

INVESTIGATIONAL ANALYSIS OF PERFORMANCE CHARACTERISTICS AND EMISSION OF CASHEW NUT SHELL BIODIESEL ON DI DIESEL ENGINE

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ABSTRACT

In this study, the combustion and emission characteristics of biodiesel produced from Cashew nut shell oil and its blends and diesel fuel were compared. The experiments were performed in a single-cylinder direct injection diesel engine at steady-state conditions over the constant RPM (1500 RPM). During the experiments, the specific fuel consumption (SFC), pollutant emissions like hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NO_x) and smoke, and in-cylinder pressures were measured. The experimental results showed that, biodiesel blends had a 26.79 - 24% reduction in brake thermal relative to diesel fuel. On the other hand, Cashew nut shell oil biodiesel drastically increases CO, HC and smoke, while the NO_x emission decreased. The combustion analysis showed that the addition of Cashew nut shell oil biodiesel to diesel fuel reduced the ignition delay period and also reduced the premixed peak. These results showed that Cashew nut shell oil biodiesel and its blends could be used without any modifications as an alternative fuel in diesel engine

Keywords: Methyl ester, Transesterification, Biodiesel, Combustion & Emission

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1. INTRODUCTION

Biodiesel is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats as an alternative fuel of diesel. It is renewable, biodegradable, non-toxic and oxygenated fuel [1,2]. Even though many researches pointed out that it might help to decrease greenhouse gas emissions, improve income distribution and promote sustainable rural development [3-6]. The primary cause is being deficient in of new knowledge about the influence of biodiesel in

diesel engines. For instance, the reduction of engine power, as well as the increase of fuel consumption for biodiesel, is not as a large amount as anticipated; the early research conclusions have been reserved, it is more prone to oxidation for biodiesel, which may result in mysterious gums and sediments that can plug the fuel filter, and thus it will influence engine durability [7,8]. In the automotive sector, the higher oxides of nitrogen (NO_x) and HC emission from the diesel engine are its main problems with respect to air pollution. In this perspective, the reductions in HC and CO emissions from the engine can be obtained by the use of biodiesel. But, NO_x emissions are slightly increased for the biodiesel blended diesel fuel [9-13]. High viscosity, surface tension and density of biodiesel influence atomization by increasing the mean fuel droplet size, which in turn increases the spray tip penetration. The higher the mean droplet size of biodiesel is because of the lower Weber number [14]. Many researchers have found that the viscosity and density are affected the atomization, whereas density is the lowest on mean droplet size and consequently to get better fuel atomization viscosity should be the first alternative of a fuel's physical property to be decreased [5-7]. The above mentioned problem can be solved by blending biodiesel with diesel fuel, which will decrease the viscosity of the fuel. India is a hot country and has a suitable climate for the development of the Java plum tree. India has potential for the growth of Java plum trees and these trees are cultivated in forests and waste lands. The growth of Java plum trees in waste lands also reduces soil erosion and lead to enhance of rain fall. The seeds obtained from Java plum trees are crushed in an explore to get the oil. The present investigation is carried out to describe the complete production process, analysis of thermo-physical properties and working characteristics of Cashew nut shell oil biodiesel in a direct injection compression ignition engine.

2. BIODIESEL PRODUCTION AND PROPERTY ANALYSIS

2.1 Transesterification

The reaction mechanism for alkali catalyzed transesterification was formulated as three steps. Transesterification is the process of conversion of the triglyceride with an alcohol in the presence of a catalyst to form esters and glycerol. Vegetable oil is subjected to chemical reactions with alcohol like methanol or ethanol in the presence of a catalyst. Since the reaction is reversible, excess methanol is required to reduce the activation energy, thereby shifting the equilibrium to the product side. The triglyceride present in the vegetable oil is converted into biodiesel. Among the alcohols used for the transesterification reaction are methanol and ethanol. However, when methanol is processed, methyl esters are formed, whereas ethanol produces ethyl esters. Both these compounds are biodiesel fuels in different chemical combinations. The mechanism of the transesterification reaction scheme is illustrated by Fig. 1. Transesterification of rapeseed oil produces ester whose properties is comparable with those of diesel fuels. Schematic diagram of biodiesel plant is shown in Fig. 2. The properties of the diesel fuel and the Cashew nut shell oil biodiesel are summarized in Table 1.

