Study of Effect of an Antioxidant on the Performance of a Diesel Engine using Diesel and Rice Bran Biodiesel Blends

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***Abstract*— It has become apparent that biodiesel is destined to make a substantial contribution to the future energy demands of the domestic and industrial economies when society is becoming increasingly aware of the declining reserves of fossil fuels beside the environmental concerns,. Though there is an increase in productivity of biodiesel, there still remains some concern for commercialization due to its susceptibility to degradation during long storage. In the present study N,N0-diphenyl-1, 4-phenylenediamine (DPPD) is used as an antioxidant for the diesel and rice bran biodiesel blends and studied the effect on the properties of the fuel blends and also on the performance characteristics of a single cylinder diesel engine. It is observed that the properties of rice bran biodiesel blends with and without are within the standard limits. The brake thermal efficiency is increased up to 3.54%, brake specific fuel consumption is reduced up to 1.81% and exhaust gas temperature is reduced by a maximum of 2.53% for the blends with the addition of antioxidant.**

Keywords*— *Diesel engine, biodiesel, performance, antioxidant

INTRODUCTION

Fuel crisis and environmental concerns have renewed the interest of scientific community to look for alternative fuels of bio origin such as vegetable oils. Biodiesel is an alternative to petroleum-based diesel fuel and is made from renewable resources such as vegetable oils, animal fats, or algae. It is an oxygenated, sulfur-free, biodegradable, non-toxic, and environmentally friendly fuel. Biodiesel fuels are obtained by transesterification of vegetable oils [1]. The major drawback of biodiesel is its inferior oxidative and storage stability. It is more susceptible to degradation compared to fossil diesel because of fatty acid chain unsaturation [2,3]. It is well reported in the literature that oxidation stability does not correlate with the total number of double bonds but with the total number and position of allylic and bisallylic carbons that are adjacent to double bonds [4]. These oxidation processes are less pronounced in the parent oil due to the presence of natural antioxidants which get partially lost during refining [5].

Ryu [6] studied the effect of antioxidant addition to soybean biodiesel. He reported that tert-butylhydroquinone (TBHQ) was the best stabilizer among the five tested antioxidants. He conducted test with varying proportions of TBHQ for performance, combustion and emission analysis. Rizwanul et al [7] investigated experimentally the effect of antioxidant additives on the performance and emission characteristics of a four cylinder four stroke indirect injection diesel engine. Two monophenolic, 2(3)-tert-Butyl-4-methoxyphenol (BHA) and 2,6-di-tert-butyl-4-methylphenol (BHT) and one diphenolic, 2-tert-butylbenzene-1,4-diol(TBHQ) were added to a blend B20. The addition of antioxidants to B20 increased oxidation stability and brake power and reduced brake specific fuel consumption slightly. The antioxidants reduced 1.6 to 3.6% NO_x emissions but increased both CO and HC emissions. Rizwanul et al [8] added two antioxidants BHA and BHT to 20% coconut biodiesel in diesel (CB20) and reported that the antioxidants significantly reduced NO_x emission with a slight effect on brake thermal efficiency.

Umesh et al [9] studied the effect on the performance and emission characteristics of a diesel engine using p-phenylenediamine (PPD) as an antioxidant for the blends of diesel and jatropha biodiesel. The addition of PPD resulted in mean increase of brake thermal efficiency by 9.29%, brake specific fuel consumption by 4.71% and exhaust gas temperature reduced by 5% when compared with a blend of diesel with 20% biodiesel (JB20). The NO_x emissions reduced by 6.86%, HC and CO emissions increased by 25.62% and 28.81% respectively when compared with JB20. Kalamand Masjuki [10] found that B20X with 1% 4-nonyl phenoxy acetic acid (NPAA) additive produced higher brake power over the entire speed range in comparison to B20 and B0 (diesel), and the maximum brake power obtained at 2500 rpm is 12.28 kW from B20X followed by 11.93 kW (B0) and 11.8 kW(B20). Varatharajan and Cheralathan [11] also used several additives such as N,N0-diphenyl-1, 4-phenylenediamine (DPPD), NPPD, p-phenylenediamine (PPD), ethylenediamine (EDA), a-Tocopherol acetate, BHT and L-ascorbic acid in 20% and 100% biodiesel in a single-cylinder diesel engine and found DPPD was more effective than others. They also reported 0.15% (m) DPPD is the optimum concentration based on emission results. G. Balaji and M. Cheralathan [12] reported that the addition of p-phenylenediamine (PPD) to pure biodiesel of neem resulted in reduced NO emissions by 35%, HC emissions by 31%

