World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:5, No:10, 2011

Performance and Emission Characteristics of a DI Diesel Engine Fuelled with Cashew Nut Shell Liquid (CNSL)-Diesel Blends

Velmurugan. A, Loganathan. M

***Abstract*—**The increased number of automobiles in recent years has resulted in great demand for fossil fuel. This has led to the development of automobile by using alternative fuels which include gaseous fuels, biofuels and vegetables oils as fuel. Energy from biomass and more specific bio-diesel is one of the opportunities that could cover the future demand of fossil fuel shortage. Biomass in the form of cashew nut shell represents a new energy source and abundant source of energy in India. The bio-fuel is derived from cashew nut shell oil and its blend with diesel are promising alternative fuel for diesel engine. In this work the pyrolysis Cashew Nut Shell Liquid (CNSL)-Diesel Blends (CDB) was used to run the Direct Injection (DI) diesel engine. The experiments were conducted with various blends of CNSL and Diesel namely B20, B40, B60, B80 and B100. The results are compared with neat diesel operation. The brake thermal efficiency was decreased for blends of CNSL and Diesel except the lower blends of B20. The brake thermal efficiency of B20 is nearly closer to that of diesel fuel. Also the emission level of the all CNSL and Diesel blends was increased compared to neat diesel. The higher viscosity and lower volatility of CNSL leads to poor mixture formation and hence lower brake thermal efficiency and higher emission levels. The higher emission level can be reduced by adding suitable additives and oxygenates with CNSL and Diesel blends.

***Keywords*—**Bio-oil, Biodiesel, Cardanol, Cashew nut shell liquid (CNSL)

I. Introduction

CASHEW nut Shell Liquid (CNSL) is a soft honey comb structure containing a dark reddish brown viscose liquid. It is a by-product of the cashew industry which is the pericarp fluid of the nut. India is a main producer of CNSL. Raw cashew nut shell contains around 20% oil. The most applied technique extraction of oil in India consists of immersion of the cashew nut in a hot bath of CNSL at 185-190°C. This method recovers about 50% of CNSL and the hot extraction produces a different CNSL from the natural, obtained by cold extraction. Due to the heat the anacardic acid undergoes decarboxylation and it is converted to cardanol. This oil is called technical CNSL [1] Cashew nut shell liquid (CNSL) a by-product of the industrial processing from cashew has gradually becoming a valuable raw material for the petrochemical area. One of its largest-yielding derivatives, the cardanol is currently being tested, as an antioxidant in the petrochemical industry [2]. In India, cashew cultivation covers a total area of about 0 .77 million hectares of land, with annual production of over 0.5 million metric tons of raw cashew nuts. The average productivity per 100000 m2 is around 760 kg. The world production of cashew nut kernel was 907,000 metric tons in 1998 The cashew nut shell liquid (CNSL) is reported to be 15-20% by weight of unshelled nut in Africa and 25-30% by weight in India and 25% overall. Considering the shell weight is about 50% of the weight of the nut-in-shell (NIS), the potential of CNSL is about 450000 metric tons per year. In India processed cashew dominates more than half the world cashew market. Various methods have been reported in literature for the extraction of CNSL from Cashew Nut Shell (CNS), which include, open pan roasting, and drum roasting, hot oil roasting, cold extrusion and solvent extraction etc. The extraction through vacuum pyrolysis has been reported recently [3]. Typically the composition of technical CNSL is approximately 52% cardanol, 10% cardol and 30% polymeric material, with remainder made up of other substances. The CNSL obtained through vacuum pyrolysis is cardanol rich. The technical CNSL is further processed by distillation at reduced pressure to remove the polymeric material. The composition of the distilled technical CNSL is about 78% cardanol, 8% cardol and 2% polymeric material and the remaining other substances. On simple heating at 100-1750 C the CNSL produced dark brown oil. This oil is further pyrolysis at 5000C under vacuum (720mm Hg) [4]. The pyrolysis oil has found to have a very high calorific value (40MJ/kg) and therefore can be considered to be promising bio oil with a potential as a fuel [5]. The use of CNSL as a potential fuel in internal combustion engines has also been suggested by [4]. The present invention is relates to Biofuel. It involves disclosure of distilled technical cashew nut shell liquid (CNSL) as one of the components for biofuel and methods for its production and formulation. In this work the cardanol of pyrolysed CNSL oil was used to run the direct injection (DI) diesel engine with various blends of diesel and the performance and emission characteristics are compared with diesel engine.

