THE USE OF BIOFUELS ON COMPRESSION-IGNITION ENGINES AND THEIR IMPACT ON THE FILTER ELEMENT

Horju-Deac Cristina Daniela

Faculty of Materials and Environmental Engineering, Technical University of Cluj-Napoca, 103-105 Muncii Avenue, Cluj-Napoca, 400641, Romania; cristina.horju@im.utcluj.ro

Abstract. Despite its recognized negative impact on nature and human health, the worldwide nations are still strongly depended on fossil fuel for their transport needs. In the present geopolitical turmoil, all EU Member States ought to look for alternative fuels that would ensure a minimum self-sufficiency for their essential supply lines. The biofuels can offer an important alternative towards reduction of fossil fuels for short and medium term. The present study observed that by using biofuels to power the MAC engines that equip tractors and cars, significant advantages are obtained compared to the use of diesel. An extra 10% oxygen, obtained based on the changes made to the fuel system, yields a considerable reduction of chemical pollution. The best performance in terms of pollution, power, momentum and consumption were obtained with the following mixtures: 30% and 40% biodiesel with diesel, respectively 20% biodiesel + 5% methanol + diesel. The only shortages in the current process are due to the multifarious composition of crude biodiesel, involving complex, energy-intensive separation stages, which is reflected in the final costs of the products.

Keywords: biofuels, biodiesel, diesel engines, kinematic viscosity, vegetable oils.

INTRODUCTION

Eastern European countries have vast agricultural areas that could be successfully exploited to produce crops with a significant eco-energy potential. This practice would produce a new category of fuels, which will be regenerated every year, unlike hydrocarbon fuels, which have a finite character.

Depleting reserves of fossil fuel and the urgent need to reduce greenhouse gas emissions bring biofuel production in general and biodiesel production in particular into the spotlight (Hajjari et al, 2017; Rozina et al. 2022). Thus, energy sustainability, increasing environmental concerns and economic considerations are the main driving forces behind the global directives in the production of biofuel from accessible bioresources.

Sustainable production of biofuels has been widely addressed in the recent years by the international community (Dahman et al., 2019; Directive 2009/30/EC; Directive 2009/28/EC). The Fuel Quality Directive (Directive 2009/30/EC) stipulates in the its sustainability criteria for biofuels chapter that the greenhouse gas emission saving from the use of biofuels starting January 2018 shall be at least 60%. Thus, they would make an important contribution to solving the problems caused by climate change.

Currently the most used biofuels are biodiesel (made from vegetable oils) and bioethanol (made from plants with a high sugar or starch content). From an ecological point of view, biodiesel is more environmentally friendly because it is made of renewable materials that emit less greenhouse gases than classic diesel.

Biodiesel is the fuel obtained from vegetable oils (rapeseed oil, peanut oil, sunflower oil, soybean oil, etc.), edible oils and from animal fats. The most applicable biodiesel technology comes from vegetable or animal oils which contain quality oils or fats. The crude methyl ester and the by-product glycerol are obtained by the esterification reaction, with the addition of methyl alcohol in the presence of a catalyst based on sodium methoxide. Biodiesel is subsequently obtained after distillation and glycerine follows a purification process by vacuum distillation. On the other hand, one of the most suitable inland plants for biodiesel production is rapeseed because its seeds contain 40-45% oil. It is obtained by pressing rapeseed and contains fatty acids with carbon chains of different lengths. Establishing independence from crude oil and reducing CO2 emissions are the main reasons why biodiesel production is of strategic importance worldwide.

The aim of this paper is to study the energy efficiency of the use of biodiesel as a fuel for compression ignition engines, taking into account the many benefits it is able to offer.

MATERIAL AND METHOD

It is well recognized that by replacing diesel with biofuel the pollutant emissions would drop significantly. It is also important to note that the carbon dioxide emitted when using biofuel is absorbed by rapeseed in the process of photosynthesis. Given that the calorific power of biofuel is lower than diesel, an attempt was made to partially replace diesel with biofuel in order to maintain engine power while reducing the concentration of pollutants in the exhaust gas.

The influence of different types of fuels (diesel-ester mixtures derived from vegetable oils, in various proportions) on the performance of compression ignition engines has been studied by conducting experimental tests. The research took place on stands equipped with D-118 and 846 HM 82 UB engines, respectively, hydraulic brake, transducer sensors and fast data acquisition system, within the laboratories of Internal Combustion Engines and Biofuels respectively (Technical University of Cluj-Napoca).

The response of the filter element, when submitted to biofuel and diesel at various temperature, was assess during a follow up experimental exercise caried out within the same laboratory. Several apparatuses were used for the purpose, namely: Eastcolight digital microscope, fuel filter for MAC engines, various samples of biofuels based on rapeseed oil, soybean oil, sunflower oil and diesel. The testing temperatures used for this experiment were: 20-25ºC, 5ºC, 0ºC and -5ºC.

