PERFORMANCE AND EMISSION CHARACTERISTICS OF A COMPRESSION IGNITION ENGINE USING BLENDS OF BIO-OIL AS A FUEL

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SHRnutí

Rostlinné oleje mohou být s výhodou využity jako paliva pro vznětové spalovací motory, protože jejich vlastnosti se blíží vlastnostem nafty. Avšak vyšší viskozita rostlinných olejů má za následek nesprávné rozprášení paliva během vstřiku, což vede k nedokonalému spalování. Viskozitu rostlinných olejů je možné snížit transesterifikací nebo smísením s naftou. Tento článek se zabývá výzkumem zaměřeným na studium vlastností neupraveného a metyl esteru oleje rostliny *jatropha curcus* (*jatropha*) a rýžového oleje vyrobeného z klíčků obilky rýže a jejich směsí s naftou od 5 do 50 objemových procent. S těmito palivy byly uskutečněny zkoušky na vznětovém motoru. Cílem zkoušek bylo dosažení porovnávacích měření výkonů a emisí pro posouzení a výpočet vlastností vznětového motoru při spalování výše uvedených paliv.

Snížení emisí společně s vyšší efektivní účinností (BTE) a snížením měrné spotřeby (BSEC) dělá ze směsi (B-20 pro metyl estery a B-15 pro nezpracované oleje) vyhovující náhradu nafty. Vlastnosti těchto olejů jsou srovnatelné s naftou.

KLÍČOVÁ SLOVA: ALTERNATIVNÍ PALIVO, TRANSESTERIFIKACE, JATROPHA CURCUS, RÝŽOVÝ OLEJ VYROBENÝ Z KLÍČKŮ OBIKY RÝŽE, VÝKON, EMISE

ABSTRACT

Vegetable oils can be used as an alternative and renewable fuel for diesel engine operation as their fuel properties are close to that of conventional diesel. However, the higher viscosity of vegetable oils causes improper atomization of the fuel during injection, resulting in incomplete combustion. The viscosity of vegetable oils can be reduced by a transesterification process or dilution with conventional diesel. This paper presents the results of investigations carried out to study the fuel properties of raw and methyl esters of *jatropha curcus* (*jatropha*) and rice bran oil, and blends with diesel fuel from 5-50% by volume, and the running of a diesel engine on these fuels. Engine tests were carried out with aim of obtaining comparative measures of performance and emissions to evaluate and compute the behavior of the diesel engine running on the above-mentioned fuels.

The reduction in exhaust emissions together with increase in brake thermal efficiency (BTE) and reduction in brake specific energy consumption (BSEC) made the blends (B-20 for methyl esters and B-15 for raw oils) a suitable alternative fuel to diesel. The properties of those oils are comparable with conventional diesel.

KEY WORDS: ALTERNATIVE FUEL, TRANSESTERIFICATION, JATROPHA CURCUS, RICE BRAN, PERFORMANCE, EMISSIONS.

1. INTRODUCTION

With increasing demand for the use of fossil fuels, a greater threat to the clean environment is being posed as the burning of fossil fuels is associated with harmful emissions. These emissions are major sources of air pollution and hence pollution of the

environment. The ideal alternative fuel would be one which IC engines could burn much more cleanly than conventional diesel without the need for significant modification to existing engines [1, 2].

Vegetable oils have the potential to be considered an appropriate alternative as they possess fuel properties similar to that of diesel. A review of published literature revealed that with the use of vegetable oils as fuel in diesel engines, harmful exhaust emissions, particularly unburnt hydrocarbons (UBHC) and carbon monoxide (CO), are considerably reduced as compared to diesel. The major problem associated with the direct use of vegetable oils is their high viscosity. Possible methods to lower the viscosity are transesterification, blending, micro-emulsion and pyrolysis. Many researchers have reported that using vegetable oil esters as a fuel in diesel engines resulted in a reduction in harmful exhaust emissions whilst achieving engine performance comparable to that with diesel. With an abundance of forest and tree born oils being available in India, an attempt has been made to study the use of blends of *Jatropha* and rice bran esters and raw oil blended with diesel as a substitute for conventional diesel fuel [1, 2, 3].

1.1 TRANSESTERIFICATION

In transesterification one ester is converted into another ester in a reaction that is catalyzed by either an acid or basic involving reaction with an alcohol, typically methanol if bio-diesel is the desired product. Commonly a basic catalyst such as sodium hydroxide is used to convert the glycerol based tri-esters which make up fats and oils to a methanol based mono-ester (methyl esters) yielding free glycerol as a byproduct [3, 4]. The chemical reaction involved in this process is as shown in Figure 1.