when compared with neem biodiesel at full load operation of the engine. There is a slight increase in CO and CO_2 emissions by the addition of PPD to the biodiesel. The brake thermal efficiency decreased and brake specific fuel consumption increased slightly with the addition of PPD to the biodiesel.

As the addition of antioxidant is preferred for higher storage stability, hence its effect on engine performance and emission needs proper investigation. Rice Bran Oil (RBO) is extracted from the germ and inner husk (called bran) of the rice. Rice bran is mostly oily inner layer of rice grain which is heated to produce RBO [13]. RBO is not a common source of edible oil compared to other traditional cereal or seed sources such as corn, cotton, sunflower or soybean. One of the best ways for the potential utilization of RBO is the production of biodiesel [14]. The performance and emission characteristics of the biodiesel blended up to 20% were close to that of diesel fuel [15, 16].

No experimental studies have been found using DPPD as an additive for rice bran biodiesel in a diesel engine. In the present investigation the performance characteristics of a diesel engine were studied by using DPPD antioxidant in a blend of 80% diesel and 20% rice bran oil biodiesel and compared with that of the diesel fuel.

I. MATERIALS & METHODS

In the present investigation conventional diesel fuel, rice bran oil biodiesel and DPPD were used. The fuels tested were pure diesel (B0), rice bran biodiesel (B100), blends of 90% diesel and 10% rice bran biodiesel (B10), B10with 0.15% DPPD (B10D15), 80% diesel and 20% rice bran biodiesel (B20) and B20 with 0.15% DPPD (B20D15). Fuel properties that are important from engine performance and emission point of view such as density, viscosity, net heating value, acid value, flash point, cetane number of the above fuel blends were determined and shown in the table 1 and table 2.

TABLE 1: properties of diesel, rice bran biodiesel blends

Property parameters	**Diesel fuel (B0)**	**Rice bran oil biodiesel(B 100)**	**Diesel rice bran biodiesel blends**	
			B10	**B20**
Density at 20 ^{0}C, g/cm3	0.82	0.874	0.083	0.838
Viscosity at 40^0 C, mm2/s	3.4	4.63	3.55	3.68
Flash point, ^{0}C	71	165	73	87
Pour point, ^{0}C	1	3	1	1
Cetane number	45	56.2	46.3	47.5
Acid value, mg KOH/g	0.07	0.25	0.1	0.14
Net heating value,MJ/kg	43.5	38.725	42.945	42.183

TABLE 2: properties of diesel and rice bran biodiesel blends with DPPD.

Property parameters	**Diesel rice bran biodiesel and DPPD blends**	
	B10D15	***B20D15***
Density at 20 ^{0}C, g/cm3	0.825	0.834
Viscosity at 40^0 C, mm2/s	3.6	3.73
Flash point, ^{0}C	74	88
Pour point, ^{0}C	1	1
Cetane number	46	47.2
Acid value, mg KOH/g	0.11	0.15
Net heating value, MJ/kg	43.12	42.43

It is observed that all the properties of the blends are within the standard limits.

The experimental set up consists of a diesel engine, engine test bed, the fuel and air consumption metering equipments. The schematic diagram of the engine test rig is shown in *fig1*.