Velmurugan.A, Assistant professor, Department of Mechanical Engineering, Annamalai University, 608001, India (phone: 914144-239733) e-mail: vel_lec@rediffmail.com).
Loganathan.M, Associate professor, Department of Mechanical Engineering, Annamalai University, 608001, India (phone: 914144-239733) (e-mail: logu692002@rediffmail.com).

TABLE I
ENGINE SPECIFICATION

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

II. TEST ENGINE AND FUEL PROPERTIES

A.The experiments were carried out on a naturally aspirated, water-cooled, single cylinder, direct-injection diesel engine. The specifications of the engine are shown in Table 1.

TABLE II
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	17.2
Calorific value (kJ/kg)	48838	45363
Flash Point (°C)	80	198
Fire Point (°C)	86	206
Ash content (%)	0.01 to 0.1	0.01

TABLE III
COLORIFIC VALUE OF VARIOUS BLENDS OF CNSL OIL

Sl. No.	CNSL blends	Calorific value (kJ/kg)
1.	B20	48143
2.	B40	47448
3.	B60	46753
4.	B80	46056
5.	B100	45363

The engine was connected to an eddy-current dynamometer, and running at constant speed of 1500 rpm. In this research work the pyrolysis cashew nut shell liquid (CNSL) (named as cardanol) is used with diesel namely CNSL-Diesel blends (CDB). The blended fuels contain 20%, 40%, 60%, 80% and 100% by volume of CNSL and are identified as B20, B40, B60, B80 and B100 fuels. The major properties of the fuels are shown in Table II and Table III.

III. EXPERIMENTAL PROCEDURE

The test engine was directly coupled to an eddy current dynamometer (shown in Fig.1). The engine was run at a constant speed of 1500 rpm. The engine was optimized for best injection timing and injector opening pressure for diesel fuel. This optimized injection timing and pressure are used for CNSL blends. The mass flow of fuel was measured by mass basis. The exhaust gas analyzer (AVL DI gas analyzer) was used to measure HC, CO and NOx. The smoke density was measured by AVL smoke meter. . In this study, the diesel engine was not modified during all the tests. At each engine operating mode, experiments were carried out for the diesel fuel, and each of the CDB blends. The different injection timing (18º, 19º, 21º, 23º, 26º, and 28ºbTDC), and different injector opening pressure (18 Mpa, 20 Mpa, and 22Mpa) were tried to optimize the best brake thermal efficiency with neat diesel.

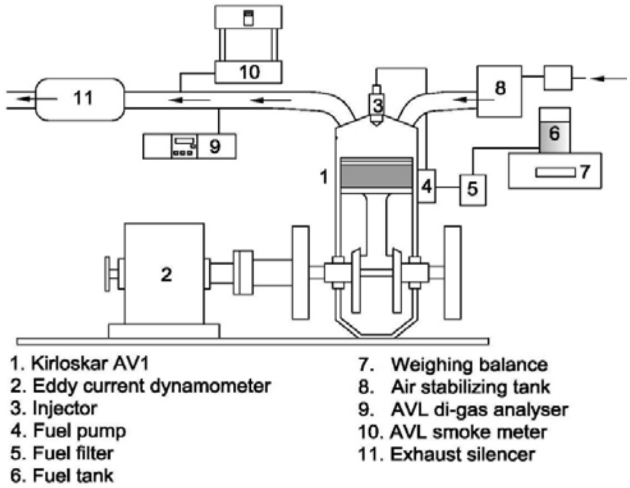

Fig. 1 Experimental setup

IV. RESULTS AND DISCUSSION

B. Optimization of Injection Timing

The test was conducted by different injection timing, namely 18º, 19º, 21º, 23º, 26º, and 28ºbTDC by neat diesel. The optimum injection time was found that 19º bTDC in which maximum brake thermal efficiency, minimum HC and smoke density observed (Fig. 2, Fig. 3 and Fig. 4).

