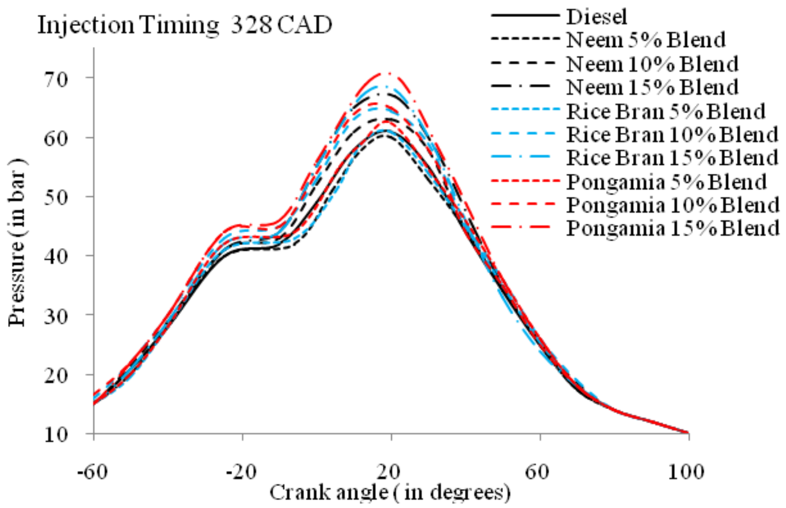

Fig 5. Comparison of cylinder pressure at Full load condition for blends of Neem, Rice bran and Pongamia with Advanced injection timing

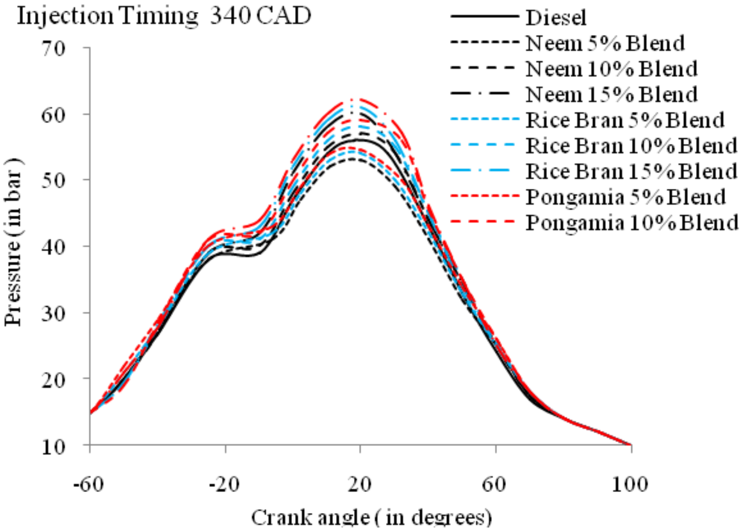

Fig 6. Comparison of cylinder pressure at Part load condition for blends of Neem, Rice bran and Pongamia with Retarded injection timing

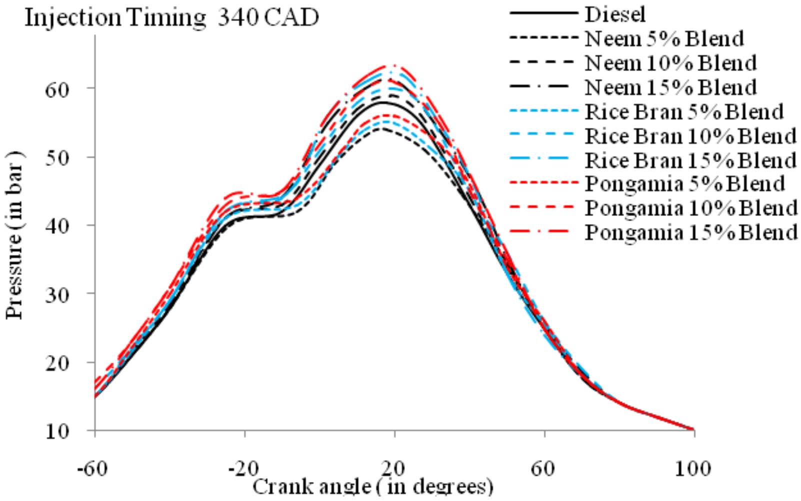

Fig 7. Comparison of cylinder pressure at Full load condition for blends of Neem, Rice bran and Pongamia with Retarded injection timing

