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An Experimental Analysis of Performance, Combustion and Emission Characteristics of Rice bran Biodiesel and Its Blends on CI Engine

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Abstract: *The use of biodiesel, the methyl esters of vegetable oils are becoming popular due to their low environmental impact and potential as a green alternative fuel for diesel engine. With this objective, the present work has focused on the performance and emission characteristics of diesel engine using rice bran oil and its blends with diesel. In this investigation, the blends of varying proportions of rice bran biodiesel with diesel (RB20, RB40, RB60, RB80 & RB100) were prepared, analyzed, and compared the performance and exhaust emission with diesel using 5.2 kW Single cylinder, 4stroke diesel engine. The performance and emission characteristics of blends are evaluated at variable loads and constant rated speed of 1500 rpm and found that the performance of RB20 blend of rice bran oil gives result, that is near to the diesel and also found that the emission CO, CO2, HC, smoke & NO_X of this blend is less than the diesel.*

Keywords: *Biodiesel, Rice bran, Alternate fuel, CI Engine.*

I. Introduction

According to the present scenario diesel engines are commonly used as prime movers in the transportation, industrial and agricultural sectors because of their high brake thermal efficiency and reliability. Energy conservation and efficiency have always been the quest of engineers concerned with internal combustion engines. In this work, we have adopted Rice bran oil. Rice bran belongs to family Oryza sativa linn.

II. Materials and Methods

The extraction of biodiesel is carried out by base catalyzed transesterification method.

2.1. Process of Extracting

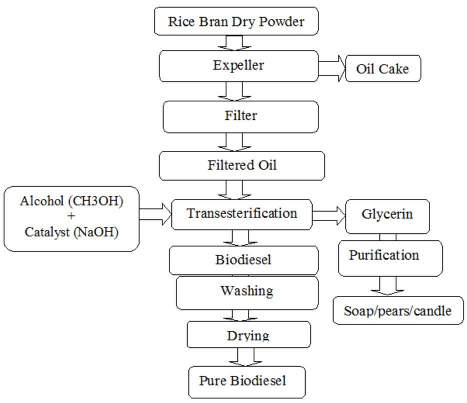

Fig 2.1: The flow chart for biodiesel production

To a one liter of raw Rice bran oil is heated up to 70^0C. 300 ml of methanol & 5-7gms of NaoH (catalyst) is added and the mixture is maintained at $65\text{-}70^0$C is about 1½ hours and stirred continuously. The mixture is allowed to settle for 20-30 min until the formation of biodiesel and glycerin layers. The glycerin is removed from the bio-diesel in a separating funnel. The bio diesel produced from Rice bran oil is ready to use.

2.2. 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.

CH2COOR1				CH2OH		R1COOR
|				|		|
CHCOOR2				CHOH		R1COOR
|	+	3ROH	⟷	|	+	|
CH2COOR3			Catalyst (NaOH)	CH2OH		R1COOR
Rice bran Glyceride		Alcohol		Glycerin		Biodiesel

Chemical reaction

Physical and chemical properties are more improved in esterified vegetable oil because esterified vegetable oil contains more cetane number than diesel fuel. These parameters induce good combustion characteristics in vegetable oil esters. So unburnt hydrocarbon level is decreased in the exhaust. It results in lower generation of hydrocarbon and carbon monoxide in the exhaust than diesel fuel. The vegetable oil esters contain more oxygen and lower calorific value than diesel. So, it enhances the combustion process and generates lower nitric oxide formation in the exhaust than diesel fuel.

III. Properties of Diesel and Some Blends

After transesterification the properties of Rice bran oil blends was determined. It was found that the properties of Rice bran oil blends were similar to diesel. Rice bran oil blends were similar to diesel.

Table 3.1: Properties of Rice bran oil blends

Properties	**Diesel**	**RB20**	**RB40**	**RB100**
Kinematic viscosity at 40^0C (Cst)	2.54	3.024	3.617	5.4
Calorific value (kJ/Kg)	42500	42270	41976	37933
Density (kg/m^3)	840	838	846	875
Flash Point (^{0}C)	54	79	98	165
Fire Point (^{0}C)	64	89	110	185

IV. Experimental Setup

The experimental setup enables study performance, combustion and emission characteristics. The experiments have been carried out on a DI compression ignition engine for various blends of rice bran oil with diesel (RB20, RB40, RB60, RB80, and RB100) with varying brake power. The experiment is carried out at constant compression ratio of 17.5:1 and constant injection pressure of 200 bar by varying brake power.

