EXPERIMENTAL INVESTIGATION OF CAMPHOR ENRICHED METHYL ESTERIFIED RICEBRAN BIODIESEL WITH PHOTOCATALYTIC EMISSION REDUCTION TECHNIQUES IN A VCR COMPRRESSION ENGINE

*G.Shaik UsmanSha, Research scholar

K.Senthil Kumar, Associate Professor

Department of Mechanical Engineering,SNS College of Engineering,Coimbatore,India

Abstract

The current scenario and the major crisis faced by automotive sector throughout the world is the depletion of fossil fuels and toxic, fatal emissions pushed out through the tailpipe of internal combustion engine. Especially the emissions from compression ignition engine has to be taken care of and with the help of technological development many are seeking to invent techniques and procedure to replace and keep aside diesel fuel with alternate fuels and especially bio-derived combustion fuels. In the recent year scientist have came up with ideas to replace diesel fuels and there are suggestions that bio oil- diesel blend bio fuels along with alcohol and other combustion enhancement or property improvement mixtures can do and bring acceptable changes with fulfilling the requirements. Former scientific investigations have presented that biodiesel and various blends can reduce emissions and improve performance of a diesel engine. In this current investigation rice bran oil-diesel blend and camphor were prepared to check its effect of performance and emission character in a compression ignition engine. Biodiesel was prepared in single stage alkaline trans-esterification process and after then biodiesel-diesel-camphor blend were prepared as B20, B30. These blends were tested in a single cylinder, diesel engine with rated power of 5KW, performance and emission data are compared with that of baseline commonly used diesel. Further it was noted with usage of bio diesel-diesel blends the NO_x emission increases and in this investigation titanium dioxide a photocatalyst which has the capability to react with NO_x in presence of a light source is used to reduce emission. Experimental investigation gave output that biodiesel-diesel-camphor blend can be used in compression ignition in without any changes in engine's working parameters and emission is reduced using a photocatalyst titanium dioxide in exhaust gas track.

Keywords: Ricebran,VCR,Camphor,emission,photocatayst

1. Introduction

Even though diesel engine's contribution to carbon emission and succeeding global warming issues can't be avoided, diesel engines are one of the dominant prerequisites nowadays in so many sectors owing to the fact that it has better fuel economy, higher efficiency, more reliability, lower fuel cost, and long lasting capacity. Tailpipe emissions from these engines are very badly affecting the mankind and habitat from so many decades. Moreover, due to the hike in automobiles on roads the fossil fuels are depleting at an alarming rate which may result in its permanent deterioration in few decades. To overcome this, diesel engine specialists, researchers, and combustion analysts are trying to find a substitute fuel which can upgrade the performance characteristics of the engine and cut down exhaust emissions (Mahalingam et al., 2018; Mahla et al., 2018a; Singh et al., 2018; Chauhan et al., 2011). Biofuels is the primary choice of the researchers amidst all alternative fuels due to its properties which help in producing fewer greenhouse gases and soot emissions. Furthermore, these are sustainable in nature and economical than conventional fuels (Singh et al., 2018). Researchers have done experimentation and simulation study on diesel engines by using biodiesel prepared from various vegetable and animal fat oils and found that amidst reasonable, low grade and renewable vegetable oils Rice bran oil secures top position (Yuan et al., 2013; Chauhan et al., 2010a; Singh et al., 2012; Chauhan et al., 2010b; Sharma et al., 2013; Rai et al., 2013b; Goga et al., 2018; Chhabra et al., 2017). Bora and Saha (2015) explored the opportunity of using Rice bran biodiesel, Palm oil biodiesel and Pongamia oil biodiesel as pilot fuel for a biogas run dual fuel diesel engine and revealed that Rice bran methyl ester was best in performance among all biodiesel oils. Liquid fuel reinstatement was also found maximal for Rice bran biodiesel whereas there was a decrement in HC and CO emissions for Rice bran methyl esters. The emission study also stated that NOx emission declined for Palm oil and Pongamia oil methyl esters. Kaimal and Vijayabalan (2015) performed an experimental investigation on a diesel engine using Rice bran oil biodiesel and plastic oil and concluded that brake specific energy consumption of Rice bran methyl esters is more than plastic whereas the thermal efficiency of the engine was on the lower side with Rice bran biodiesel and plastic oil as compared to that of diesel.

