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Ecological fuel made from polymer waste for diesel engines

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ABSTRACT

The topicality of the problem related to the use of synthetic polymer fuels to power compression-ignition engines results from two interrelated issues: recycling of municipal waste and decreasing oil resources. The processing of polymer plastic waste into liquid fuels is only one of a series of tasks that can be defined as technological issues related to strictly defined municipal waste recycling processes. The second task is to determine the possibility of using recycled liquid fuels to power internal combustion engines. It should be emphasized that the use of a mixture of petroleum fuels with biocomponents in diesel engines was preceded by a large number of scientific studies and experiments, which in turn led to the relevant legal acts regulating the operating conditions of these mixtures. The analysis of the state of knowledge regarding the use of liquid fuels from the processing of polymer waste in wet-ignition engines indicates the lack of a detailed analysis of the phenomena occurring in individual processes of supplying fuel to the combustion chamber and obtaining the best engine operating parameters in technical terms. The aim of the article is to analyses the possibility of using synthetic polymer fuels to power diesel engines.

1. Introduction

Processing of polymer plastic waste into synthetic liquid fuel.

Due to the variety of types of polymeric materials and the ways of their use, there is no single solution to all problems related to the management of this type of waste. One of the possible directions of their use is raw material (chemical) recycling related to the production of liquid alternative fuels. It should be emphasized that in accordance with Directive 2014/94/EU of 22 October 2014, alternative fuels are fuels or energy sources that serve at least partly as a substitute for energy sources derived from crude oil in transport and that may potentially contribute to decarbonizing transport and improving the greening of the transport sector. These include: electricity, hydrogen, biofuels, synthetic fuels, paraffin fuels and natural gas [4].

Compared to petroleum-derived fuels, alternative fuels are distinguished by three advantages: energy independence (they can be produced from own raw materials/waste and agricultural products), lower emissions (reduced emissions of toxic compounds) and low operating costs [5]. What is more, due to the small own resources of crude oil, fuel production in Poland is based mainly on crude oil imports from third countries. According to energy forecasts, the demand for fuels in Poland will grow in the coming years, which means that the development of the use of alternative fuels in transport will

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have an impact both on reducing the level of Poland's dependence on imported crude oil and on reducing the harmfulness of the transport sector to the natural environment in our country [2].

Technologies of processing polymeric materials into fuel.

The goal of these technologies is to recover energy from waste materials, including non-biodegradable materials such as biomass, municipal solid waste, agricultural waste, and high energy density materials such as rubber and polymers. Polymer plastics are non-degradable polymers that contain carbon, hydrogen and other elements (chlorine, nitrogen, etc.) [1,3] The methods of processing polymer waste into liquid fuels include:

- pyrolysis,
- catalytic cracking,
- catalytic depolymerization,
- thermolysis with hydrogenation and isomerization.

2. Determining physical and chemical parameters of synthetic polymer fuels

The parameters selected to represent the physicochemical properties of the individual concentrations of the tested fuel are as follows:

- density,
- kinematic viscosity,
- cetane number,
- flash-point,
- cold filter plugging temperature,
- water content.

The selection of the above parameters was guided mainly by the review of physicochemical properties affecting the process of fuel use in the engine. The selected parameters do not exhaust the list of all possible physicochemical tests, but they have relatively the most significant impact on the working processes in the engine. The tests of the physicochemical properties of the synthetic fuel and its mixtures were carried out in the research laboratory of the Fuel, Working Fluids and Environmental Protection Research Center of the Faculty of Mechanical Engineering of the Maritime University of Szczecin. In the laboratory tests determining the physical parameters, the following fuel composition was selected - 100% petroleum diesel oil and its mixture with 3-, 5-, 7-, 20- and 100% (pure synthetic fuel) synthetic polymer fuel obtained in the process of catalytic depolymerization. The choice of such a composition of the mixture was not accidental, because the fuel standards for compression ignition engines provide for a maximum admixture concentration of up to 7%. The use of 3% and 5% additives is related to the determination of the physical parameters of the fuel mixture at low concentrations of additives, which can be easily implemented in modern engines.

3. Test results of physicochemical parameters

Fig. 1-6 present the results of physicochemical measurements. The red lines indicate the limit values allowed by the standard. Black lines indicate approximation of dependencies using a straight line.