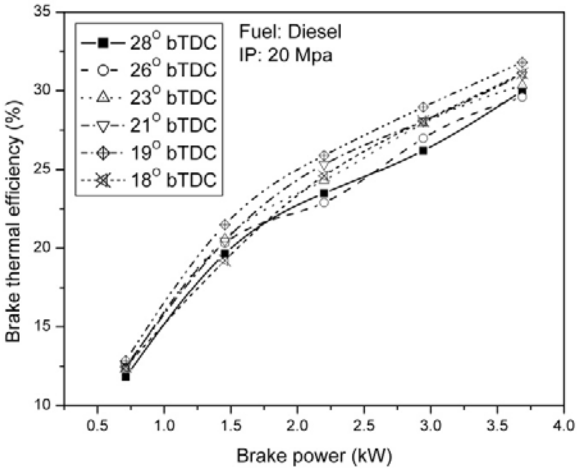

Fig. 2 Comparison of brake thermal efficiency

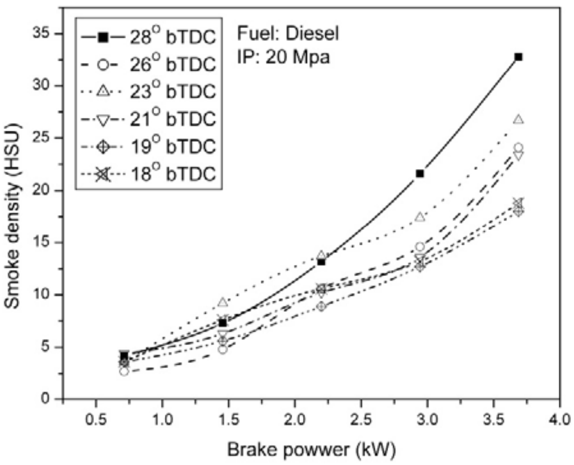

Fig. 3 Comparison of Smoke density

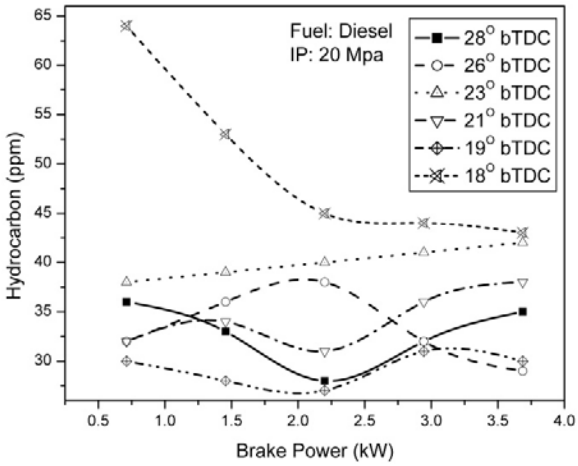

Fig. 4 Comparison of Hydrocarbon

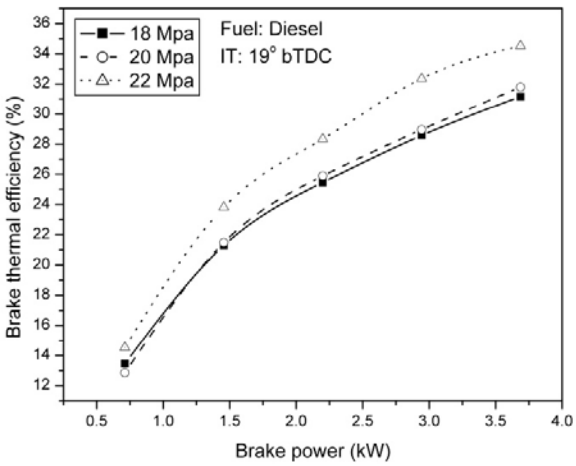

Fig. 5 Comparison of Brake thermal efficiency

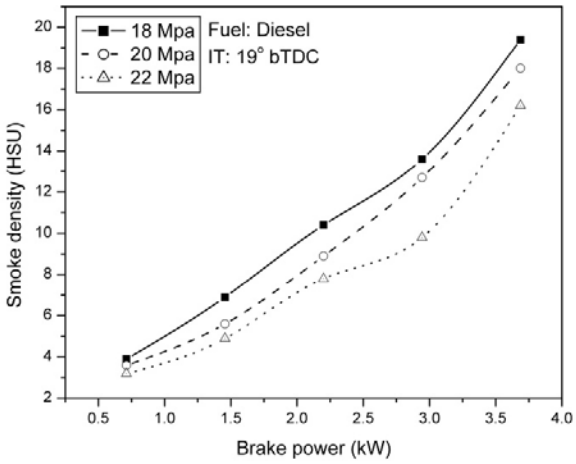

Fig. 6 Comparison of Smoke density

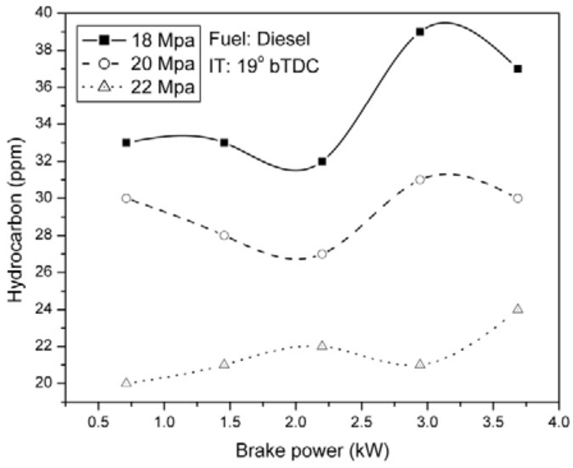

Fig. 7 Comparison of Hydrocarbon

V. Performance and Emission Characteristics of CNSL Oil

C. Brake thermal efficiency

The variation of brake thermal efficiency with respect to load for different blends of CNSL oil were considered for the present analysis and presented in Fig. 8 In all cases, brake thermal efficiency has the tendency to increase with increase in applied load. This is due to the reduction in heat loss and

World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:5, No:10, 2011

increase in power developed with increase in load. The thermal efficiency of all blends of CNSL oil is lower than that of neat diesel. This is due to poor mixture formation as a result of low volatility, higher viscosity and higher density of CNSL oil. The thermal efficiency of B20 blends gives the higher efficiency compared to other blends namely B40, B60, B80 this is because of more blends gives the high viscosity of fuel and poor atomization and hence poor combustion. Lower brake thermal efficiency obtained for B100 could be due to the poor mixture formation as compared to B20. While running the engine with neat CNSL oil, brake thermal efficiency is always lower than the blends of CNSL oil as well as diesel.

