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Energy-exergy analysis of biodiesel fuels produced from waste cooking oil and mustard oil

Arvind Kumar Madheshiya[a,b], Ajitanshu Vedrtnam[a,b,*]

[a] Department of Mechanical Engineering, Invertis University, Bareilly, UP 243001, India
[b] Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad, Allahabad, UP 211004, India

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ABSTRACT

The present work includes the production of six blends of biodiesel using waste cooking oil/mustard oil with methanol (99% pure) having NaOH/KOH (91% pure) as the catalysts. The kinematic viscosity, density, calorific value, flash point, cloud point, pour point, and cetane number of prepared bio-fuels were determined. The comparative energy-exergy analyses for six biodiesel fuels were conducted using a 4 inline-4stroke diesel engine with 2392 cc at 0%, 25%, 50%, and 100% load for constant/varying speed. The break-power (BP), heat taken by cooling water (Q_w), heat taken away by exhaust gases (Q_{ex}), and unaccountable losses were evaluated. It was found that the tested biodiesels offer competitive energetic performance to the diesel. The exergetic performance parameters followed similar trends with the corresponding energetic ones, but with increased brake specific fuel consumption and reduced exhaust emission due to higher oxygen content in biodiesel fuel. The results of analysis of variance clearly reflect that the B.P. is influenced most by the load, followed by the type of oil and speed has the least effect. It was also found that the biodiesels are having considerably lower CO emission than diesel. NOx emissions were least at higher load in diesel followed by waste cooking oils. Soot emissions were alike for diesel, waste cooking oils, and mustered oils at low load, but at higher load diesel has an exponential increment in soot emissions.

1. Introduction

Biodiesel is referred as 'fuel for future' as it is biodegradable and nontoxic unconventional fuel having properties similar to the diesel. Biofuels are derived from renewable resources and utilized as fuels in the transport. The production of biofuels is important for decreasing the exhaust emissions and dependability on fossil fuels [1–3]. The biodiesel has competitive properties to the petroleum-based diesel and is nowadays commercialized for certain vehicles. Generally, biodiesel is produced by mixing of methyl esters of fatty acids, by reacting different oils with methanol (using some catalyst) [4]. The transesterification process converts the vegetable oil into biodiesel after removal of glycerol [5]. The market allocation of glycerol becoming difficult (also having a price fall) as the production of biodiesel is increasing [6]. A lot of investigations are going on for the novel utilization of the glycerol by transforming it into the ether derivatives [6,7]. In this direction, new methods are explored for making esters from lipids [8]. For the same, di-methyl carbonate could be devised as a transesterification reagent for the oils [9]. The di-methyl carbonate is a green reagent due to the environmental inertness [10,11]. Presently, di-methyl carbonate is manufactured by environmentally safer methods that avoid perilous phosgene [11].

As the properties of biodiesel are very close to diesel fuel, diesel engines can use biodiesel without modification in many cases. The exhaust emissions of biodiesel fuel contain less carbon monoxide, hydrocarbon, and particulate matter. Biodiesel contains 10–11% oxygen by weight, higher cetane number, no aromatics, and no sulphur [12–15]. The use of raw vegetable oils and methyl/ethyl esters of sunflower oil [16], rice bran oil, palm oil [17], mahua oil, jatropha oil, karanja oil [18], soybean oil, rapeseed oil and rubber seed oil in the diesel engine have discussed in the literature. Detailed exergy analysis/performance and/or exhaust emissions of diesel engines fuelled with various biodiesels have been also discussed by many researchers [12–31]. The performance parameters of the engine are generally determined using the first law of thermodynamics but the use of merely the first law is insufficient for evaluating all the features of the energy utilization [24,25]. An exergy analysis is required to understand the thermodynamic details of the operation - locations, causes, and magnitudes of energy flow in a thermal system. The exergy analysis can be utilized for designing new efficient systems and also for improving the

* Corresponding author.
E-mail addresses: arvind.m@invertis.org (A.K. Madheshiya), ajitanshu.m@invertis.org (A. Vedrtnam).

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Table 1
Yield of various seeds.

Crop	Yield (gal/acre)
Palm oil	508
Coconut	230
Rapeseed	102
Soy (Indiana)	59.2–98.6
Peanut	90
Sunflower	82

performance of existing systems.