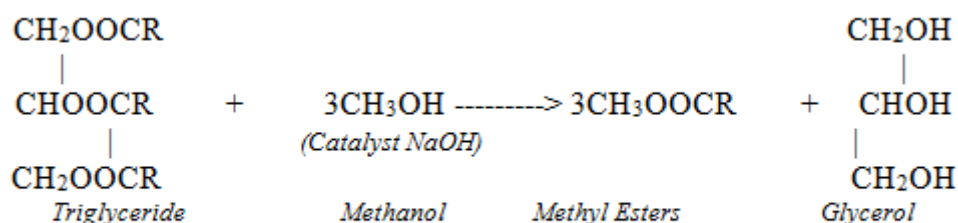


Figure 1 Mechanism of transesterification process.

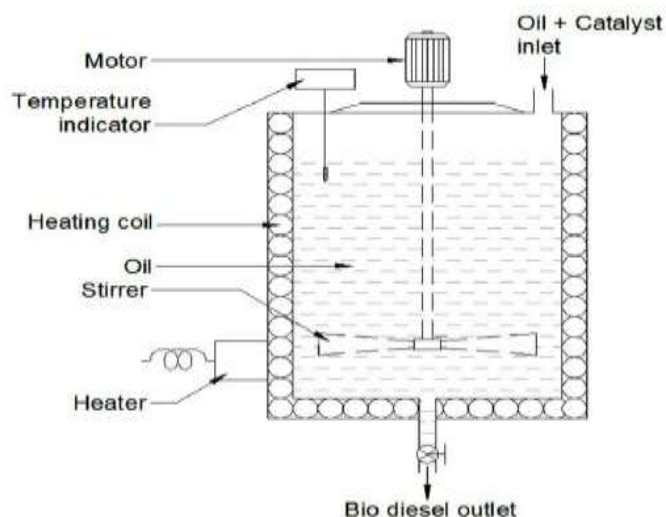


Figure 2 Schematic diagram of Biodiesel Plant.

Table 1 Properties of diesel and biodiesel blends

Properties	Specific gravity@ 15/15 (C (GM/cc)	Kinematic Viscosity @ 40 (C (CST)	Flash Point (°C)	Fire Point (°C)	Gross calorific value (Kcals/kg)	Density @ 15 (C (GM/cc)
Diesel	0.835	2.56	44	48	10,660	0.834
Biodiesel 100%	0.8996	5.6	82	98	9980	0.9835

3. EXPERIMENTAL SETUP

The diesel engine used for experimentation is Kirloskar TV1, single cylinder, water cooled engine coupled to eddy current dynamometer with computer interface and it is shown in Fig. 3. The properties of diesel and cashew nut oil are given in Table 2. The detailed specification of the engine is shown in Table 3. A data acquisition system is used to collect and analyze the combustion data like in-cylinder pressure and heat release rate during the experiment by using AVL transducer. The tests are conducted at the rated speed of 1500 RPM. In every test, exhaust emission such as nitrogen oxides (NOx), hydrocarbon (HC), carbon monoxide (CO) and smoke are measured. From the initial measurement, brake thermal efficiency (BTE) and specific fuel consumption (SFC) with respect to brake power (BP) for different blends are calculated. The blends of biodiesel and diesel used were B20 and B40. B20 means 20 % biodiesel fuel and 80% of diesel fuel by volume. In order to study the effect of biodiesel blends on the engine combustion and emission characteristics, the injection timing was kept constant at 23° BTDC. The effect of biodiesel blends was studied and the results were compared with neat diesel.