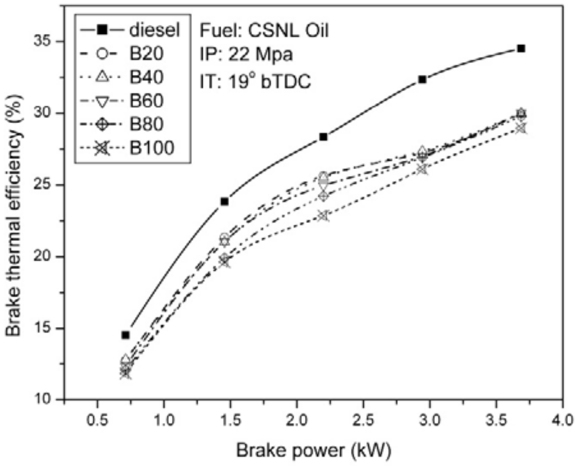

Fig. 8 Comparison of Brake thermal efficiency

D. Specific fuel consumption

The variation of specific fuel consumption with load for different fuels is presented in Fig.9 The specific fuel consumption of CNSL oil is higher than that of diesel for all loads. This is caused due to the effect of higher viscosity and poor mixture formation of CNSL oil. For all fuels tested, specific fuel consumption is found to decrease with increase in the load. This is due to more blended fuel is used to produce same power as compared to diesel. Hence the mixture formation is very poor if we increase the amount of CNSL oil with diesel. This is proved from the graph that the B20 blend gives less fuel consumption compared to B100 blends. With increase in blend percentage in, the calorific value of fuel decreases. Hence, the specific fuel consumption of the higher percentage of blends increases as compared to that of diesel.

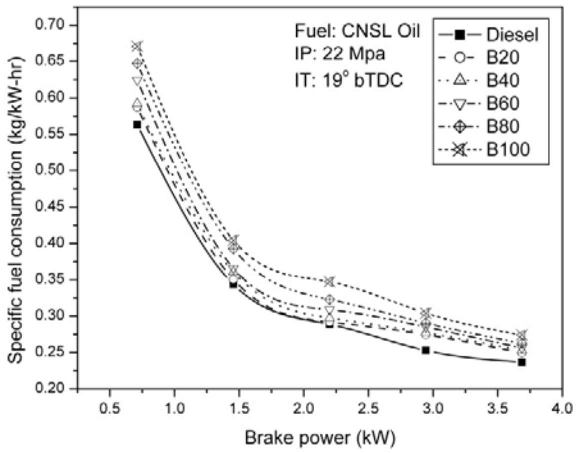

Fig. 9 Comparison of Specific fuel consumption

E. Hydrocarbon

The hydrocarbon emission is seen in Fig.10 the unburned hydrocarbon emission of blends of CNSL oil is more compared to that for neat diesel for all loads. This is because of poor mixture formation tendency of blends of CNSL oil. In addition to the other factors, the lower thermal efficiency with these blends also is responsible for this trend. It may be noted that a lower thermal efficiency with these blends will lead to injection of higher quantities for the same load condition.

