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Corn and soybean biodiesel blends as alternative fuels for diesel engine at different injection pressures

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HIGHLIGHTS

- Pre-heat up to 80 °C for biodiesel blends should compensate the high viscosity.
- The increase of injection pressure (IP) improves engine performance parameters.
- At high IP (200 bar), peak pressure for diesel fuel exceeds that for fuel blends.
- The difference in the position of P_{max} for all fuels are in range of 1–2 °C.A.

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ABSTRACT

Experimental study has been carried out using corn and soybean fuel blends at the most recommended blending ratio of 20% biodiesel (C20 and S20) with conventional diesel fuel as alternative fuel for diesel engines. The effect of fuel injection pressure (IP) on diesel engine performance using C20 and S20 blends in comparison with that using neat diesel fuel is studied. Preliminary experiments regarding the analysis of fuel properties indicate that a preheat temperature up to 60–80 °C for these biodiesel fuel blends is necessary to compensate their high viscosity as compared with that of neat diesel fuel. A series of tests are conducted on four-stroke single cylinder air cooled direct injection (DI) diesel engine at different engine speeds, loads and IP of 180, 190 and 200 bar. The investigating parameters include the engine performance parameters (brake thermal efficiency – η_B and brake specific fuel consumption – BSFC) and other necessary parameters (air-to-fuel ratio – A/F ratio, mass of injected fuel – m_f, exhaust gas temperature – T_{exh}, cylinder wall temperature – T_{wall}, in-cylinder dynamic pressure – P_{cyl}, and both value and position of maximum pressure – P_{max} and $\theta_{@Pmax}$, respectively). The properties of corn and soybean blended fuels affect the fuel injection system and cause an increase in the duration of fuel injection to cover more time according to the increase in the amount of injected fuel necessary to overcome the power loss accompanied with the biodiesel low energy content. The major conclusion is that, the increased injection pressure gives better results regarding the engine performance parameters (both BSFC and η_B) in comparison with case of the original injection pressure for all tested fuels, thus the best results are obtained at high injection pressure of 200 bar. At this conditions it is concluded that, the increase of engine η_B and the decrease of BSFC approach 15% (from the original pressure of 180 bar), while the values of P_{max} for diesel fuel are slightly higher than those for blended fuels no matter the engine operating conditions.

1. Introduction

Diesel engines have been received a great attention due to their high power performance, thermal efficiency and low emissions in comparison with gasoline engines. This sector of transportation systems consumes a large portion of non-renewable petroleum fuels. Thus it is urgent to look for a renewable fuel resource that will replace (or at least reduce the consumption of) traditional fuels. One of promising resources is the production of biodiesel from vegetable oils. The physical properties of the biodiesel fuel such as viscosity, volatility and flash point affect the different processes occurring within the diesel engine cylinder; including fuel

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Nomenclature

ATDC	after top dead center	RPM	revolution per minute
A/F	air/fuel mass ratio, kg of air/kg of fuel	P_{cyl}	in-cylinder pressure, kPa
BTDC	before top dead center	P_{max}	maximum in cylinder pressure, bar
BSFC	brake specific fuel consumption, kg/kW h	T_{exh}	exhaust gas temperature, K
BP	brake power, kW	T_{fuel}	inlet fuel temperature, K
C.A.	crank angle, °	T_{wal}	engine wall temperature, K
CO	carbon monoxide, %	S20	fuel blend containing 20% soybean methyl ester biodiesel and 80% neat diesel
CN	cetane number	UHC	unburned hydrocarbon carbon, PPM
C20	fuel blend containing 20% corn methyl ester biodiesel and 80% neat diesel	U_R	uncertainty in the result "R"
IP	injection pressure, bar	X_i	variable, i
m_f	fuel mass flow rate, kg/s	η_B	brake thermal efficiency, %
NO_X	nitric oxide, ppm	η_V	volumetric efficiency, %