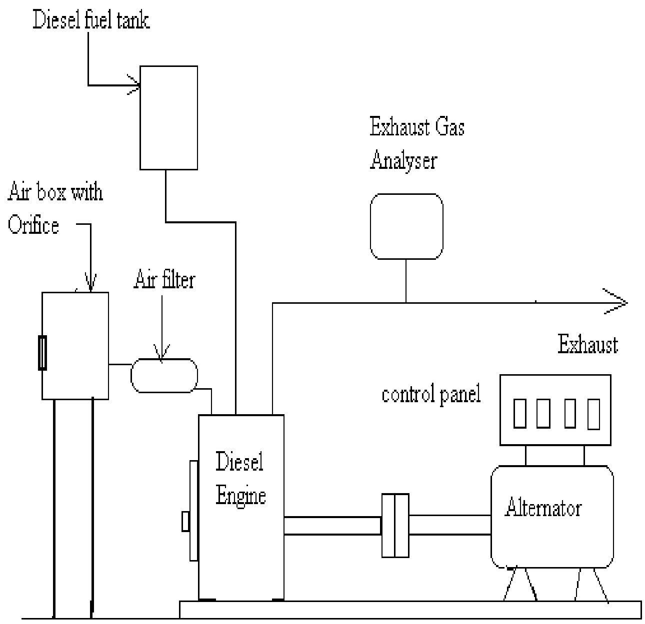

Fig.1: Schematic diagram of the experimental setup

The specifications of the test engine are given in the table 3.

TABLE 3. Specifications of diesel engine

Make	Kirloskar model AV1
No. of Strokes per cycle	4
No. of Cylinders	single
Combustion chamber position	vertical
Cooling method	Water cooled
Starting condition	Cold start
Ignition technique	Compression ignition
Bore (D)	80 mm
Stroke (L)	110 mm
Rated speed	1500 rpm
Rated power	5 hp (3.72 kW)
Compression ratio	16.5 : 1

The engine was first operated on diesel fuel with no load for few minutes at rated speed of 1500 rpm until the cooling water and lubricating oil temperatures comes to 85^0 C. The same temperatures were maintained throughout the experiments with all the fuel modes. The baseline parameters were obtained at the rated speed by varying 0 to 100% of load on the engine with an increment of 20%. The diesel fuel was replaced with the rice bran oil biodiesel and test was conducted by varying 0 to 100% of load on the engine with an increment of 20%. After using rice bran biodiesel, the blends of diesel and rice bran biodiesel B10, B20 & diesel, rice bran biodiesel and DPPD blends B10D15, B20D15 were used one after the other. The tests were conducted with these blends by varying the load on the engine. The brake power, fuel consumption and exhaust gas temperature were measured for diesel fuel, RBD and all its blends with DPPD separately under all load conditions. The brake power was measured with the help of eddy current dynamometer. The fuel consumption was measures by using a pipette with three way cock and a stop watch. The exhaust gas temperature was measured with the help of iron-constantan thermocouples. The results of the engine operating on rice biodiesel and its blends were compared with the baseline parameters obtained during engine fuelled with diesel fuel at rated speed of 1500 rpm.

II. RESULTS & DISCUSSIONS

The variation of brake thermal efficiency for diesel, RBD and its blends with DPPD is shown in the *fig.2*. The brake thermal efficiency (BTE) of rice bran biodiesel is higher than that of the diesel fuel at all conditions of load on the engine. The BTE of B10 and B20 is 0.735% and 1.1% respectively higher than that of diesel fuel at full load operation of the engine. The BTE of B10 and B20 increased with the addition of DPPD and it is respectively 2.94% and 3.54% higher than that of diesel fuel at full load operation of the engine.