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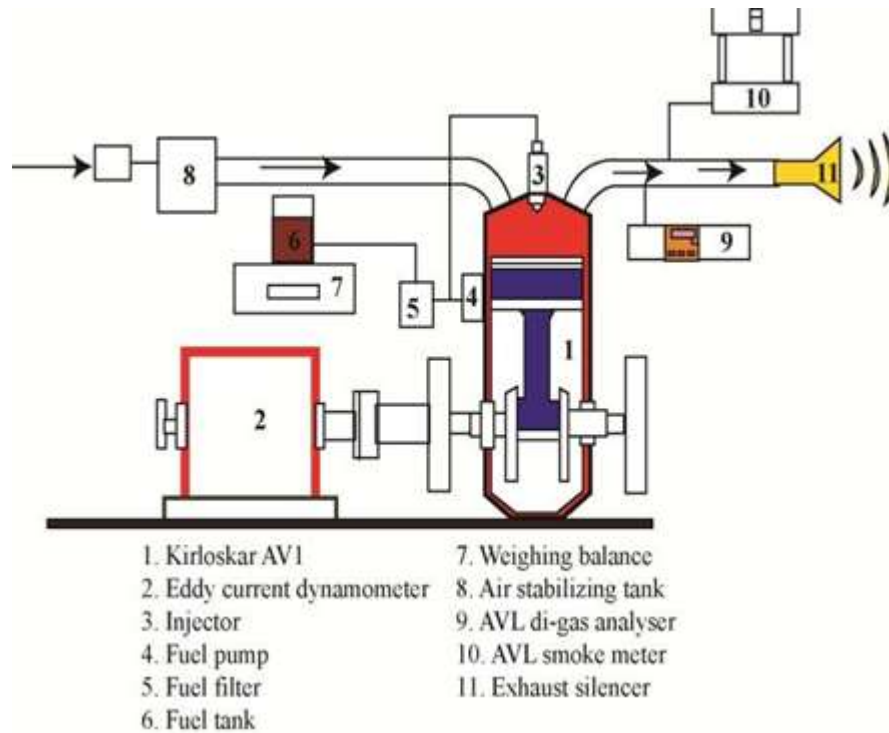


Figure 3 Schematic diagram of the experimental setup

Table 2 Properties of diesel and CNSL oil

Properties of diesel and CNSL oil (Source: ITA laboratory- chennai)		
Properties	Diesel	CNSL
Density at (g/cc)	0.8/0.84	0.9326
Kinematic Viscosity @ 40 °C (cSt)	2.0 to 4.5	12.27
Calorific value (kJ/kg)	47693	20836
Flash Point (°C)	80	98
Fire Point (°C)	86	108

Table 3 Specification of test engine

ENGINE SPECIFICATION	
Make	Vertical, Water cooled, KIRLOSKAR AV-1
Number of cylinder	One
Bore	87.5 mm
Stroke	110mm
Maximum power	3.7 kW
Compression ratio	17.5: 1
Displacement Volume	661 CC
Speed	1500 rpm
Injection opening angle	23° b TDC
Injection opening pressure	180 bar
Dynamometer	Eddy current dynamometer

4. RESULT AND DISCUSSION

4.1. Performance Characteristics

Fig. 4 shows the variations in brake thermal efficiency with respect to brake power. The Brake thermal efficiency (BTE) of neat diesel is more than other blends, i.e. B20 has lower brake thermal efficiency followed by B40, B60, B80 and B100 respectively. The reason may be the higher viscosity of the Cashew nut shell oil biodiesel blends that leads to poor atomization in the injector. B20 has shown better results than other blends since it has lower viscosity when compared to other biodiesel blends. The BTE of blend B20 shows an increase of 8.04% when compared to B100 at full load.