Table 4.1: Engine specifications

Manufacturer	Kirloskar oil engines Ltd, India
Model	TV-SR, naturally aspirated
Engine	Single cylinder, DI
Bore/stroke	87.5mm/110mm
Compression Ratio	17.5:1
speed	1500r/min, constant
Rated power	5.2kw
Working cycle	4 stroke
Injection pressure	200bar/23 def TDC
Type of sensor	Piezo electric
Response time	4 micro seconds

Fig 4.1: Photograph of engine setup

V. Result and Discussion

5.1 Performance characteristics

5.1.1 Specific fuel consumption

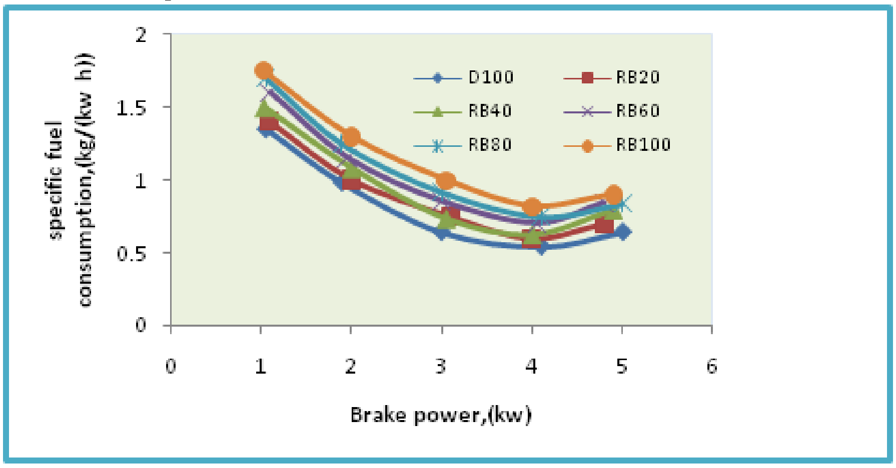

Fig 5.1 Variation of the specific fuel consumption with brake power for diesel and rice bran blends

The variation of specific fuel consumption with Brake power for diesel, and rice bran biodiesel oil and it's blends are shown in figure 5.1. The specific fuel consumption for rice bran biodiesel blends are higher than diesel for certain lower loads, but for higher loads, consumption rate remains almost constant as evident from the graph. This may be due to fuel density, viscosity and heating value of the fuels. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads.

5.1.2 Air fuel ratio

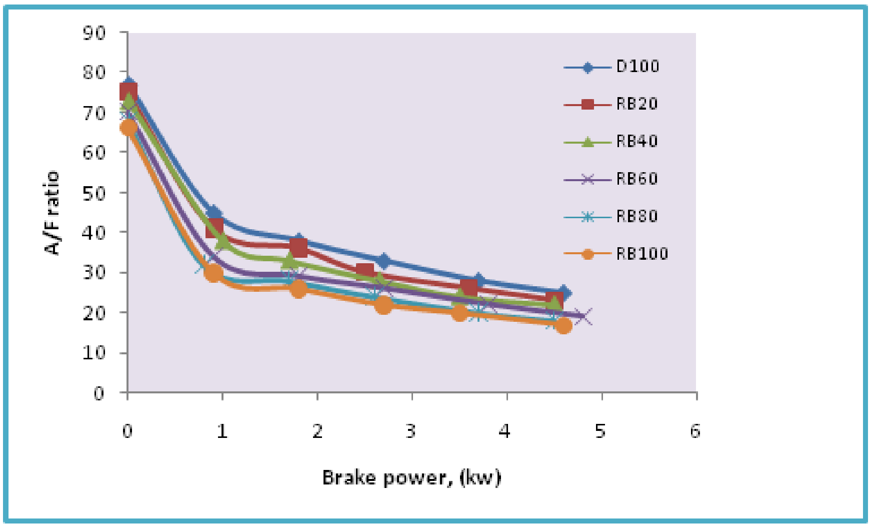

Fig 5.2 Variation of the specific fuel consumption with brake power for diesel and rice bran blends

The variation of air fuel ratio with brake power for diesel and rice bran biodiesel blends are shown in figure 5.2. It can be observed that air fuel ratio of pure diesel is higher than other rice bran biodiesel and its blends, and we can also see that the air fuel ratio decreases as the load increases. Because the reason is air fuel ratio decreases due to increase in load because of the compensation of load can only be done with increasing the quantity of fuel injection to develop the power required to bare the load.