atomization, fuel evaporation, fuel mixing with air and fuel burning and thereby engine performance. The injection pressure (IP) plays an important role in metering the desired amount of fuel at correct time depending on engine operating conditions. For diesel engine, the direct injection fuel system is used to achieve a high degree of atomization in order to enable sufficient fuel evaporation in short time and sufficient spray penetration in order to mix fuel effectively with air and so enhance the combustion process. The fuel injection process is influenced not only by the fuel properties, but also by the injection system construction (number and dimensions of nozzles), the injection timing, and the injection operating conditions (as the injection pressure and the in-cylinder air conditions). It will be valuable to maintain engine parameters without (or at least with minimum practical) modifications to save time and efforts spent to develop the current fuel injection systems at safe and effective operating conditions. The biodiesel fuel atomization characteristics are expected to be worsened in comparison with that of neat diesel fuel. This behavior can be owing to the fact that, biodiesel fuels have higher values of density, viscosity, and molecular weight than those of neat diesel fuel. Thus biodiesel properties negatively interfere with the injection process leading to poor fuel atomization, incomplete combustion and excessive carbon deposits on fuel nozzles. In this regard, the regulation of fuel properties in conjunction with re-setting the fuel injection pressure may be acceptable solution to simultaneously regulate the fuel atomization and keep engine with minor modifications. At high the injection pressure, the droplets of the injected fuel become smaller and so better fuel atomization is achieved. Generally, the increase of injection pressure supports the completeness of fuel and air mixing providing better combustion process and thus to improve the engine specific power (kW/liter) [1]. The increase of injection pressure is recorded as one of the basic parameters that tend to reduce particulate matter emissions and fuel consumption in addition to other influences; including the increase of fuel portion burned by premixed combustion, the increase of mixture homogeneity, the increase of local A/F ratio, the decrease of combustion duration, the increase of the in-cylinder peak pressure, and the increase of NOx emissions [2]. For this reason, the improving of diesel combustion and emission characteristics by optimizing the fuel injection strategy received a great concern during the past few years especially those operated on traditional diesel fuels. But for engines operated with neat or blended biodiesels produced from corn and soybean oils there are few available literatures.

Reddy et al. [3] studied the effect of changing the IP on combustion and emissions characteristics of diesel engine using cotton seed oil methyl ester blended with diesel fuel. Authors concluded that, as the IP is increased from 170 to 200 bar, the values of brake thermal efficiency (η_B) are increased and those of brake specific fuel consumption (BSFC) are decreased. Kumar et al. [4] studied the effect of compression ratio, fuel atomization, IP, fuel quality, combustion rate, A/F ratio, intake temperature and pressure on engine performance parameters. Authors founded that, the increase in air motion into diesel engine improves the fuel atomization, the heat release rate and reduces the levels of exhausted emissions. Sayin et al. [5] studied the effect of fuel atomization and fuel distribution through combustion chamber using a single cylinder diesel engine operated with canola oil methyl esters (COME) and its blends with diesel fuel. The experimental results showed that, fuel exhibits different combustion and performance characteristics for different IP and engine loads. From their study, Sayin et al. [5] found that, (i) the use of COME instead of diesel fuel resulted in an earlier injection timing, (ii) the maximum in-cylinder pressure (P_{cyl}), the maximum rate of pressure rise and the maximum heat release rate are slightly lower for COME and its blend, (iii) the values of BSFC for COME are higher than those for diesel fuel while values of η_B for COME are lower than those for neat diesel fuel, and (iv) the increase of IP gave good results for BSFC and η_B compared to values obtained at the original IP. Kannan and Udayakumar [6] studied the effect of IP on performance and emissions from diesel engine. Authors concluded that, good performance and low emissions occur at high IP of 200 bar. Canakci et al. [7] observed the decrease of engine mechanical performance parameters (as in-cylinder peak pressure, rate of heat release, and engine efficiency) and the increase of most engine emissions (smoke opacity, UHC and CO) except NOx and CO_2 when the injection pressure becomes lower than the engine original injection pressure. Nagaraju et al. [8] carried out an experimental study to determine the effect of using B20 (fuel blend containing 20% soybean methyl ester biodiesel and 80% neat diesel fuel) on the combustion process, performance and exhaust emissions of diesel engine. Their results indicated that, the emissions of NO_X, CO, UHC and soot for B20 are lower than those for diesel fuel, while BSFC and T_{exh} are higher for B20 than for diesel fuel. Krahl et al. [9] studied the effect of using biodiesel fuels on diesel engine performance and concluded that, the high BSFC and low brake power (BP) obtained with biodiesel are related to the biodiesel low heating value. Song et al. [10] carried out an experimental study on a diesel engine fueled with soybean biodiesel under different engine loads and speeds. The results showed that, the BP, BSFC and torque are increased with the increase of biodiesel portion in the fuel blend. Prasad et al. [11] carried out an experimental