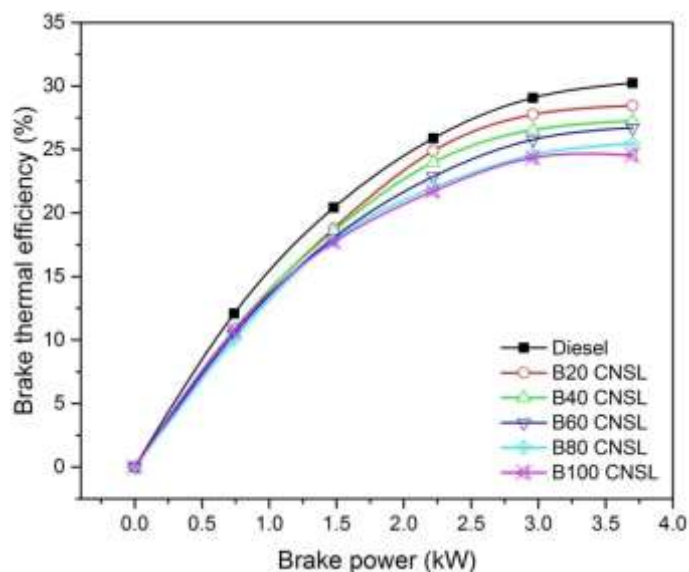


Figure. 4 Brake thermal efficiency against brake power

4.2. Emission Characteristics

Fig. 5 shows the variations of oxides of nitrogen with brake power. The oxides of nitrogen (NO_x) emission after combustion is less in diesel fuel compared to Cashew nut shell oil biodiesel and its blends. From the graph it is clear that the NO_x emission in B20, B40, B80 and B100 are less when compared with neat diesel. The reason is the reduced combustion temperature that prevails inside the combustion chamber due to the higher heating value of the Cashew nut shell oil biodiesel blends. The blend B100 has shown an increase of NO_x emission 6.35% when compared to that of diesel fuel at full load.

The variation in HC emission with brake power results is shown in Fig. 6. The HC emission was increased to 35, 27.3, 27, 24, 22 and 18 ppm for the B100, B80, B60, B40 and B20 blends, respectively. A possible explanation for the increment in the HC emission, when fueling with biodiesel and its blends is that lower calorific value and a certain number of the Cashew nut shell oil biodiesel compared with the diesel fuel. The reason may cause an incomplete combustion of fuel, increase the HC emission [9,13]. The HC emission increased 26.29% compared to that of diesel when B100 used as fuel.

The variation in CO emission with brake power is shown in Fig. 7. An average of 1.83% and 1.33% CO emission increment were observed in 20% and 40% Cashew nut shell oil biodiesel blends, respectively. CO emission becomes highly significant, when the cylinder temperature is low and the in-cylinder combustion is incomplete. CO emission for all Cashew nut shell oil biodiesel blends are in incomplete combustion. A lower cetane number of biodiesel blends exhibits a longer ignition delay and allows longer combustion duration. Then the viscosity of biodiesel comes into play, which reduce the combustion process. The CO emission was 0.28% for diesel fuel and it was reduced to 0.38% by volume when B100 used as fuel.

Smoke emission is the visible product of diesel engine emission. The comparison of smoke emission of B20, B40, B60, B80, B100 and diesel fuel with respect to brake power is shown in Fig. 8. From the graph, it is observed that smoke emission of Cashew nut shell oil biodiesel and its blends are significantly higher than that of neat diesel at all load conditions. However, when the load increases to maximum level, smoke emission is increased for Cashew nut shell oil biodiesel and its blends with diesel. The formation of local rich mixtures

of fuel in the combustion chamber due to high viscosity and density of biodiesel blends results in poor atomization.

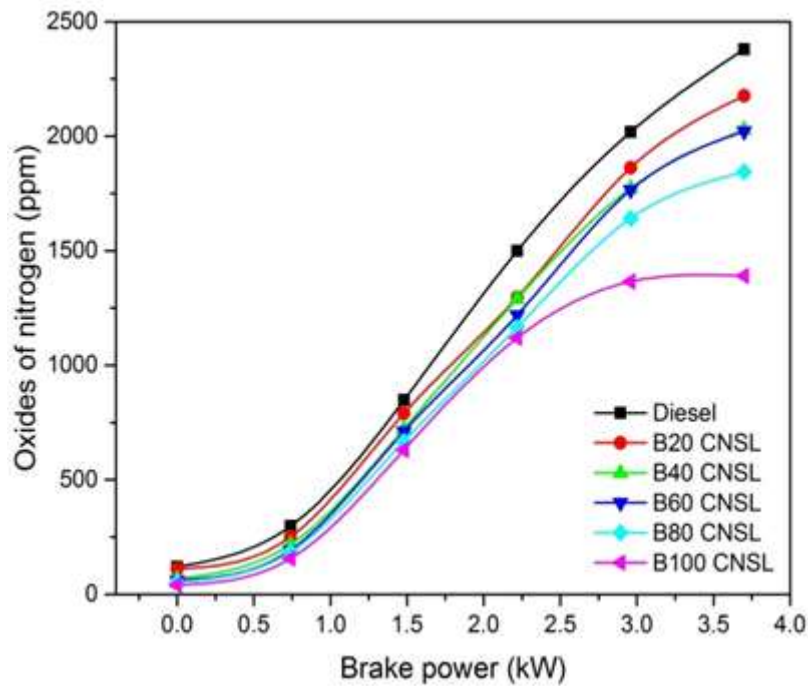


Figure 5 Oxides of nitrogen emission against brake power.