5.1.3 Brake thermal efficiency

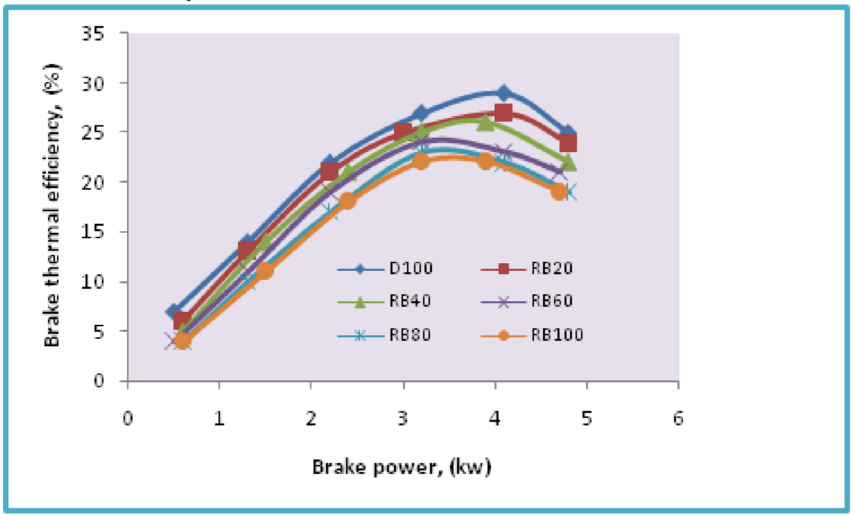

Fig 5. 3 The variation of the brake thermal efficiency with brake power for diesel and rice bran blends

The variation of brake thermal efficiency with brake power for diesel, and rice bran biodiesel and its blend are shown in figure 5.3. shows the break thermal efficiency of rice bran biodiesel and its blends with respect to brake power. The Increase in thermal efficiency due to high percentage of oxygen presence in the biodiesel, the extra oxygen leads to causes better combustion inside the combustion chamber. The thermal efficiency of the engine is improved by increasing the concentration of the biodiesel in the blends and also the additional lubricant provided by biodiesel. The decrease in brake thermal efficiency with increase in rice bran biodiesel concentration is due to the poor atomization of the blends due to their high viscosity and reduction in heat loss and increase in power with increase in load.

5.1.4 Exhaust gas emission

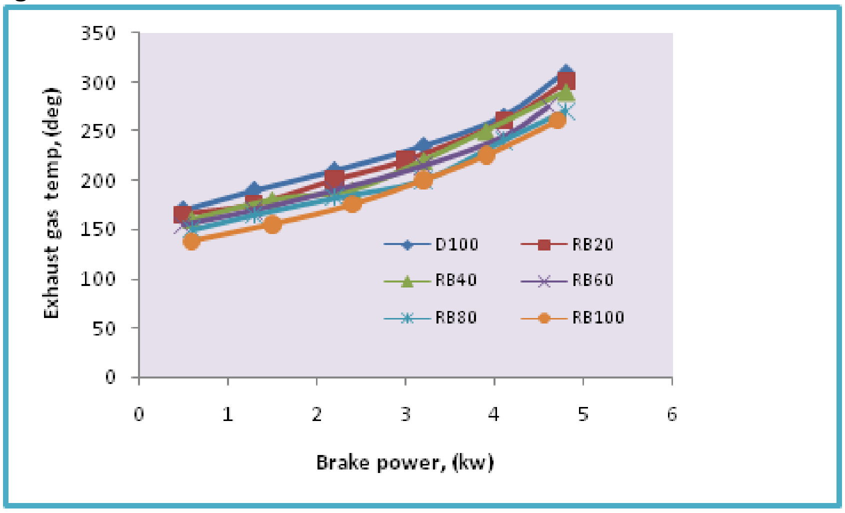

Fig 5.4 The variation of the exhaust gas temperature with brake power for diesel and rice bran blends

Figure 5.4 shows the Exhaust gas temperature the variation of exhaust emission temperature with brake power for diesel, and other blends of rice bran biodiesel is shown. the exhaust emission temperature of all the biodiesel are higher than the diesel as it is evident from the graph. The exhaust gas temperature of all the blends and 100% diesel increase as the load increases. It is observed that, at full load the exhaust gas temperature is maximum, this is because; at full load the chemically correct ratio of air and fuel is used, due to chemically correct ratio of air and fuel, high heat is generated inside the cylinder.

