AVAILABILITY ANALYSES OF SME/JET FUEL BLENDS COMBUSTION IN DIESEL ENGINE

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Abstract
This article presents a comparative energy and exergy analyses of a No.2 diesel fuel, jet fuel and four various biodiesel fuels for four cylinder, four-stroke, direct injection diesel engine. Engine was used to obtain the experimental data at full load conditions between 1200-1600 rpm speed. It was found that the first and second law efficiencies increased with biodiesel addition and the minimum exergy destruction was obtained at the 100 % biodiesel fuels. On the other hand exhaust exergy was found to be inversely proportional to the biodiesel addition. It is also shown with extensive emission analysis that the addition of bio diesel fuels to the standard diesel fuel enhances the emission characteristics of diesel engines.

Key Words: *energy; emission; availability analyses; jet fuel; biodiesel*

1. Introduction

Recently, biodiesel has received significant attention both as a possible renewable alternative fuel and as an additive to the existing petroleum-based fuels. Biodiesel exhibits several merits when compared to that of the existing petroleum fuels. Many researchers have shown that particulate matter, unburned hydrocarbons, carbon monoxide, and sulphur levels are significantly less in the exhaust gas while using biodiesel as fuel. However, an increase in the levels of oxides of nitrogen is reported with biodiesel [1]. In addition, since biodiesel does not contain carcinogens such as polyaromatic hydrocarbons and nitrous poly-aromatic hydrocarbons, it produces less detrimental to human health pollutants [2]. Many investigators have studied the performance and exhaust emissions of diesel engines using various biodiesel [2-8]. According to Gokalp et al, diesel fuels and marine fuels are also shown with extensive emission analysis that the addition of biodiesel fuels to the standard diesel fuel enhances the emission characteristics of diesel engines [9]. Rakopoulos et al. are conducted to evaluate the use of sunflower and cottonseed oil methyl esters (biodiesels) of Greek origin as supplements in the diesel fuel at blend ratios of 10/90 and 20/80, in a fully instrumented, six-cylinder, turbocharged and after-cooled, direct injection (DI), Mercedes-Benz, mini-bus diesel engine. Fuel consumption, exhaust smokiness and exhaust regulated gas emissions such as nitrogen oxides, carbon monoxide and total unburned hydrocarbons are measured. They showed that all the tested bio-diesel blends can be used safely and advantageously in the present bus diesel engine, at least in these small blending ratios, with the cottonseed bio-diesel showing emissions-wise a small superiority over its sunflower bio-diesel counterpart concerning soot and CO emissions [10]. They surveyed the publications that available on the literature which concerning the application of the second-law of thermodynamics to internal combustion engines. Special attention was given to identification and quantification of second-law efficiencies, irreversibility of various processes, subsystems as compressor, after cooler, inlet manifold, cylinder, exhaust manifold, turbine. The main differences between the results of second and first-law analyses are highlighted and discussed at this paper [11]. On the other experimental study, Rakapopulos evaluated and compared the use of various Diesel fuel supplements at blend ratios of 10/90 and 20/80. Theoretical aspects of the Diesel engine combustion, combined with the widely differing physical and chemical properties of these Diesel fuel supplements against the normal Diesel fuel, are used to aid the correct interpretation of the observed engine behaviour [12]. Van Gerpen and Shapiro investigated the second law analysis of diesel engine combustion and defined a thermodynamic system as outside the engine cylinder and discussed the chemical availability [13]. Primus and Flynn showed the benefits of using the second law in determining various energy losses in a diesel engine [14]. Lipkea and De Joode compared the performance of two direct injection diesel engines through the use of energy and energy balances [15]. Rakopoluulos et al. investigated the accumulation and destruction of energy in a direct-injection diesel engine based on experimental data [16].

When producing an alternative fuel, it is important to consider that net energy output is positive, i.e. the production yields more energy, if renewable energy is excluded, than it needs for cultivation, transportations, extraction, etc. Another important parameter is relation between the energy input and output. These parameters can be examined with energy analyses [17]. Bozza and Rakopoulos suggest that this portion of chemical availability should not be taken into account when studying internal combustion engines applications [18, 19]. Analysis of thermodynamic systems and processes are usually base on the first law of thermodynamics. This type of analysis permits to the designer to evaluate the internal energy variation as a function of the energy transfers across the boundaries as heat or work, and the enthalpies associated with the mass flow crossing these boundaries. However, the first law is deficient for evaluating some features of energy resource utilization [21, 22, 23]. The thermodynamic details of thermal system operations can better understand by performing exergy analysis, not only energy analysis of the system. The exergy analysis reveals the locations, sources and magnitudes of energy resources wasted in the system [21, 22]. The exergy analysis on internal combustion engines has been studied by many researchers. [21-26]. Kumar et al. [32] used the definition of total available flow and a simulation model of a diesel engine cycle. They obtained the distribution of losses and overall engine irreversibility. Alkidas [33] carried out an overall energy and availability balance for different operating conditions of a diesel engine from values that obtained experimentally for the shaft power, energy cost in the exhaust gas, and the amount of heat transfer to the cooling water, lubricating oil, exhaust pipe, and ambient air. Rakopoulos [34] described a first and second law analysis of a SI engine using a cycle simulation and experiment. The author discussed possible ways for improving cycle performance by reducing availability losses due to combustion through improvements in combustion chamber design, fuel-air mixing, and ignition processes. Rakopoulos and Giakoumis [35] analyzed a turbocharged diesel engine operating under transient load conditions. Their model simulates the transient operation on a crank angle degree basis, using a detailed analysis of mechanical friction. Flynn et al. [29] theoretically studied the effect of insulating the cylinder wall on the availability destruction and showed that the lower availability destruction of the heat release in the in-cylinder gases could be obtained by insulation. Alasfour [36] performed an exergy analysis of a SI engine to evaluate the butanol-gasoline blend as fuel. Caton [37] reviewed several studies on the exergetic performance of internal combustion (IC) engines. The aim of this study, experimental and computational analysis on first and second law is performed for a four-cylinder and four-stroke direct injection "TZDK Basak" diesel engine which originally designed for No. 2 diesel fuel (D2) and jet fuel (JF) at 1600 rpm by using several fuels: No. 2 diesel fuel (D2), jet fuel (JF), pure bio diesel fuel (Soya oil methyl ester) and their mixtures in different percentages (100%, 50%, 20% and 5%). Extensive emission analyses are also performed to investigate effects of bio diesel fuels mixed with standard diesel fuel to enhance emission characteristics of diesel engines using standard diesel fuel.

