Applied Thermal Engineering 124 (2017) 124–135

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

The determination of effects of soybean and hazelnut methyl ester addition to the diesel fuel on the engine performance and exhaust emissions

Mehmet Çelik [a,*], Yaşar Önder Özgören [b]

[a] Nigde Vocational High School, Omer Halisdemir University, Nigde, Turkey
[b] Automotive Engineering Department, Faculty of Technology, Afyon Kocatepe Unıversity, Afyon, Turkey

HIGHLIGHTS

- Different biodiesel blends were used in a diesel engine.
- Combustion, performance and emission characteristics were examined.
- At full load effective pressure brake mean is obtained as 6.89 for diesel fuel.
- As the biodiesel ratio increases, the ignition delay decreases.
- CO, smoke emissions decreased while CO_2 and NO_x emissions increased partially.

ARTICLE INFO

Article history:
Received 20 January 2017
Revised 31 May 2017
Accepted 4 June 2017
Available online 7 June 2017

Keywords:
Diesel
Hazelnut methyl esters
Soybean methyl esters
Combustion
Exhaust emissions

ABSTRACT

As biodiesel has better exhaust emissions then the diesel fuel and it is renewable. Biodiesel which is an alternative fuel has become popular worldwide. There are various studies concerning biodiesel fuel and its spraying, combustion and emission properties within the diesel engines. In this paper, soybean biodiesel and hazelnut biodiesel which were produced with the transesterification method were added to the diesel fuel at equal amounts. The engine experiments were performed at 2200 rpm fixed engine speed; and with 5 different loads. While maximum cylinder pressure occurred only wit diesel fuel at full load, the average effective pressure and ignition delay decreased and the combustion duration increased once biodiesel was added. The maximum change in emissions at full load occurred at the mixture of DHS30 (70% diesel +15% hazelnut methyl ester +15% soybean methyl ester) fuel per diesel fuel. CO_2 increased by 45.66% while CO emission decreased by 48.88% and smoke emission decreased by 46.03%. The increasing rate of NO_x was very high.

1. Introduction

Most of world's energy needs are met with fossil fuels. The engines which were produced until 1970 were designed in the way so that they may be operated with fossil fuels. However, the price of fossil fuels increased especially after 1973 oil shock and Gulf war which led to challenges in meeting the fuel needs of countries [1]. The usage of fossil fuels increased due to its use at power plants, engines, electric generators and locomotives [2]. Along with the increase in number of vehicles in the transportation sector, the energy demand has considerably increased. Besides that, EURO VI emission standards imposed strict regulations on the exhaust emissions since usage of motorized vehicles leads to environmental pollution [3]. According to International Energy Outlook, it is estimated that the world energy need will increase by 50% in 2030 compared to 2005 and 26–27% of this energy need will be met via the fossil fuels [4]. Today the diesel engines are much more attractive compared to gasoline engines due to high thermal efficiency, reliability, resistance and high power generation [5]. In the researches conducted, in expensive, clean and reliable alternative energy sources which are one of the most significant sources for global and national economies were researched [6]. Biodiesel is produced from vegetable oils and used as an alternative fuel since it is environmental friendly [7]. Biodiesel is mostly produced from vegetable oils, animal fats, waste restraint and cooking oils using the transesterification method. The transesterification

* Corresponding author.
E-mail addresses: mehmetcelik@ohu.edu.tr (M. Çelik), yasarozgoren@aku.edu.tr (Y. Önder Özgören).

http://dx.doi.org/10.1016/j.applthermaleng.2017.06.008
1359-4311/

Nomenclature

DHS10	90% diesel + 5% hazelnut methyl ester + 5% soybean methyl ester	CO_2	carbon dioxide
DHS20	80% diesel + 10% hazelnut methyl ester + 10% soybean methyl ester	CO	carbon monoxide (%)
DHS30	70% diesel + 15% hazelnut methyl ester + 15% soybean methyl ester	CA	crank angle, (degree)
TDC	top dead center (°CA)	P_i	functions refer to cylinder pressure signals
THC	total hydrocarbon (ppm)	i	incidences refer to a specific crankshaft ranges
NO_x	nitrogen oxides (ppm)	b_e	specifies fuel consumption (g/kW h)
		H_u	lower heating value (kj/kg)

reaction transforms the vegetable oils into biodiesel fuel of which fatty acid is methyl ester. Biodiesel can be used by it self or be blended with diesel fuel without making any change to the engine. Additionally, it is a renewable, biologically degradable, oxygenated and non-toxic sustainable fuel which does not contain sulphur. In the diesel engines, the hazardous emissions such as carbonmonoxide (CO), carbondioxide (CO_2), hydrocarbon (HC) and particle matter (PM) decreased along with the use of biodiesel. However a slight increase in azotoxit (NO_x) emissions was observed due to the use of biodiesel which is an oxygenated fuel [2,8,9]. Today, biodiesel is commercially used in various countries such as Europe, USA and China [10]. And, it is produced from cole in European Union and soybean oil in USA, these products are preferred due to fact that they are renewable and create less greenhouse effect compared to plain diesel fuel. As of 2011, 44% of world biodiesel market is in EU. EU requires vehicles to be efficient in a way that 10% of EU's fuel needs will be met by using biodiesel by 2020 [11]. In addition to using new energy sources, a way to increase the energy efficiency is by developing combustion technology [6]. The exhaust emissions that result from the use of diesel engines such as NO_x, CO, particle substance and SO_x are hazards to the environment and humans a like. In order to decrease these hazardous gases, various EGR (Exhaust Gas Recirculation), SCR (Selective Catalytic Reduction), particle filter and catalytic converter are used. However, these systems are insufficient in the long term due to the cost associated with emission restrictions. Therefore, preventing the development of hazardous gases by developing combustion procedures that lower this development is the smartest solution to the emission problem [12]. There are various studies concerning what happens with spraying, combustion and emission properties when diesel fuel is mixed with biodiesel fuel [10].