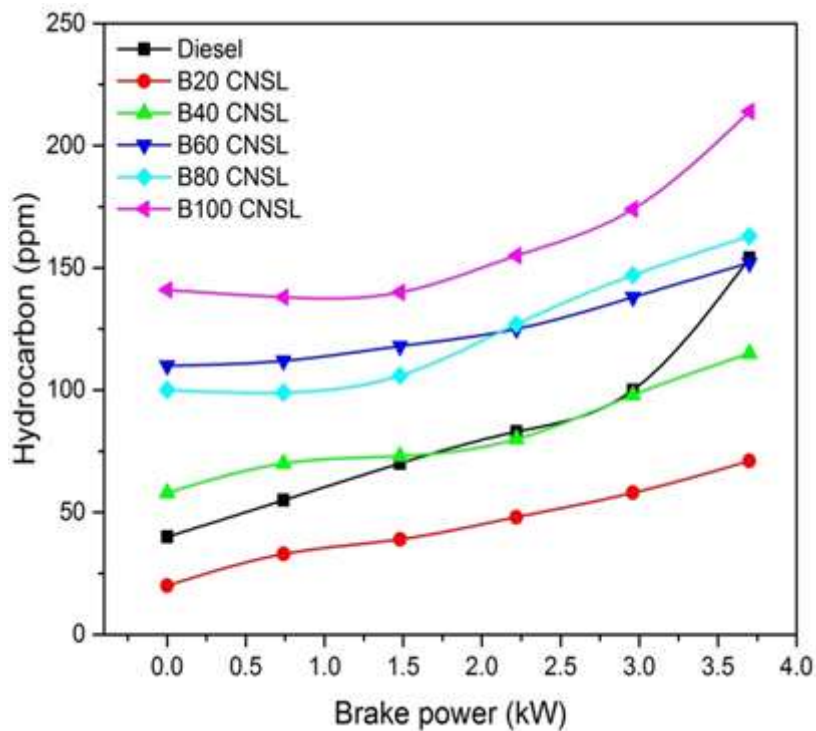


Figure 6 Hydrocarbon emission against brake power.

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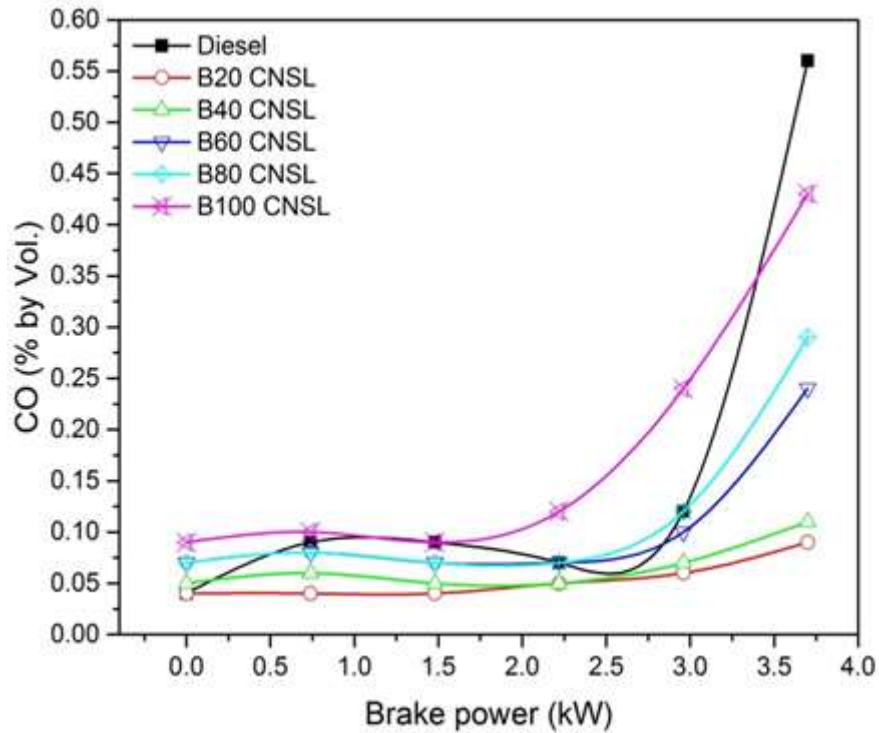