2.Experimental

The experiments were performed on a four-cylinder four-stroke direct injection "TZDK Basak" diesel engine that was used with No.2 diesel fuel (D2) in technical manual book. The test motor is shown in Fig.2 The engine has a maximum power output of 40 kW, a compression ratio of 16.8:1, a cylinder bore of 100 mm, a stroke of 100 mm, and a displacement of 3.14 l. The engine was coupled to Schenk eddy current hydraulic dynamometer and the engine speed was measured with a tacho-generator connected to the dynamometer. Adjusting the dynamometer resistance and injection rate of the fuel pump controlled the load and speed of the engine. The fuel consumption of the engine was determined by measuring the fuel level decrease in a measurement container in a given period of time. The volumetric flow rate of the intake air was measured using a rotary type flow meter. A surge tank located between the air flow meter and intake manifold was used for damping out the pulsations produced by the engine, thus obtaining a steady airflow. The exhaust gas temperature was measured using a thermocouple connected to the exhaust pipe just downstream of the exhaust manifold. The cooling water temperatures at the inlet and outlet of the engine block were measured using "Pt 100" thermocouples. The exhaust emissions, namely CO, CO_2 and NO_x, were measured using Horiba gas analyser. Further details of the instrumentation are summarized in Table 2. First, the engine was tested with the pure fuels of No.2 diesel fuel (D2), jet fuel (JF) and soybean oil methyl ester (SME). Then, 5%, 20% and 50% blends of SME with D2 and 5%, 20% and 50% blends of SME with JF were also tested. Physical characteristics of the tested fuels are given in Table 3. All tests were performed under steady-state conditions. The brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), mechanical efficiency (ME), exhaust gas temperature, and exhaust emissions such as CO, CO_2 and NO_x have been investigated. In the tests, the engine speed was changed between 1200 and 2400 rpm with intervals of 400 rpm, while the engine was operated at full load. At full load conditions, the produced torque changed between 163.2 Nm (at 2400 rpm) and 196.4 Nm (at 1200 rpm). Before each fuel test, the fuel tank of 16-liter capacity and fuel lines were drained, and the engine was operated at least 15 minutes to stabilize on the new fuel. At each speed, the engine was operated five minutes to achieve steady-state conditions, and the data were collected at sixth minute. Each test was repeated 3 times and the results of the three repetitions were averaged. In each test, coolant and exhaust temperatures, fuel consumption, airflow rate, and exhaust emissions were recorded systematically. The fuel delivery angle of the traditional fuel injection system was kept constant at 14d BTDC.

3.Conclusion

Detailed comparative experimental and computational first and second law analysis were performed to investigate effects of energy and exergy balances of four cylinders four stroke CI engine at 1600 rpm by using several fuels. The following conclusions are drawn: Standard diesel fuel (D2), jet fuel (JF), pure bio diesel fuel

(Soya oil methyl ester) and their mixtures in different percentages (100 %, 50 %, 20 % and 5 %). For all fuels, maximum thermal efficiency is obtained in 1600 rpm where mean fuel consumption is minimum. Biodiesel addition enhances thermal efficiency. The maximum thermal efficiency is observed with B 100 and the minimum with pure JF and pure D2. It is shown that bio diesel as fuel increase the engine performance and enhances the exhaust emissions compared the standard diesel fuel. Biodiesel addition to the standard diesel fuel in several ratios increases the exergy efficiency as well. As known, exergy destruction occurs by irreversibilities in the system and decreases the system efficiency. One of the main sources for this is the exergy destruction by exhaust gas and heat transfer. For avoiding these losses, EGR systems can be used to reduce the in-cylinder temperatures after combustion process and thus to reduce heat transfer. The engine inefficiency is mainly caused by the exergy destruction due to the irreversible processes such as combustion Exergy losses due to exhaust process; heat transfer and friction are the other contributors to inefficiency. It is shown in this paper that bio-diesel fuels can be used as an alternative fuel pure form however using it as additive to commercial diesel fuel is much effective in reducing the emissions and increasing the performance especially in diesel engines produced for marines. We hope that the results presented in this work will help understanding interactions between bio-diesel fuel and conventional diesel fuels and their mixtures.