Blends of diesel and biodiesel have been tested by so many diesel engine experts, but the use of these blends for an extended period results in a dilemma concerning operation and endurance of the engine due to higher viscosity, lower energy content, higher pour point, lower volatility etc. of biodiesel (Murugesan et al., 2009; Sivalakshmi and Balusamy, 2011). To overcome this camphor is added to blends of diesel and biodiesel which can assist in utilizing these blends in diesel engines for a long-term without any hassle owing to properties of n-butanol like lower pour point, lower viscosity, higher miscibility, lower density, improved blending stability etc.

The review of the literature has concentrated largely on performance and emission characteristics of diesel engines fuelled with biodiesel and camphor blends. It can be seen that methyl esters and camphor can increase the efficiency of the engine and can also help in reducing the harmful gases emitted from the exhaust. According to open literature, no study has yet been initiated by any researcher to find out the effect of camphor on a diesel engine fuelled with Rice bran biodiesel and emission reduction possible with titanium dioxide as a photocatalyst. Hence, in the current experimentation, the effect of Rice bran methyl esters blended with camphor will be evaluated on a diesel engine and emission reduction experimentation done with exhaust track coated with photocatalyst TiO_2 in presence of 5W light source.

2. Materials and methodology

2.1. Fuel properties and mixing

The oil derived from the tough outlaying beige coloured coating of rice is known as Rice bran oil. Non-edible grade Rice bran oil was purchased from the local market to prepare biodiesel. Transesterification process was used to produce biodiesel from Rice bran oil in the chemistry lab. Other chemicals like methanol (purity 98%), camphor (purity 99.8%), and potassium hydroxide (purity 97%) were bought from bawa chemicals, kerala, India. camphor was added as combustion enhancer while methanol and potassium hydroxide was used as alcohol and catalyst respectively for preparing biodiesel.

In the present experimentation diesel and Rice bran oil biodiesel blends were prepared. The blended fuel comprises 10% and 20% of biodiesel by volume and camphor is named as B10 and B20 respectively.

The basic composition of any vegetable oil is triglyceride, which is of three fatty acids and one glycerol molecule. Biodiesel is defined as the mono-alkyl esters of fatty acids derived from vegetable oils or animal fats. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat is chemically reacted with an alcohol to produce fatty acid alkyl esters in the presence of a catalyst (sodium or potassium hydroxide). In the process, glycerol is obtained as a co-product. The fatty acid composition of different biodiesel fuels is given in Table 1.

Table 1. Composition of bio-diesel

Fatty Acids	Chain Length	Type	Fatty Acid Composition wt%
lauric	12:0	S	0.82
myristic	14:0	S	0.42
palmitic	16:0	S	17.9
stearic	18:0	S	21.3
oleic	18:1	US	42.6
linoleic	18:2	US	15.3
linolenic	18:3	US	0.28

2.2 Biodiesel production

A two step “acid – base” process with acid – pretreatment followed by main base – transesterification process was done. Methanol was used as a reagent and H_2SO_4 and KOH as catalysts for acid and base reactions. Accordingly, biodiesels were produced from crude rice bran.

Table 2: Engine specification

PARAMETER	DESCRIPTION
Manufacture	kirloskar
Rated power output (kW)	3.5
Engine cooling	Air cooled
Engine speed(rpm)	1500
Number of cylinders	1

Stroke length (mm)	110
Bore (mm)	87.5
Compression ratio	16:1 (VCR with range of 12-18:1)
Displacement (cc)	661
Injection pressure (kg cm^{-2})	200

3. Experimental Set Up

A single cylinder, small utility diesel engine with a rated power output of 3.5 kW was employed in this study. It was direct injection; air-cooled engine manufactured by Kirloskar Oil IndiaLtd. Experimentation was done at a constant speed of 1500 rpm.Technical specification of the experimental test set up is illustrated in Table 2.The power output of the engine was measured by an eddy current dynamometer coupled with the engine shaft and loaded with help of resistive load bank. An AVL DIGAS 444 N gas analyser was used to measure the concentration of gaseous emissions such as unburned hydrocarbon, carbon monoxide, carbon dioxide, and nitrogen oxides. Digital readings of all the gaseous emissions were obtained by placing the probe in the exhaust of cylinder. A smoke meter was used to measure the smoke opacity. Accuracy and range of gas analyser and smoke meter are shown in Table 3 and test rig and analyser shown in figure 1&2 respectively. Figure 3 shows the exhaust gas track coated with photocatalyst titanium dioxide (TiO_2) and a light source of 5W attached along for its proper functioning to reduce emissions.