FIGURE 1: Basic Scheme for Bio-diesel Production
OBRÁZEK 1: Základní schéma výroby bionafty

2. RESULTS AND DISCUSSIONS

2.1 FUEL PROPERTIES

The important properties of raw oils and their methyl esters are presented in Table 1 and compared with diesel fuel.

Conventional diesel has a flash point of 80°C, whilst methyl ester has a considerable higher flash point. Thus the fire hazard associated with transportation, storage and utilization of methyl esters is much less. The kinematic viscosity of raw oil is 40–49 centistokes (C.st.) and that of methyl esters of oils are 5.3 to 5.8 centistokes (C.st.). The calorific value of diesel is close to the raw and methyl ester of oils. The cetane number of vegetable oils is almost same as diesel. However, it is increased after transesterification. Therefore the properties of methyl esters are compatible with conventional diesel. Vegetable oils and esters are miscible with diesel in all proportions and hence investigation is carried out on the use of blends with diesel.

TABLE 1: Comparison of Fuel Properties of Raw and Methyl Esters of Jatropha and Rice Bran Oil with Diesel

TABULKA 1: Srovnání vlastností paliv nezpracovaného a metylesteru oleje *Jatropha* a rýžového oleje s naftou

Property	Unit	Diesel	RJO	JME	RRO	RME
Density at 40 °C	kg.m ⁻³	840	918	863	927	877
Specific gravity at 40 °C		0.84	0.918	0.863	0.927	0.877
Kinematic viscosity at 40 °C	C.st.	4.59	49.93	5.8	41.7	5.3
Calorific value	kJ/kg	42490	39774	40695	38952	39840
Cetane number		45-55	40-45	52-54	35-45	52-53
Flash point	°C	76	252	140	236	132
Fire point	°C	84	263	151	245	140
Carbon residue	%	0.1	0.54	0.23	0.81	0.34
Ash content	%	< 0.001	0.03	< 0.01	0.04	< 0.01
Color		Light yellow-blue	Light brown	Honey color	Light yellow	Light yellow

TABLE 2: Properties of Vegetable Oil Blended with Diesel in Different Proportions**TABULKA 2:** Vlastnosti rostlinného oleje smíšeného s naftou v různých objemových procentech

% of vegetable oil with diesel blend	Density Kg.m ⁻³				Calorific value kJ/kg				Kinematic viscosity at 40 °C C.st.	
	JME	RJO	RME	RRO	JME	RJO	RME	RRO	RJO	RRO
5	841	843	841	844	42400	42351	42357	42513	6.8	6.4
10	842	847	843	848	42310	42203	42203	42136	8.9	8.3
15	843	851	846	851	42206	42056	42051	41948	11.3	10.1
20	844	854	847	854	42112	41920	41881	41710	13.7	12.0
25	846	858	849	858	42041	41812	41789	41644	15.9	13.9
30	847	863	851	861	41951	41675	41645	41430	18.2	15.7
50	851	878	858	881	41592	41130	41124	40722	27.3	23.2

2.2 ENGINE TEST

The engine used for the study: Kirloskar (AV-1), single cylinder, four stroke, constant speed, vertical cylinder, water cooled, direct injection, 5HP diesel engine. The computer assisted experimental set up of the engine is shown in Figure 2. An eddy current dynamometer was used for load measurement; the engine speed was sensed and indicated by an inductive pick up sensor with digital meter output. Carbon monoxide (CO), and unburnt hydrocarbon (UBHC) content was measured using a MRU emission monitoring system shown in Figure 3.

The investigation involves the experimental analysis of the use of blends of diesel with raw oil and methyl esters of jatropha and rice bran oils.

FIGURE 2: Experimental Set up
OBRÁZEK 2: Experimentální zařízení

Tests were repeated three times and the average value was taken for analysis. The resulting data were analyzed from a graph for brake thermal efficiency (BTE), brake specific energy consumption (BSEC), unburnt hydro carbon (UBHC) and carbon monoxide (CO).

FIGURE 3: MRU Emission Monitoring System
OBRÁZEK 3: Zařízení pro měření emisí

3. ENGINE PERFORMANCE

The experiments were conducted to evaluate the performance and emissions of the diesel engine with blends of raw oils and methyl esters with diesel at 5%, 10%, 15%, 20%, 25%, 30% and 50%. Based on the results of these experiments it was observed that the best performance is obtained with B20 blend for methyl ester and B15 for raw oil blend with diesel. Hence performance and emissions of the diesel engine are discussed in this paper at optimum blend values.