5.2 Emission characteristics

5.2.1 Carbon monoxide

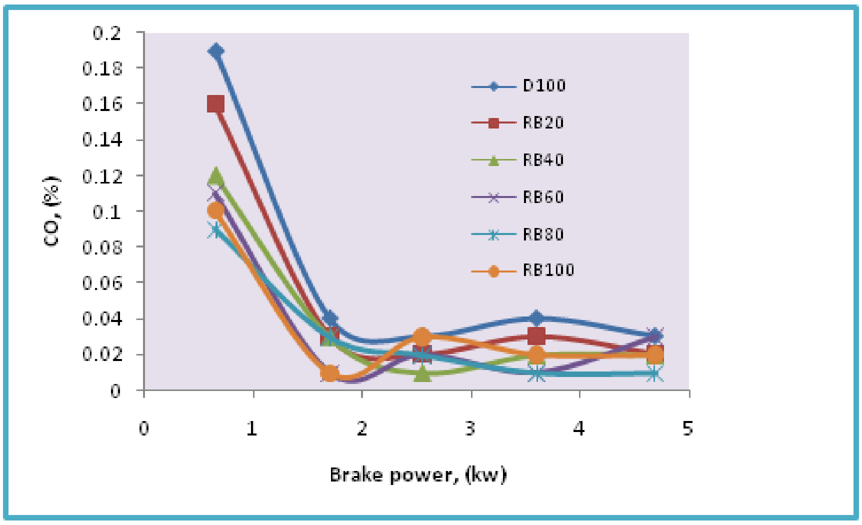

Fig 5.5 The variation of the carbon monoxide with brake power for diesel and rice bran blends

The plots of carbon monoxide CO emissions of rice bran and diesel fuel operation at different load conditions are shown in figure 5.5 The plots show reducing CO emissions at higher loads. The decrease in carbon monoxide emission for biodiesel is due to more oxygen molecule present in the fuel and more atomization of fuel as compared to that of diesel. The decrease in CO emission may be due to better vaporization biodiesel fuel and more oxygen present in the biodiesel, resulting in complete combustion.

5.2.2 Hydro carbon

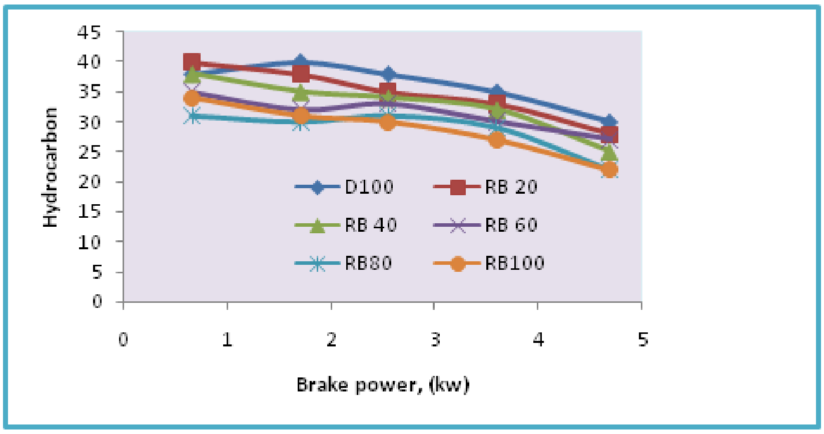

Fig 5.6 The variation of the hydro carbon with brake power for diesel and rice bran blends

The variations of HC emission for diesel and biodiesel are shown in the figure 5.6 it has been observed that HC emissions are nominal for RB80, RB100, and more at RB20, RB40 and RB60. The reason for this may be incomplete combustion. The higher cetane number of biodiesel results decrease in HC emission due to shorter ignition delay. Lower HC emissions in the exhaust gas of the engine may be attributed to the efficient combustion of rice bran biodiesel and blends due to the presence of fuel bound oxygen and warmed-up conditions at higher loads. This is due to the reason that at lower loads the lower cylinder pressure and temperatures were experienced that was caused by lower rate of burning. This feature results in higher HC emissions.