RESULTS AND DISCUSSION

By testing the influence of different types of biofuels on compression-ignition engines it was observed that modifications to the classic engine power system show better power, torque and pollution performance than the engine without modifications. Diesel can be successfully replaced with biofuel or mixtures thereof with diesel, thus ensuring the reduction of chemical pollution into the environment. Mixtures of 30% and 40% biodiesel with diesel, respectively 20% biodiesel + 5% methanol + diesel give the best results in terms of power and torque. On the other hand, the best results in terms of specific fuel consumption were obtained with mixtures of 10% and 40% biodiesel with diesel, respectively 20% biodiesel + 5% methanol + diesel. Looking into carbon monoxide emissions, the results indicated a much better outcome than when using diesel and better than those obtained from engines without modifications. Overall, the best results are obtained with mixtures of 30% and 40% biodiesel with diesel, respectively 20% biodiesel + 5% methanol + diesel. In terms of carbon dioxide emissions, most mixtures perform better than diesel, the mixture of 40% biodiesel with diesel showing the highest performance. From the point of view of hydrocarbon emissions, the superiority of the mixtures over diesel is noticeable in several mixtures (30% and 40% biodiesel with diesel, respectively 20% biodiesel + 5% methanol + diesel). The smoke emission depends strongly on the operating mode. The best performance on the entire speed range is the mixture of 50% biodiesel + diesel.

Overall, the existence of 10% oxygen in the biodiesel composition, obtained based on the changes made to the fuel system, yields a considerable reduction of chemical pollution with CO, CO2, CmHn, respectively the lack of sulphur in the biofuel composition leads to a reduction in SO2 emissions. The best performance of pollution, power, momentum and consumption are obtained with the mixtures of 30% and 40% biodiesel with diesel, respectively 20% biodiesel + 5% methanol + diesel. Moreover, the comparative experimental tests performed on the D-118 engine confirmed the results obtained on the 846 HM 82 UB engine.

Taking into account the findings presented above, two directions of action are recommended:

a. The use of 40% biodiesel mixtures with diesel in tractors. This will ensure a significant reduction in atmospheric pollution, create new jobs, contribute to the fuel supply issue, and ultimately ensure a minimum energy independence.

b. Removal of sulphur from diesel and the use of 5-10% biodiesel as an additive for all diesel fuels. This will ensure a reduction in the greenhouse effect, increase the durability of diesel engines and reduce the cost of fuel. It is found that by using biofuels to power the MAC engines that equip tractors and cars, significant advantages are obtained compared to the use of diesel.

It is therefore necessary to develop research in this field in order to solve all aspects related to other modifications of engines used in road vehicles, new combinations of mixtures, the behaviour of other types of engines with compression ignition, durability, etc.

The follow up experiment looked into the kinematic viscosity, in this case the response of the filter element, when submitted to biofuel and diesel at various temperature.

The kinematic viscosity (flow resistance) is an important parameter for the direct use of vegetable oils as fuel for internal combustion engines. A high viscosity of the fuel can cause poor dispersion, which in turn can lead to deposition of the residue in the injectors or on the valves. High viscosity can lead to large droplets, low spray and vaporization, low injection angle (dispersion) of the injection, and high penetration into the cylinder of the sprayed fuel. It can also reduce the rate of fuel leakage, which could lead to improper fuelling or damage to the pump. High viscosity of the fuel results in a worsening of the combustion process, higher pollutant emissions and increased dilution of oil.

While diesel fuel must have a viscosity between 2,5 - 4,0 mm^2/s (at a temperature of 40°C), all vegetable oils have a viscosity well above the maximum limit. These high viscosity values of biofuels are one of the main reasons for the conversion of vegetable oils into the respective ester-methyl fatty acids.

The following figures show the variations of the diameters of the flakes of the analysed fluids in direct correlation with the kinematic viscosity, at 20-25 ºC, 5 ºC, 0ºC and -5ºC.

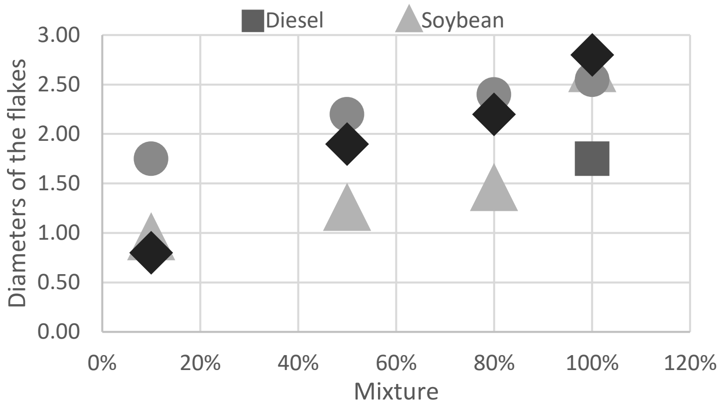

Fig 1. Variations of the diameters of the flakes of the analysed fluids in direct correlation with the kinematic viscosity, at 20-25 ºC.