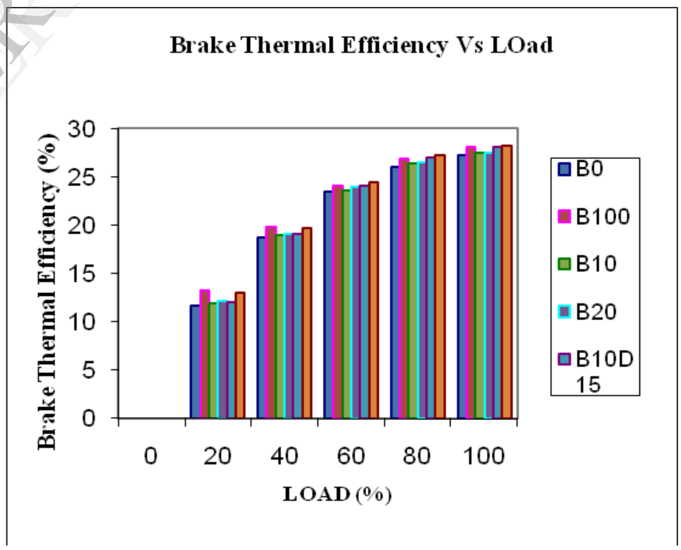

Fig.2. Variation of brake thermal efficiency with load

The variation of brake specific fuel consumption (BSFC) with load for diesel, rice bran biodiesel and their blends with and without anti oxidant are shown in the *Fig.3*. The BSFC is decreasing with load for all the fuels tested. The BSFC of rice bran biodiesel is higher than all the other fuels samples at all load conditions of the engine. It is due to lower heating value and higher viscosity of the biodiesel. The BSFC of B10 and B20 is 3.69% and 5.4% higher than that of diesel at full load operation of the engine. The BSFC of B10 and B20 reduced by 1.81% and 1.7% with the addition of the antioxidant DPPD.

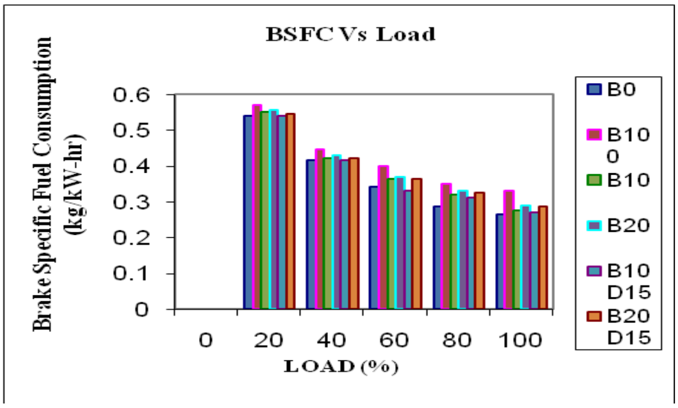

Fig.3. Variation of brake specific fuel consumption with load

The variation of exhaust gas temperature (EGT) with load for diesel, rice bran biodiesel and their blends with and without anti oxidant are shown in the *fig.4*. The exhaust temperature of rice bran biodiesel is higher than all the fuel samples at all load conditions of the engine. The EGT of pure rice bran biodiesel is at a maximum 37.6% higher than that of diesel fuel at full load operation of the engine. The EGT of B10 and B20 is 6.8% and 11.4% respectively higher than that of diesel fuel. The EGT of B10 and B20 is reduced with the antioxidant. The EGT of B10 and B20 is respectively reduced by 2.4% and 2.53% with the addition of DPPD.

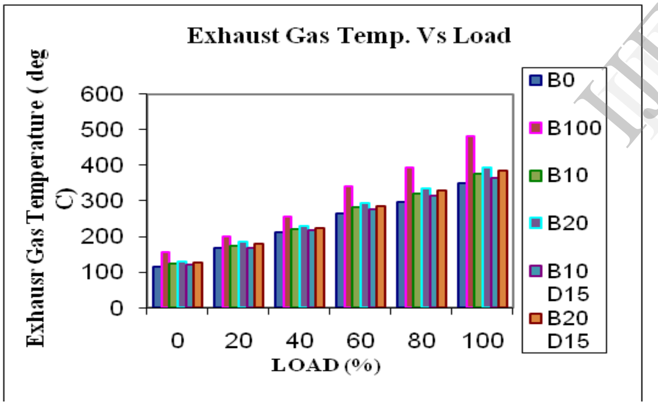

Fig.4. Variation of exhaust gas temperature with load

III. CONCLUSIONS

- The properties of diesel and rice bran biodiesel blends with and without the additive are within the standard limits of a diesel engine fuel.
- The brake thermal efficiency of the blends B10 and B20 is higher than that of diesel fuel and further improved by adding antioxidant to them.
- The brake specific fuel consumption of the blends B10 and B20 is higher than that of the diesel fuel but reduced with the addition of antioxidant to them.
- The exhaust gas temperature of the blends B10 and B20 is higher than that of the diesel fuel but reduced with the addition of antioxidant to them
- The addition of DPPD as an additive to the diesel and rice bran biodiesel blends prevents the oxidation of biodiesel, improves brake thermal efficiency and reduces brake specific fuel consumption and exhaust temperature.