Soybean and hazelnut oil is used as biodiesel raw material in large amounts. The object of this study is to increase the cetane number by blending the two fuels which have different characteristic properties as fuel and to improve the physical properties of fuel. This mixing will provided improvement in combustion and emission characteristics. In this paper, soybean biodiesel and hazelnut biodiesel were added in equal amounts into the diesel fuel. The effect of the new blended fuel on the combustion, performance and emission characteristics in a single cylinder diesel engine was afterwards invesigated. Biodiesel fuel used in the experiments was produced with the method of transesterification. To begin NaOH was used as a catalyzer and Methanol was used as alcohol. The different mixes of fuel were named DHS10 (90% diesel + 5% hazelnut methyl ester + 5% soybean methyl ester), DHS20 (80% diesel + 10% hazelnut methyl ester + 10% soybean methyl ester) and DHS30 (70% diesel + 15% hazelnut methyl ester + 15% soybean methyl ester). The physical and chemical properties of the fuel obtained are shown in Table 1. The engine experiments were performed at 2200 rpm fixed engine speed at which maximum moment was obtained; also 5 different loads (3.75–7.5–11.25–15 Nm and maximum load) were used.

2. Experimental setup and procedure

The experiments were conducted using Cussons brand P8160 model single cylinder engine. In Fig. 1, the test apparatus schematics are shown. In the experiments, a diesel engine with a single cylinder and direct injection (DI) of which technical properties are shown in Table 2 was used. The indicator system consisted of in-cylinder pressure sensor, encoder, indicator device, data collection card and computer. The analog in-cylinder pressure signals were received and transformed into digital signals using a data collection card made by National Instrument. In the indicator system, AVL brand 8QP500c model water-cooled quartz cylinder pressure sensor was used of which technical properties are given in Table 3. The measurements for the cylinder pressure were conducted via a piezo electrical channel that Cussons P4110 model combustion analysis device had and the AVL 3009 A04 charging amplifier was used for measuring the diesel fuel line pressure.

The crank angle was determined with a Koyo model TRD J1000-RZ model incremental encoder. For each tour of the engine, took 1000 units. Therefore, recording of analog signals received from the charging amplifiers into the digital environment was made at 0.36 °CA resolution.

THC, NO_x, O_2, CO_2, CO emission measurements were conducted with a EGAS-2 M model analytical raw exhaust gas measurement system which is produced by Environment SA company. The operating ranges and technical properties of the analyzers are shown in Table 4. The smoke measurements were conducted with an AVL 4000 DiSmoke model partial flow opacimeter. The technical properties of the device are given in Table 5.

The pressure data was measured by using in-cylinder pressure sensor and a encoder and these values were used in order to calculate 50 units of consecutive cycle average cylinder pressure. In one cycle, 2000 units of raw in-cylinder pressure data was obtained at a 0.36 °CA intervals and transformed into digital signals. When derivative of pressure data is transformed digital signals are received, however noise occurs during the calculation of heat distribution. With the aim of preventing this noise, the pressure data is filtered with the Eq. (1) shown below. In this paper, the heat distribution was subjected to the 4th degree filtering procedure. The in-cylinder pressure signals may be found according to 4th series in the Taylor series format in Eq. (1).

$$
\begin{aligned}
P_{i+2} &= P_i + \frac{2P_i' d\theta}{1!} + \frac{2^2 P_i'' d\theta^2}{2!} + \frac{2^3 P_i''' d\theta^3}{3!} + \frac{2^4 P_i'''' d\theta^4}{4!} + \dots \\
P_{i+1} &= P_i + \frac{P_i' d\theta}{1!} + \frac{P_i'' d\theta^2}{2!} + \frac{P_i''' d\theta^3}{3!} + \frac{2^4 P_i'''' d\theta^4}{4!} + \dots \\
P_i &= P_i \qquad (1) \\
P_{i-1} &= P_i - \frac{P_i' d\theta}{1!} - \frac{P_i'' d\theta^2}{2!} - \frac{P_i''' d\theta^3}{3!} - \frac{2^4 P_i'''' d\theta^4}{4!} - \dots \\
P_{i-2} &= P_i - \frac{2P_i' d\theta}{1!} - \frac{2^2 P_i'' d\theta^2}{2!} - \frac{2^3 P_i''' d\theta^3}{3!} - \frac{2^4 P_i'''' d\theta^4}{4!} - \dots
\end{aligned}
$$