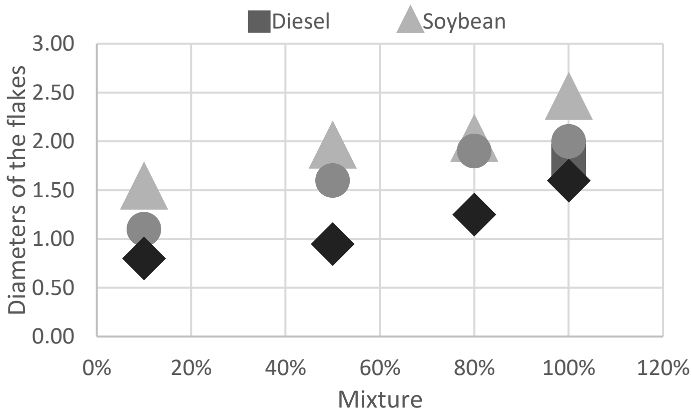

Fig 2. Variations of the diameters of the flakes of the analysed fluids in direct correlation with the kinematic viscosity, at 5 ºC.

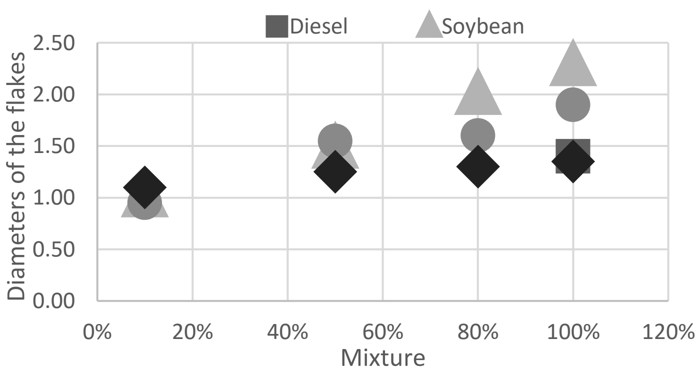

Fig 3. Variations of the diameters of the flakes of the analyzed fluids in direct correlation with the kinematic viscosity, at 0 ºC.

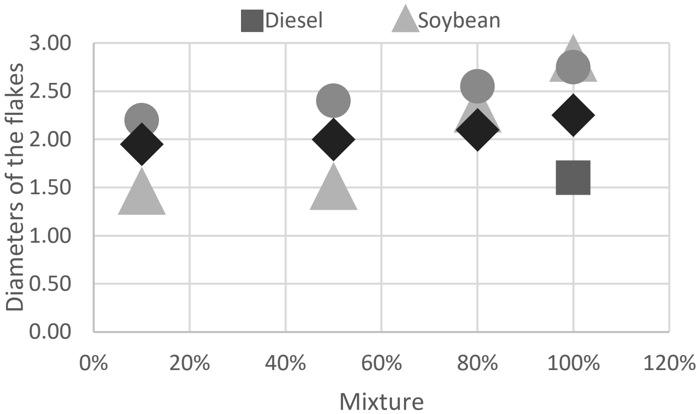

Fig 4. Variations of the diameters of the flakes of the analysed fluids in direct correlation with the kinematic viscosity, at -5 ºC

The study demonstrated that the rapeseed oils, soybeans and sunflower generally have a higher viscosity than diesel. Given the direct correlation between the size of the flakes and the kinematic viscosity of the fluid it is important that this parameter is controlled, in order to avoid the negative impact on the fuel injection system.

The highest value of kinematic viscosity was observed in case of sunflower oil and the lowest fuel mixture, with 10% rapeseed oil. If biodiesel is used instead of oil, a viscosity of fuel similar to diesel is obtained, which leads to the possibility of its use either directly in diesel engines or as an addition to conventional diesel.

Viscosity is the main reason why vegetable oils require the stage of chemical transformation into esters (it is about 10 times higher than diesel). Oils cannot be used independently as fuel, because they have large variations in viscosity as a function of temperature.

CONCLUSIONS

1. The continuous rise in the price of oil worldwide has led many countries to look for ways to identify and capitalize new and renewable energy resources. The perspective of depleting fossil fuel resources, in the context of an increasing number of means of transport, has led to the search for and use of alternative fuels.
2. Biofuels obtained from different plant species, used as such or mixed with conventional fuels, can replace various categories of fuels.
3. Biodiesel has diesel-like properties, so it can be used either directly in diesel engines or as an additive to conventional diesel. Being a first-generation biofuel, is obtained by the transesterification reaction of vegetable oils (soybean, sunflower, rapeseed, etc.) or animal fats with lower alcohols. Although the production costs of biodiesel are higher than those of conventional diesel, there are a number of advantages related to its use as a fuel: improved lubricating qualities of low sulphur diesel, lower smoke density, low CO and CO_2 emissions. All these advantages make biodiesel a good candidate for its use in compression ignition engines.

4. Romania has an important agricultural potential for the cultivation of raw materials necessary for the manufacture of biofuels. Rapeseed cultivation, for example, could soon be a business for Romanian farmers, with production costs being very advantageous. In the same context, soil and climate, which are extremely important assets, can make Romania an important player in the EU biofuels market.

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