Figure 7 Carbon-monoxide emission against brake power

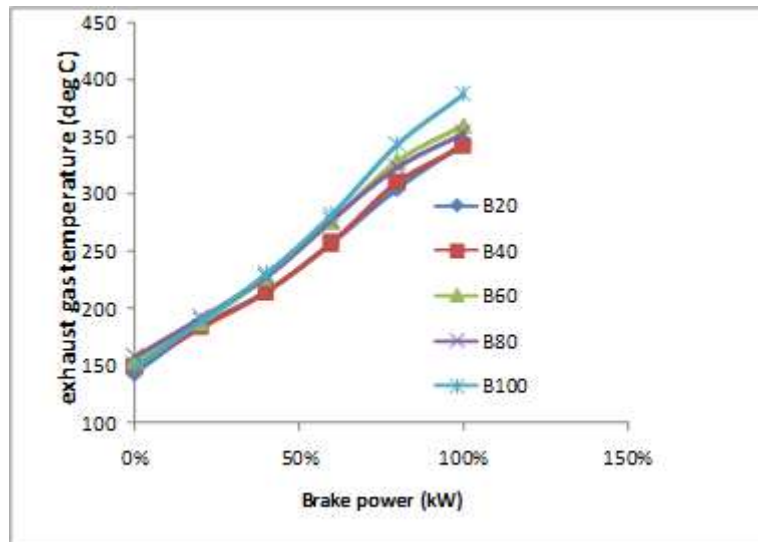


Figure 8 Specific fuel consumption against brake power.

The fig.9 represents the variation of exhaust gas temperature and brake power of the engine. The results showed the exhaust gas temperature increased with increasing the blend ratio of the CNSL. This is due to after burning of unburned fuel in the exhaust pipe.

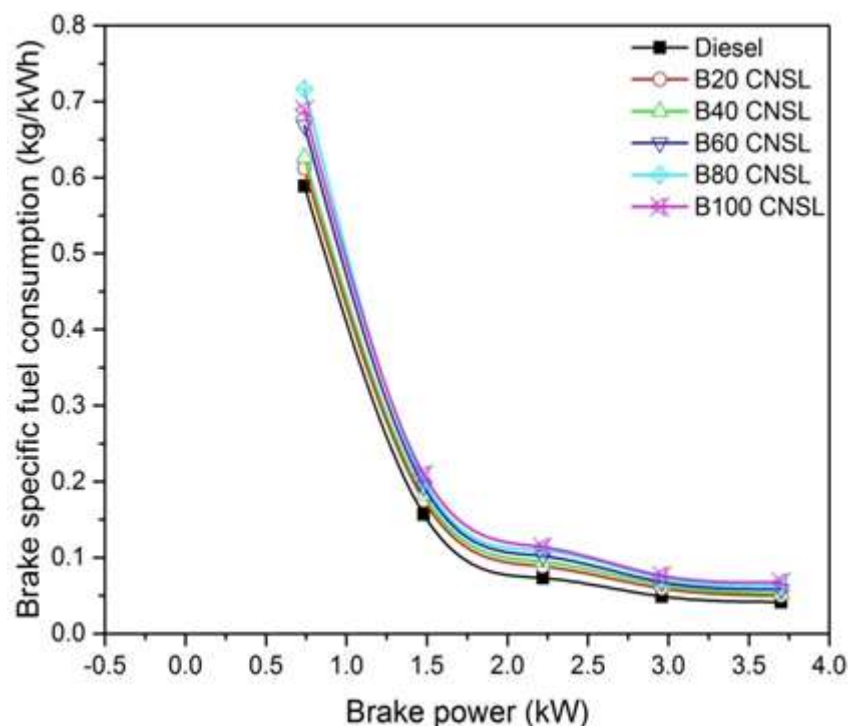


Figure 9 variation of exhaust gas temperature.

5. CONCLUSIONS

The following conclusions are drawn based on this experimental investigation on diesel engine when Cashew nut shell oilbiodiesel and its blends were used as fuel.