The present work includes the production of biodiesel using waste cooking oil/ mustard oil (10/20/30%) with the methanol. An energy balance sheet is prepared for different biodiesels by conducting experimentation on multi-cylinder diesel engine. (99% pure) having NaOH/KOH (91% pure) as the catalysts. The experimentation was performed under different loading conditions for constant/ varying speeds. The performance parameters are evaluated for all experimental runs. Further, an analysis of variance (ANOVA) is used for the validation of the experiments and for determining the dependability of the BP

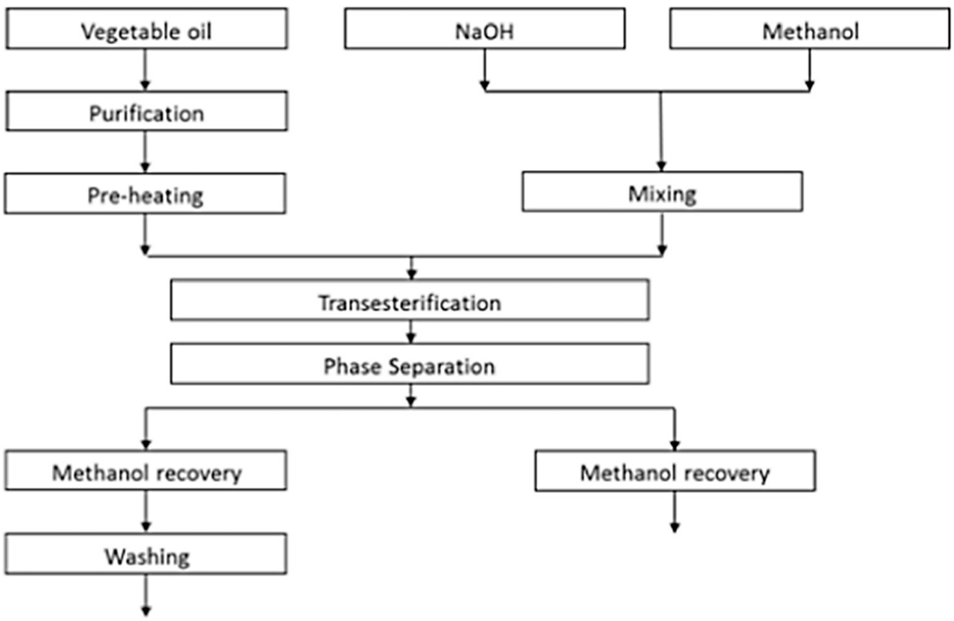

Fig. 1. Block diagram for biodiesel production.

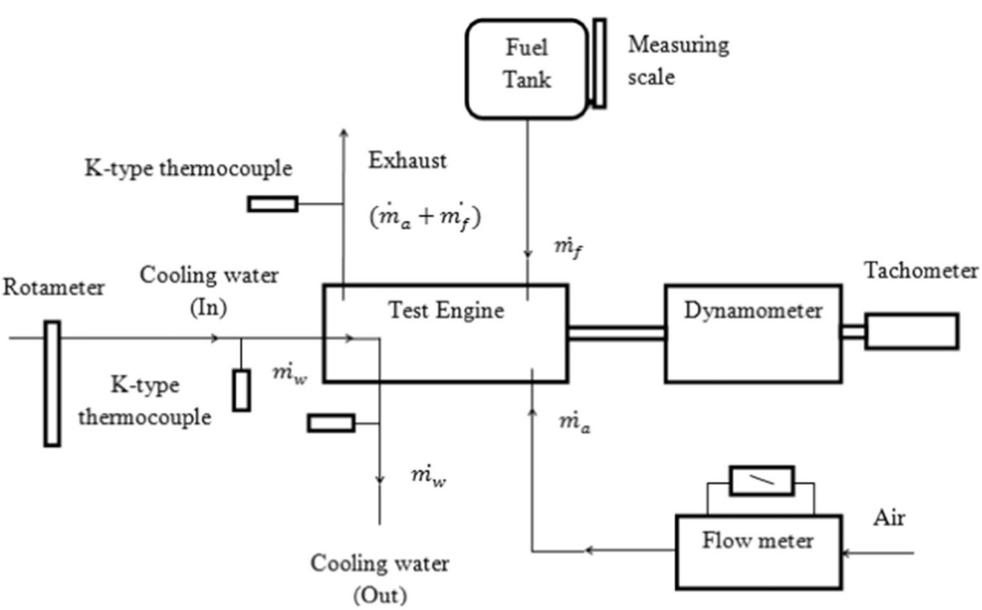

Fig. 2. Schematic of the engine testing system.