It is clear from fig (2) and fig (3) that peak pressure for Neem 5%, 10% and 15%, Rice bran 5%, 10% and 15%, Pongamia 5%, 10% and 15% biodiesel blends at standard injection timing (334 CAD) shows 59 bar, 62.5 bar, 66 bar, 60 bar, 63 bar, 67 bar, 61 bar, 64 bar and 68 bar pressure respectively with standard injection timing at part load condition while advancing the injection timing by 6 CAD (fig.2) represents 3% to 4% increase in in-cylinder pressure (i.e) 60 bar, 63 bar and 67 bar for Neem, 61 bar, 64 bar and 68 bar for Rice bran and 62.5 bar, 65 bar and 70 bar for Pongamia blends respectively at full load condition. This may be due to greater premixed combustion phase resulted because of longer ignition delay [3,8]. Since the increase in calorific value of the fuel, Pongamia blends show 2% to 3% higher combustion pressure when compared with Neem and Rice bran. Pongamia 15% blend showed 70 bar and 67.5 bar in-cylinder pressure at full and part load respectively. All the blends of biodiesel shows the peak combustion pressure 10 to 15 CAD after TDC which clearly indicates that the engine is safe from detonation and thereby the life of the engine is considerably increased with all the above biodiesels [17,18]. Fig (4) and fig (5) represents variation in in-cylinder pressure with advanced injection timing for Neem, Rice bran and Pongamia biodiesel at part and full load which shows 3% to 4% increase in cylinder pressure may be due to prolonged injection delay so that the duration for complete combustion is achieved and peak cylinder pressure is increased considerably. It is also seen that at no load and low load condition, the in-cylinder pressure for diesel and blends of Neem, Rice bran and Pongamia were almost similar at standard and advanced injection timing but retarded injection timing showed 2% to 3% reduction in combustion pressure. The in-cylinder pressure for Neem, Rice bran and Pongamia at part and full load with retarded injection timing is shown in fig (6) and fig (7) represents 4% to 6% negative improvement in peak pressure which may be due to shortened ignition delay and lower premixed combustion period. It also reduces the burning rate during initial phase of combustion due to shorter ignition delay. It can be concluded that Pongamia 15% blend shows 4% to 5% positive improvement in in-cylinder pressure at part load and full load condition with advancement of injection timing by 6 CAD.

4.2 Effect of Rate of heat release

The comparative effect of rate of heat release at full load condition for Neem, Rice bran and Pongamia biodiesel with standard, advanced and retarded injection timing is shown in fig (8), fig (9) and fig (10). Theoretically, rate of heat release was calculated using the equation (1)

$$\frac{dQ_{ch}}{dt} = \frac{\gamma}{\gamma-1} P \frac{dV}{dt} + \frac{1}{\gamma-1} V \frac{dp}{dt} \qquad \text{(eq. 1)}$$

in which $\gamma = \frac{Cp}{Cv}$ and $\frac{dQ_{ch}}{dt}$ is the net heat release in kJ/deg CA, P and V are instantaneous in-cylinder pressure and volume during the expansion process [13]. The signal of the pressure transducer which was acquired for every 0.26 CAD for 100 cycles was used to compute the rate of heat release. The rate of heat release was very much useful to analyze the combustion process and engine operating performance.

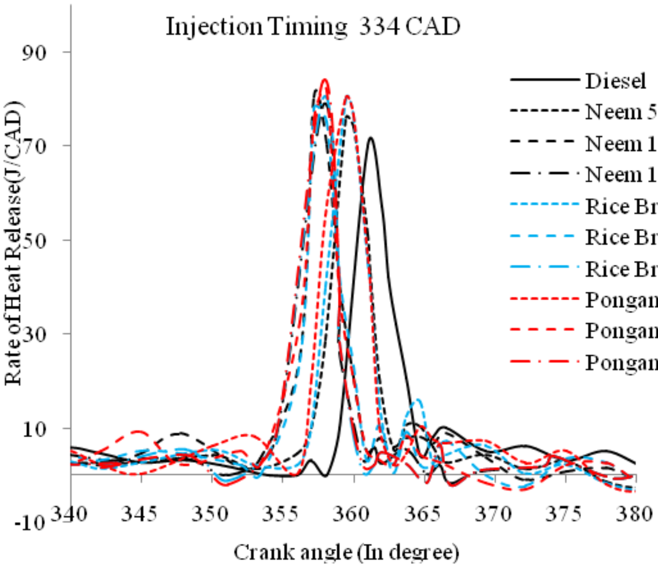

Fig 8. Comparison of Heat release rate at Full load condition for blends of Neem, Rice bran and Pongamia with Standard injection timing