5.2.3 Nitrogen oxide

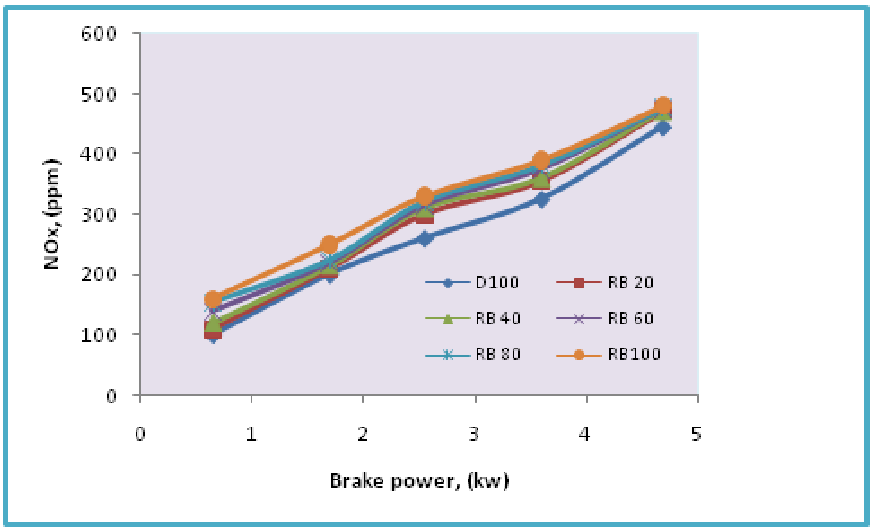

Fig 5.7 The variation of the nitrogen oxide with brake power for diesel and rice bran blends

The average percentage of change in NO_x emission for RB20, RB40, RB60, RB80, and RB100 are shown in the graph. This shows that the NO_x emission increased with the increase of percentage ratio of biodiesel. NO_x emission is primarily a function of total oxygen inside the combustion chamber, temperature, pressure, compressibility, and velocity of sound. Invariably biodiesel has high level of oxygen bound to its chemical structures. Thus, oxygen concentration in biodiesel blends fuel might have caused the formation of NO_x . Furthermore, the increase of NO_x emission is due to the higher cetane number of biodiesel which will reduce the ignition delay. The increase of NO_x emission is a result of the reduced ignition delay. However, the NO_x emissions can be reduced through engine tuning or using exhaust catalytic converter. At any rate, the NO_x still can be reduced with the advanced technologies such as catalytic converter, EGR and engine tuning.

5.3 Combustion Characteristics

5.3.1 Variation of crank angle versus cylinder pressure

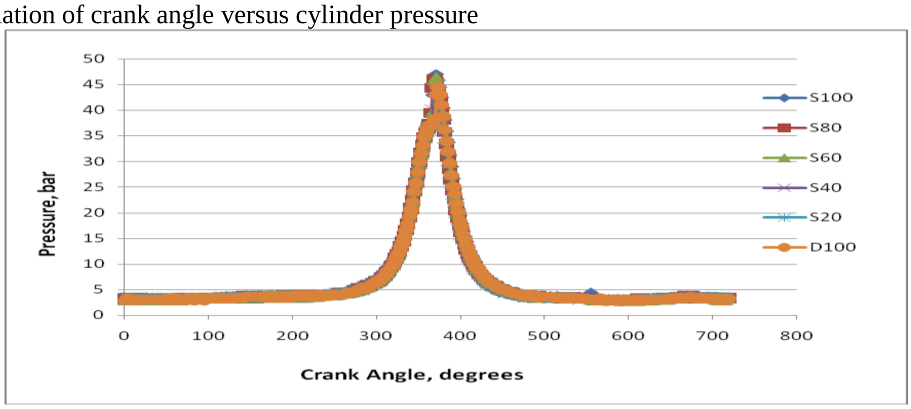

Fig 5.8 Variation of crank angle versus cylinder pressure

In a CI engine the cylinder pressure is depends on the fuel-burning rate during the premixed burning phase, which in turn leads better combusion and heat release. The variation of cylinder pressure with respective crange angle for diesel and different blends of simarouba biodiesel are presented in fig 5.8 peak pressure of 44.54bar and 43.69bar are found for puer diesel and RB40 respectively. From the test results it is observed that the peak presure variations are less since the properties such as calorific value, viscosity and density are brought closer to diesel after transestirification of vagitable oil, no magare variation in the pressure are found.