3.1 BRAKE THERMAL EFFICIENCY (BTE)

Figure 4 shows the variation of BTE with BP for diesel and optimum blends of raw and methyl esters of bio-fuels. From the figure it is observed that the BTE of all oils gradually increases with BP. The maximum BTE of 23.34% is achieved with diesel, whereas for B20 and B15 blend this is 25.7% and 25.1% respectively at full load condition. The marginal variation of BTE may be due to the presence of oxygen in bio-oils, which promotes the combustion process [5, 6, 7].

FIGURE 4: Variation of BTE with BP for diesel and optimum blends of raw oils and methyl esters

OBRÁZEK 4: Změna efektivního účinnosti v závislosti na výkonu pro naftu a směsi nezpracovanými oleji a metylestery

3.2 BRAKE SPECIFIC ENERGY CONSUMPTION (BSEC)

Figure 5 shows BSEC for the considered oil fuels. BSEC is an ideal variable because it is independent of the fuel. Hence it is easy to compare energy consumption rather than fuel consumption. The energy consumption is the energy input required to develop unit power. At the full load condition BSEC is lower in the case of vegetable oil blends compared to diesel. This is due to the combined effect of the low heating value and high density of vegetable oil blends [6, 9, 10].

FIGURE 5: Variation of BSEC with BP for diesel and optimum blends of raw oils and methyl esters

OBRÁZEK 5: Změna měrné spotřeby v závislosti na výkonu pro naftu a směsi nezpracovanými oleji a metylestery

4. EMISSIONS

4.1 CARBON MONOXIDE (CO)

Figure 6 shows CO emissions with BP for all diesel and blends of raw and methyl esters.

It is observed from the figure that the blend of methyl esters displays lower values and the raw oil blend shows similar values of CO emissions when compared with diesel fuel. This may be due to the chemical composition of methyl esters [3, 5, 6].

FIGURE 6: Variation of CO with BP for diesel and optimum blends of raw oils and methyl esters

OBRÁZEK 6: Změna emisí CO v závislosti na výkonu pro naftu a směsi nezpracovanými oleji a metylestery

4.2 UNBURNT HYDRO CARBON (UBHC)

Figure 7 shows the variation of HC emissions with BP for diesel and optimum blends of bio-fuels. For efficient combustion, the fuel has to atomize, mix and ignite properly. The cetane number of the fuel plays an important role in the ignition process. As the cetane number of methyl ester is higher than for diesel or a blend of raw bio-oil, it exhibits a shorter delay period and results in better combustion. Therefore the oxygen (O_2) content and cetane number of the fuel leads to low CO and HC emissions. It is very clear from the figure that methyl esters emit lower HC than diesel or the raw oil blend [3, 5, 6].

FIGURE 7: Variation of UBHC with BP for diesel and optimum blends of raw oils and methyl esters

OBRÁZEK 7: Změna nespálených uhlovodíků v závislosti na výkonu pro naftu a směsi nezpracovanými oleji a metylestery

5. CONCLUSIONS

The following conclusions are drawn based on experimental results.

1. Transesterification yields vegetable oil properties closest to that of diesel fuel.
2. The engine runs on B20 blend of methyl ester and B15 blend of raw oil with diesel without any hardware modification to the existing diesel engine.
3. The BSEC of methyl esters is marginally lower compared to diesel and raw oil blend operation.
4. BTE of bio-fuel blends (methyl ester and raw oil) is nearly equal to diesel fuel.
5. CO and HC emissions are significantly lower with vegetable oil blends than with diesel.

The above investigation suggest that jatropha and rice bran oils in the form of 20% methyl ester and 15% of raw oil-diesel oil blends can be efficiently employed in existing diesel engines to achieve substantial savings in diesel oil and at the same time obtain comparable engine performance and exhaust emissions.

NOMENCLATURE

BP	Brake Power
BTE	Brake Thermal Efficiency
BSEC	Brake Specific Energy Consumption
CO	Carbon Monoxide
UBHC	Un Burnt Hydro Carbon
JME	Jatropha Methyl Ester
RME	Rice bran Methyl Ester
RRO	Raw Rice bran Oil
RJO	Raw Jatropha Oil

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