- ✓ An average of 4% BTE decrease was observed in 100% Cashew nut shell oilbiodiesel. Viscosity, density, and a certain number of the Cashew nut shell oil biodiesel played vital role in engine performance.
- ✓ An average of 0.26% CO and 102 ppm HC emission increment were observed in 100% Cashew nut shell oilbiodiesel and an average of 0.16% CO and 56 ppm HC emission reductions were observed for 20% blend compared with diesel fuel.
- ✓ The NO_x emission is decreased by 3.57% to 18.06% for the addition of 20% to 100% Cashew nut shell oilbiodiesel, respectively. Diesel fuel exhibited a moderate level of NO_x emission. It was observed that higher viscosity and density are the most desirable properties of biodiesel for lower NO_x emission.
- ✓ Lower in-cylinder pressure and lower heat release rate was found in all the biodiesel cases.

REFERENCES

- [1] L.C. Meher, D. VidyaSagar, S.N. Naik, Technical aspects of biodiesel production by Transesterification-a review, Renewable and Sustainable Energy Reviews, Volume 10, 2006, Pages 248-268.
- [2] Garpen, J.V., Biodiesel processing and production, Fuel Processing Technology, Vol. 86, 2005, Pages 1097-1107.
- [3] Vlada B. Veljkovic ,Ivana B. Bankovic-Ilic, Olivera S. Stamenkovic: Purification of crude biodiesel obtained by heterogeneouslycatalyzedtransesterification, Renewable and Sustainable Energy Reviews, Volume 49, 2015, Pages 500-516.

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- [4] C. Syed Aalam, C.G. Saravanan: Biodiesel Production Techniques: A Review. International Journal for Research in Applied Science and Engineering Technology, Volume 3, 2015, Pages 41-45.
- [5] C. Syed Aalam, C.G. Saravanan. Biodiesel Production from Mahua oil via Catalytic transesterification method. International Journal of ChemTech Research.Vol.8 (4), pp 1706-1709, 2015.
- [6] A.M. Ashraful, H.H. Masjuki, M.A. Kalam, I.M. Rizwanul Fattah, S. Imtenan, S.A. Shahir, H.M. Mobarak. Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: A review. Energy Conversion and Management, Volume 80, 2014, Pages 202-228.
- [7] GauravDwivedi, M.P. Sharma, Potential and limitation of straight vegetable oils as engine fuel - An Indian perspective, Renewable and Sustainable Energy Reviews, Volume 33, 2014, Pages 316-322.
- [8] Loganathan. M. Velmurgan.A, “Performance and Emission characteristics of DI Diesel Engine Fuelled with Cashew Nut Shell Liquid (CNSL) – Diesel Blends”, world academy of science, Engineering and Technology Vol:5,2011.
- [9] E.F. Aransiola, T.V. Ojumu, O.O. Oyekola, T.F. Madzimbamuto, and D.I.O. Ikhu-Omoregbe: A review of current technology for biodiesel production: State of the art. Biomass and Bioenergy, Volume 61, 2014, Pages 276-297.
- [10] D.C. Rakopoulos, C.D. Rakopoulos, E.G. Giakoumis, A.M. Dimaratos,M.A. Founti, Comparative environmental behavior of bus engine operating on blends of diesel fuel with four straight vegetable oils of Greek origin: Sunflower, cottonseed, corn and olive, Fuel, Volume 90, 2011, Pages 3439-3446.
- [11] C. Syed Aalam, C.G. Saravanan, B. PremAnand. Impact of high fuel injection pressure on the characteristics of CRDI diesel engine powered by mahua methyl ester blend. Applied Thermal Engineering 106 (2016) 702–711.
- [12] I.M. Atadashi, M.K. Aroua, A.R. Abdul Aziz, and N.M.N. Sulaiman: The effects of catalysts in biodiesel production: A review. Journal of Industrial and Engineering Chemistry, Volume 19, Issue 1, 2013, Pages 14-26.
- [13] M. Aarthy, P. Saravanan, M.K. Gowthaman, C. Rose, N.R. Kamini: Enzymatic transesterification for production of biodiesel using yeast lipases: An overview. Chemical Engineering Research and Design, Volume 92, Issue 8, 2014, Pages 1591-1601.
- [14] Ching-Lung Chen, Jo-Shu Change, Chien-Chang Huang, Kao-Chia Ho, Ping-Xuan Hsiao, Meng-Shan Wu: A Novel Biodiesel Production Method Consisting of Oil Extraction and Transesterification from Wet Microalgae, Energy Procedia, Volume 61, 2014, Pages 1294-1297.