REFERENCES

[1] Devershi Mourya, Vivek Roy. "Combustion modeling and simulation of combustion emissions for diesel engine operating on the blends of jatropha biodiesel and diesel", International Journal of Engineering science and Technology,vol.4, No.4, pp. 1373-1381, April 2012.

[2] J Pullen, K Saeed . "An overview of biodiesel oxidation stability", Renewable and sustainable energy reviews, vol.16,(8), pp.5924-5950, 2012

[3] S Jain , M.P.Sharma M. "Stability of biodiesel and its blends: A review", Renewable and sustainable energy reviews, vol. 14,(2), pp.667-678, 2010

[4] H. L.Fang and R. L. McCormick . "Spectroscopic study of biodiesel degradation pathways," SAE Technical Paper, Society of AutomotiveEngineers: Warrendale, 2006, PA: 01-3300.

[5] Y. B. Lamba, H. Singh and M. S. M. Rawat (2011), "Oxidation stability of methyl ester and diesel fuel blends,"-ErdolErdgasKohle, 127:91–93.

[6] K Ryu . "The characteristics of performance and exhaust emissions of a diesel engine using a biodiesel with antioxidants", Bioresources Technology, vol 101, 2010(1, supplement), s 78-s82.

[7] I.M. Rizwanul Fattah, H.H. Masjuki, M.A. Kalam, M.A. Wakil, A.M. Ashraful, S.A. Shahir . "Experimental investigation of performance and regulated emissions of a diesel engine with Calophyllum inophyllum biodiesel blends accompanied by oxidation inhibitors", Energy conversion and management, vol. 83, pp. 232-240, 2014

[8] I.M. Rizwanul Fattah, Masjuki Hj Hassan, Md Abul Kalam, Abdelaziz Emad Atabani, Md Joynul Abedin. "Synthetic phenolic antioxidants to biodiesel: Path towards NO_x reduction of an unmodified indirect injection diesel engine", Journal of Cleaner Production, vol. 79, pp.82-90, 2014

[9] Umesh G Gharat, Raj kumar Gupta, K Madhu Murthy. "Experimental investigation to reduce emissions of direct injection diesel engine fuelled with methyl ester of jatropha oil using antioxidant", International journal of engineering development and research, vol. 2, Issue 2., pp.2922-2929, 2014

[10] M.A Kalam, H.H Masjuki. "Testing palm biodiesel and NPAA additives to controlNOx and CO while improving efficiency in diesel engines", Biomass Bioenergy, vol.3, pp.:1116–22, 2018

[11] K Varatharajan , M Cheralathan. " Effect of aromatic amine antioxidants on NOx emissions from a soybean biodiesel powered DI diesel engine", Fuel Process Technology, vol. 106, pp.526–32,2013.

[12] G. Balaji and M. Cheralathan. "Experimental reduction of NOx and HC emissions in a CI engine fuelled with methyl ester of neem oil using p-phenylenediamine antioxidant", Journal of Scientific & Industrial research, vol.73, pp. 177-180, March 2014

[13] Syed Altaf Hussain, G.Venkata subbaiah, and V. Pandurangadu. "Performance and emission characteristics of a supercharged direct injection diesel engine using rice bran oil", i-manager's Journal on Future Engineering & Technology, vol. 4, No. 4, pp. 48-53,2009

[14] Yi-Hsu Ju, and Shaik Ramjan Vali. "Rice bran oil as a potential source for biodiesel: A review" Journal of Scientific & Industrial Research, vol. 64, pp.866-882, 2005

[15] D FJayant Singh, T. N. Mishra, T. K. Bhattacharya, and M. P. Singh. "Emission Characteristics of methyl ester of rice bran oil as fuel incompression ignition engine". World Academy of Science. Engineering and Technology, vol. 3(6), pp.198-202,2007

[16] B.K.Venkanna, C. Venkataramana Reddy, Swati B Wadawadagi. "Performance, Emission and Combustion Characteristics of Direct Injection Diesel Engine Running on Rice Bran Oil / Diesel Fuel Blend", International Journal of Chemical and Biomolecular Engineering, vo. 2(3), pp. 131-137,2009