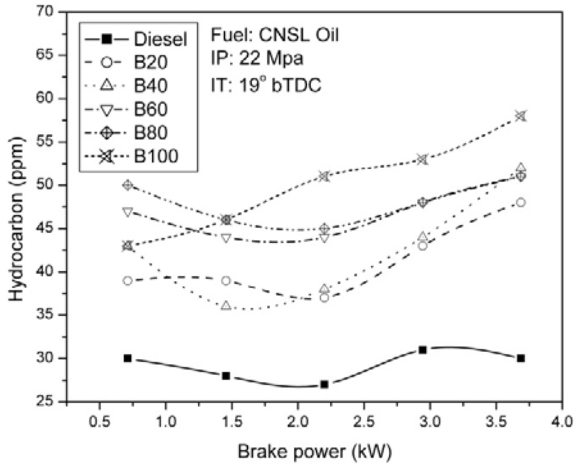

Fig. 10 Comparison of Hydrocarbon

F. Carbon monoxide

Fig.11 shows the plots of carbon monoxide emissions of the CNSL oil and various blends of biodiesel operation at the rated engine speed of 1500 rpm at various load conditions. The CO emissions increase as the air fuel ratio becomes greater than the stoichiometric value. CO concentration in the exhaust emission is negligibly small when a homogeneous mixture is burned at stoichiometric air–fuel ratio mixture or on the lean side stoichiometric. With increasing CNSL oil percentage, CO emission level increases. In the case of, 100% CNSL oil, the carbon monoxide emission is higher than that of diesel blends. This is due higher viscosity and poor atomization tendency of CNSL oil leads to poor combustion and higher carbon monoxide emission.

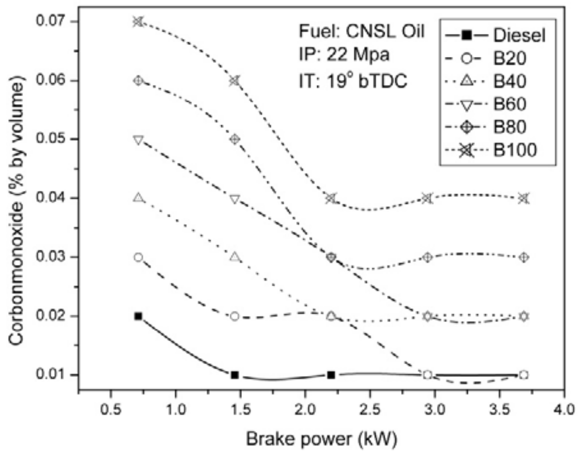

Fig. 11 Comparison of Carbon monoxide

G. Exhaust gas temperature

The variation of exhaust gas temperature with respect to applied load for different fuels tested is shown in Fig.12 It is seen that the exhaust temperature of CNSL oil is decreased because of poor combustion takes place compare to neat diesel.

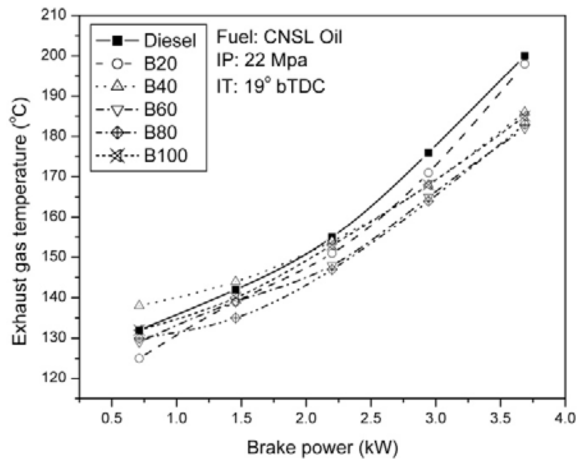

Fig. 12 Comparison of Exhaust gas temperature

H. Smoke density

The variation of smoke density with respect to different fuels is considered and depicted in Fig. 13 Smoke density for CNSL oil blends is noticed to be generally higher than that of the diesel oil. This is due to the heavier molecular structure, poor atomization, presence of high carbon residue. The viscosity of blends is comparatively lower than neat CNSL oil tested. Due to this, the spray pattern and fuel penetration are improved. The smoke density of neat diesel and B20 blend is almost same compared to neat CNSL oil this is because of less viscosity and improved atomization of fuel.