5.3.2 Variation of crank angle versus heat release rate

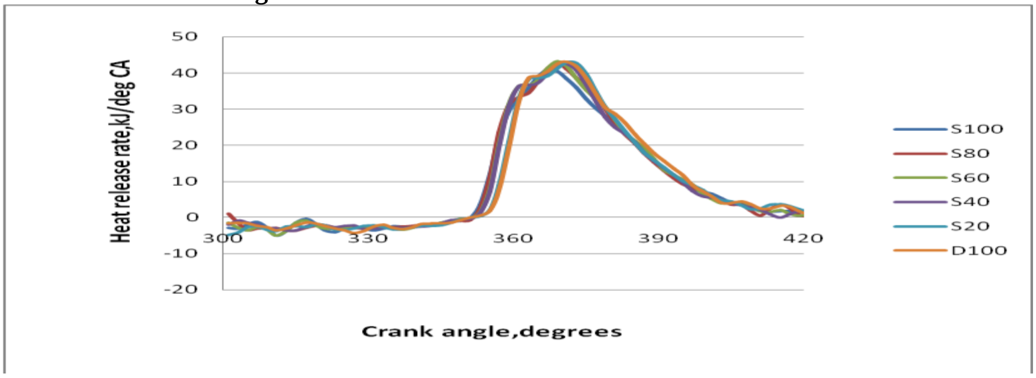

Fig 5.9 Variation of crank angle versus heat release rate

The fig-5.9 shows that the variation of the heat release rate with crank angle.It is observed that all the blends of rice bran oil traces the path of pure diesel and RB60 are 43,11044kj and 43,2087kj at 3710.

5.3.3 Variation of crank angle versus cumulative heat release rate

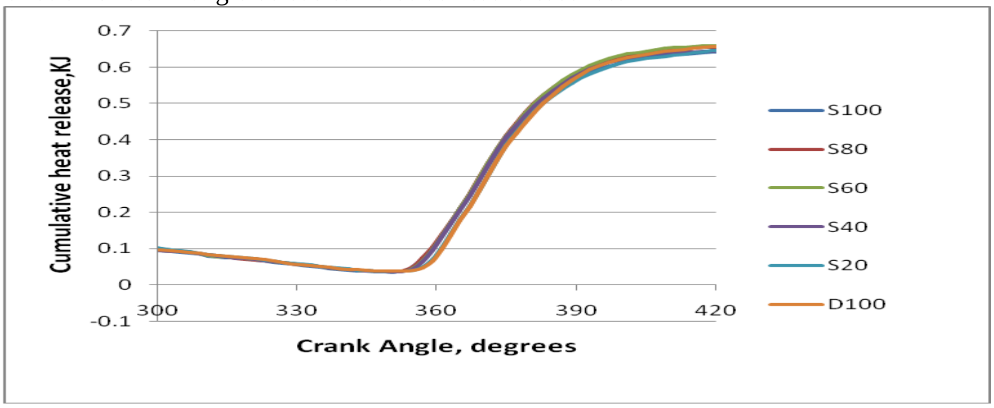

Fig 5.10 Variation of crank angle versus cumulative heat release rate

The fig-5.10 shows the variation of comulative heat transfer with crank angle. It is observed that from the fig-5.10 that all blends of rice bran biodiesl traces the same path as that of the diesel.initially the cumulative heat transfer decreases at first cycle and then increases in the second cycle as shown in the fig-5.3.3.

VI. Conclusion

- Specific fuel consumption increases as the concentration of rice bran biodiesel increases so we can observe that with 20% rice bran biodiesel blend almost matches with diesel fuel.
- Air fuel ratio for diesel is lower than rice bran biodiesel and its blends which is evident from the graph.
- The mechanical efficiency of diesel is slightly higher than the rice bran biodiesel blends and D100 and RB20 are seen to be almost nearer to each other also from the graph.
- Brake thermal efficiency of rice bran biodiesel at 20% blend has slightly higher efficiency than diesel.
- The exhaust emission temperature of all the biodiesel are higher than the diesel and It is observed that, at full load the exhaust gas temperature is maximum, due to chemically correct ratio of air and fuel.
- The RB20 has lower average percentage of change in CO, and HC compared to Diesel. Yet, S20 is producing higher NOx emission. Nevertheless, the RB20 is still the suitable biodiesel blend amongst all as the NOx emission can be reduced with the advanced technologies.

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