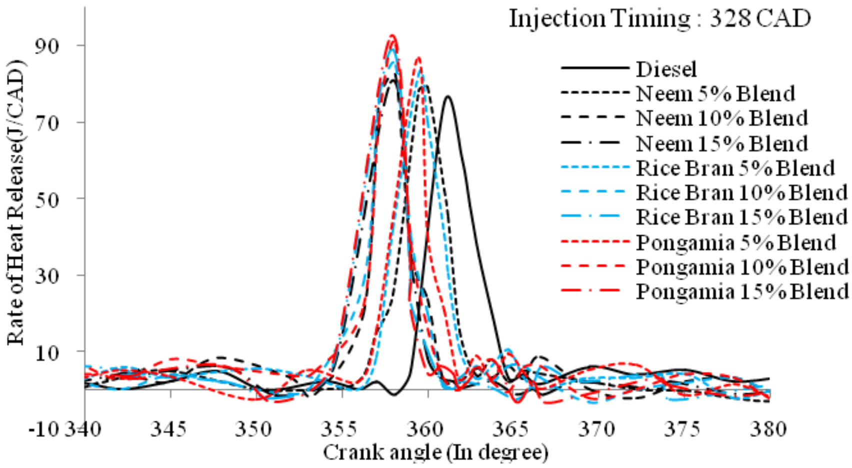

Fig 9. Comparison of Heat release rate at Full load condition for blends of Neem, Rice bran and Pongamia with Advanced injection timing

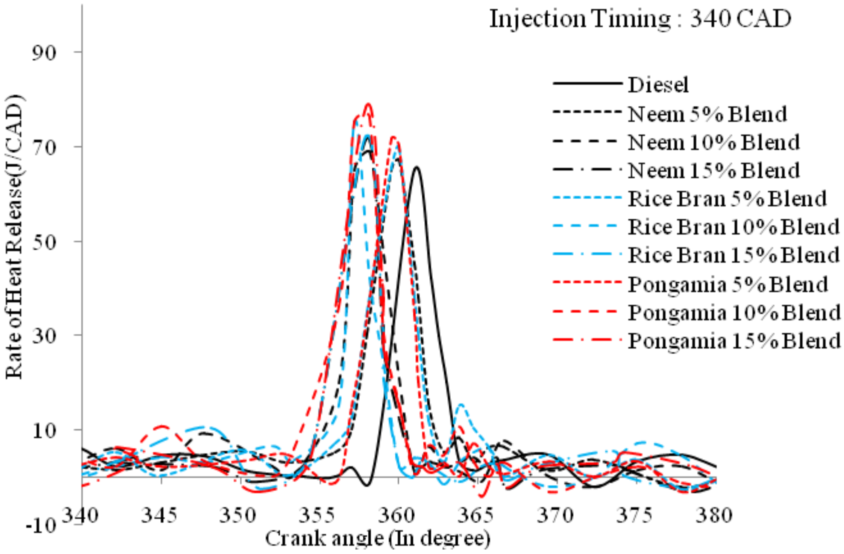

Fig 10. Comparison of Heat release rate at Full load condition for blends of Neem, Rice bran and Pongamia with Retarded injection timing

It is observed that at standard injection timing, the rate of heat release was 3% to 4% higher for blends of biodiesel than diesel as shown in fig (8). At standard injection timing, the ignition delay for Neem, Rice bran and Pongamia was found to be shorter than diesel. Advancing the injection timing by 6 CAD showed positive improvement in rate of heat release for blends of biodiesel by 6% to 8% which may be due to longer ignition delay and intense premixed combustion phase (i.e) fuel is accumulated in the combustion chamber for longer period and duration for complete combustion was provided by increasing the ignition delay by injection advancement [9]. It can also be observed that the rate of heat release is higher for Pongamia biodiesel at any injection timing and load, which indicates more monatomic oxygen is liberated during combustion and complete combustion is initiated. Blends of Rice bran biodiesel also shows 2% to 3% increase in rate of heat release but lower that Pongamia biodiesel because of lower calorific value and lower latent heat of vaporization [11,15].
Retardment of injection timing by 6 CAD for Neem, Rice bran and Pongamia blends are shown in fig. (10) which exhibits reduction in rate of heat release when compared with standard and advanced injection timing because of relatively shorter ignition delay and less intense premixed combustion period. It can be concluded that higher blends of Neem, Rice bran and Pongamia biodiesel shows 3% to 4% increase in net heat release rate with advancement in injection timing.

V. Conclusion

The effect of injection timing on the usage of biodiesel from Neem, Rice bran and Pongamia were compared and analyzed on its combustion and rate of heat release. The following conclusions were arrived,

- Transesterification process was carried out using 2.5 gms Sodium hydroxide and 400 ml of methanol in which 92% to 95% of biodiesel was extracted.
- The injection timing played a very role in combustion an heat release rate (i.e) advancing the injection timing by 6 CAD from the standard setting of 334 Cad proved to be advantageous with positive improvements in combustion and rate of heat release for all blends of biodiesel.
- Advancement of injection timing for higher blend of Pongamia showed 4% to 6% increase in maximum in-cylinder pressure.
- Neem and Rice bran biodiesel blends also showed 2% to 4% increase in the in-cylinder pressure.
- Because of longer ignition delay and intense premixed combustion phase, rate of heat release also showed 6% to 8% increase than diesel and other blends of Neem and Rice bran.
- Retardment of injection timing by 6 CAD (i.e) 340 CAD proved to exhibit 3% to 4% negative improvement that standard injection timing for all blends of biodiesel across all loading conditions.

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