Table 3: Uncertainty, Range and accuracy of gas analyzer

Exhaust emissions	Range	Accuracy	uncertainties
HC	0-20,000 ppm	± 10 ppm	± 0.1(%)
CO	0-3000 ppm	0.0015 %	±0.4 (%)
NO_x	0-3000 ppm	± 10 ppm	±0.2 (%)

Figure 1: Engine test rig

Figure 2: Exhaust gas analyzer

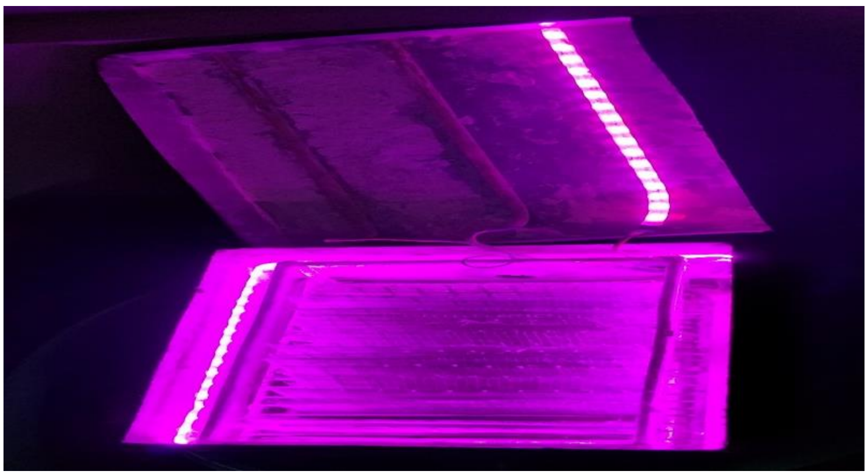

Figure 3: Exhaust gas track coated with TiO_2 and arrangement of 5W UV light source

4. Result and discussion

The performance and emission parameters of the diesel engine energized with rice bran methyl esters and camphor are discussed in this segment. Whole experimentation was repeated for three times and mean value was taken to assure the certainty of the result.

Brake thermal efficiency

The table 4 and 5 illustrates the comparison of Brake thermal efficiency values of biodiesel blends and straight diesel. The blend has higher BTE than diesel. This is due to the inhumed mixing of biodiesel-air along with better combustion results leading to maximum thermal efficiency. The BTE of the diesel increases initially but as the RPM keeps on increasing

Table 4: BTE of B20 fuel

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1528.00	6.19	69.32	22.78
1510.00	9.27	67.14	27.52
1496.00	12.14	59.07	29.89

Table 5: BTE of pure diesel

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1525.00	6.12	69.24	21.44
1511.00	9.17	65.33	26.52
1498.00	12.09	61.91	29.70

Specific fuel consumption

Table 6 and 7 indicates the variation of SFC values against various load and RPM for the tested biodiesel blend. When brake mean effective pressure of the cylinder increases along with RPM and load, specific fuel consumption will decrease. The specific fuel consumption values of blends normally decreases for all the blends and straight diesel with increase in the BMEP values. The blend B20 and diesel show sudden increase in fuel consumption at pressure. The reason is at higher pressure fine atomized fuel mixes homogenously with air and additives and hence less fuel is needed.