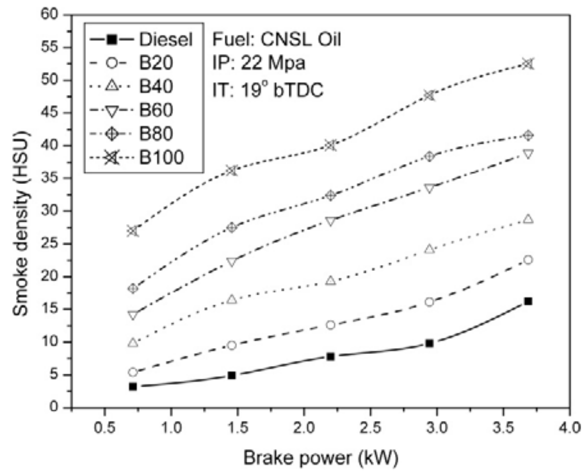

Fig. 13 Comparison of Smoke density

I. Oxides of nitrogen

Fig.14 indicates that blends of CNSL oil shows lower NOx emission compared to neat diesel fuel. This is due to poor atomization of CNSL oil leads to poor combustion and lead lower NOx emission.

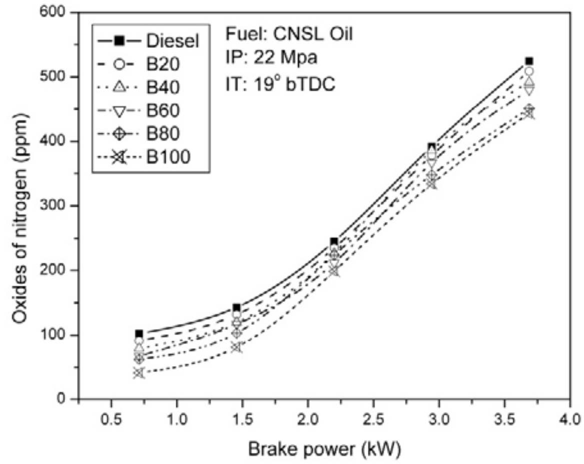

Fig. 14 Comparison of Oxides of nitrogen

VI. CONCLUSION

The performance and emissions characteristics of diesel engine using CNSL-Diesel blends have been analysed and presented as follows. It is found that the optimized injection timing and optimized injection pressure is 19° bTDC and 22 Mpa respectively for diesel operation. The brake thermal efficiency is decreased with higher blends of CNSL oil (B40, B60, B80 and B100) compared to neat diesel operation. But in the case of lower blend B20 the brake thermal efficiency is closer to diesel operation. The specific fuel consumption is increased in the case of CNSL-Diesel blends compared to neat diesel. The unburned hydrocarbon and carbon monoxide emissions are increased with blends of CNSL-Diesel as compared to neat diesel. The smoke density also increases for the blends of CNSL-Diesel compared to neat diesel operation. The Oxides of Nitrogen (NOx) emission level is decreased with the blends of CNSL oil compared to neat diesel. The exhaust gas temperature decrease with the blends CNSL-Diesel compared to neat diesel. In general the performance and emission level of CNSL-Diesel blends does not improve, but it can be used as a low cost alternative fuel for diesel engine. In future the additives and oxygenates can be used with CNSL–Diesel fuel to improve the performance and emission of direct injection diesel engine.

REFERENCES

[1] Fernando José Araújo da Silva, José Everardo Xavier de Matos (2009)“A note on the potential of CNSL in fuel blends for engines in Brazil” Rev. Tecnol., Fortaleza, v.30, n.1, p. 89-96
[2] Maria Alexsandra Rios Fac¸anha ,Selma Elaine Mazzetto, Jose´ Osvaldo Beserra Carioca, Glaucione Gomes de Barros(2007) “Evaluation of antioxidant properties of a phosphorated cardanol compound on mineral oils (NH10 and NH20)” Fuel 86 2416–2421
[3] RajeshN,Patel,santanu Bandyopadhyay and Anuradda Ganesh(2006) “Extraction of cashew (Anacardium occidentale) nut shell liquid using supercritical carbon dioxide” Bio re source technology 97 847-853.
[4] Piyali Das,T.Sreelatha and Anuradda Ganesh(2004) “ Bio fuel from pyrolysis of Cashew nut shell – characterization and related properties”. Biomass and bioenergy 27 265-275.
[5] Piyali Das and Anuradda Ganesh (2003) “Bio fuel from pyrolysis of Cashew nut shell – a near fuel” Biomass and bioenergy 25 113-117.