Table 6: SFC of B20 fuel

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1528.00	6.19	0.42	0.75
1510.00	9.27	0.32	0.85
1496.00	12.14	0.32	1.10

Table 7: SFC of pure diesel

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1525.00	6.12	0.42	0.75
1511.00	9.17	0.34	0.90
1498.00	12.09	0.30	1.05

Table 8: Emission result of pure diesel @ compression ratio value 16

FUEL	COMPRESSION RATIO	LOAD	EMISSIONS	EMISSION VALUES	UNIT	EMISSION VALUES WITH TiO_2 5W
DIESEL	16	6	CO	0.32	% VOL	0.1
			HC	65	PPM HEX	39
			CO2	3.4	% VOL	0.8
			O2	15.64	% VOL	19.42
			NO	136	PPM VOL	22
			LAMDA	5.107	DEG CEL	
DIESEL	16	9	CO	0.21	% VOL	0.03
			HC	61	PPM HEX	35
			CO2	4.3	% VOL	0.4
			O2	14.21	% VOL	20.07
			NO	505	PPM VOL	32
			LAMDA	4.094	DEG CEL	
DIESEL	16	12	CO	0.18	% VOL	0.18
			HC	56	PPM HEX	66
			CO2	5.7	% VOL	6.1
			O2	12.36	% VOL	11.69
			NO	894	PPM VOL	1025
			LAMDA	3.069	DEG CEL	2.829

Table 9: Emission result of B20 diesel with 5 grams of camphor and TiO_2, 5 W light source

FUEL	COMPRESSION RATIO	LOAD	EMISSIONS	EMISSION VALUES	UNIT	TiO_2 5W
			CO	0.28	% VOL	0.05
			HC	63	PPM HEX	42
			CO2	3.3	% VOL	0.7
			O2	15.65	% VOL	19.48
			NO	200	PPM VOL	78
			LAMDA	5.276	DEG CEL	
			CO	0.19	% VOL	0.11
			HC	62	PPM HEX	55
			CO2	4.5	% VOL	2.7
			O2	14.08	% VOL	16.64
			NO	564	PPM VOL	361
			LAMDA	3.95	DEG CEL	6.822
			CO	0.19	% VOL	0.14
			HC	74	PPM HEX	71
			CO2	5.8	% VOL	4.7
			O2	12.2	% VOL	13.68
			NO	992	PPM VOL	841
			LAMDA	2.998	DEG CEL	3.778

Carbon monoxides

The CO emission of biodiesel blend with action of photocatalyst and straight diesel at different load conditions are shown in table 8&9. The carbon monoxide emission is found to be maximum for diesel among all tested fuels at all loads. The reason for this is due to the incomplete combustion of diesel fuel in the engine cylinder. When the engine load increases the CO emission for diesel increases but this trend could not be seen in the biodiesel blends.

Hydro carbons

The emission of unburnt hydro carbons in the exhaust gasses has many adverse effects on the atmosphere which leads to global warming. The table 8&9 indicates the HC emission at different loads for diesel and biodiesel with photocatalyst in conventional engines. Diesel records the highest HC emission at all loads.

Carbon di oxides

The table 8&9 presents the variation of CO_2 emissions in the exhaust gases of tested blend with photocatalytic presence and straight diesel. The straight diesel has almost same emission as that of the biodiesel at various loads with little variations. This indicates that the combustion pattern of the biodiesel blends is similar to that of the straight diesel.

Nitrogen oxides

Furnishes the NO_x emission values for the biodiesel blend in the presence of photocatalyst and diesel against rated loads. N_{Ox} emission is least for bio-diesel in the presence of photocatalyst among all the tested fuels at all loads.

5. Conclusions

An experimental investigation was performed on a single cylinder diesel engine using rice bran biodiesel and camphor blend B20, in presence of photocatalyst titanium dioxide. Performance and emissions characteristics were noted at various engine loads and SFC, BTE, CO, HC and NOx, were compared with diesel fuel. Following was concluded:

1. Brake specific fuel consumption increased with increase in the quantity of biodiesel and camphor in the blends and is higher than diesel fuel.
2. Brake thermal efficiency enhanced for camphor added B20 bio-diesel fuel
3. Carbon monoxide emissions and smoke were found to be decreased with the inclusion of rice bran biodiesel in the blends and were further decreased with photocatalyst
4. Blends with rice bran oil also found to reduce hydrocarbon emissions, further reduced with the help of photocatalyst
5. Nitrogen oxide emissions reported more by adding biodiesel but experimenting photocatalyst in exhaust gas track and triggering its working with a light source showed lowering of nitrogen oxide values through tail pipe

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