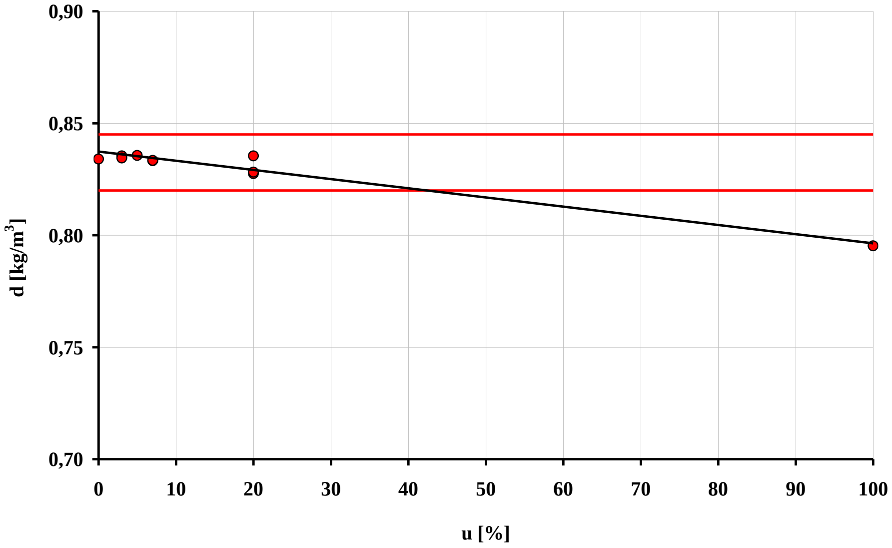

Fig. 1. Dependence of density on the concentration of synthetic fuel in the mixture

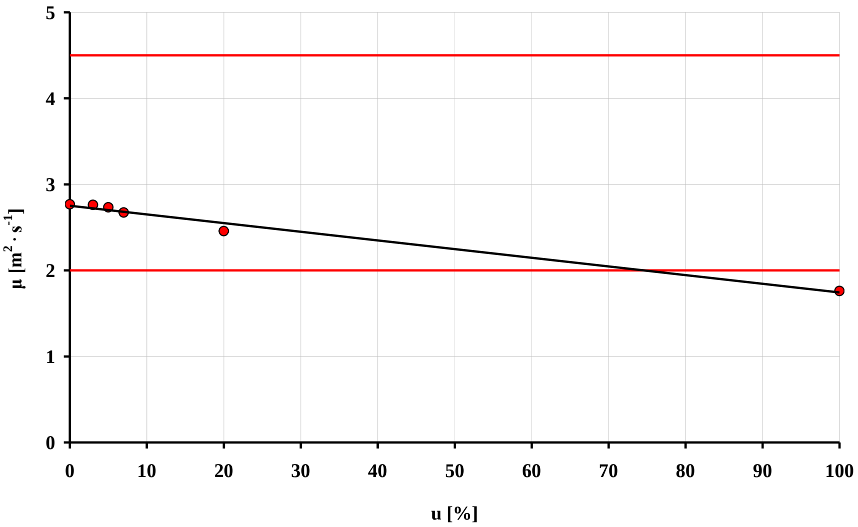

Fig. 2. Dependence of kinematic viscosity on the concentration of synthetic fuel in the mixture

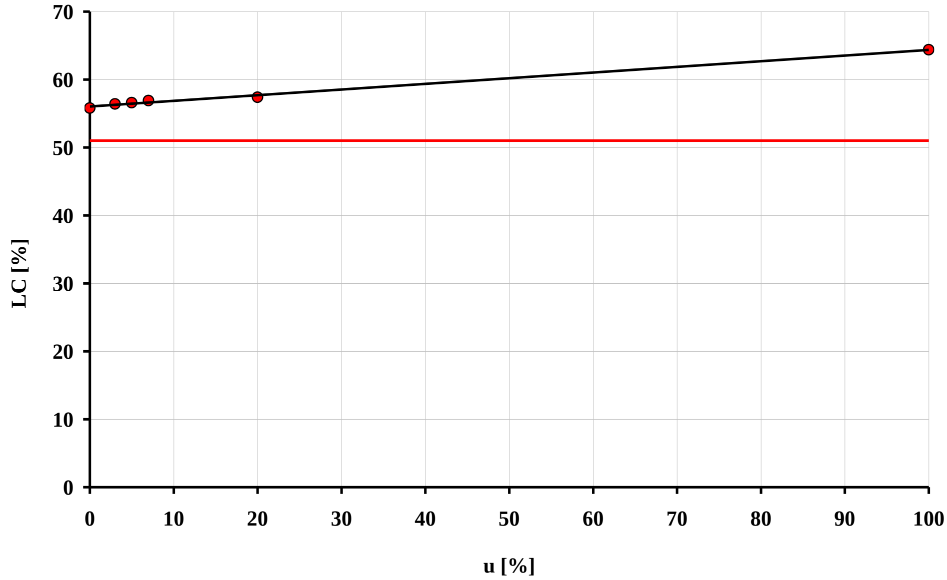

Fig. 3. Dependence of the cetane number on the concentration of synthetic fuel in the mixture

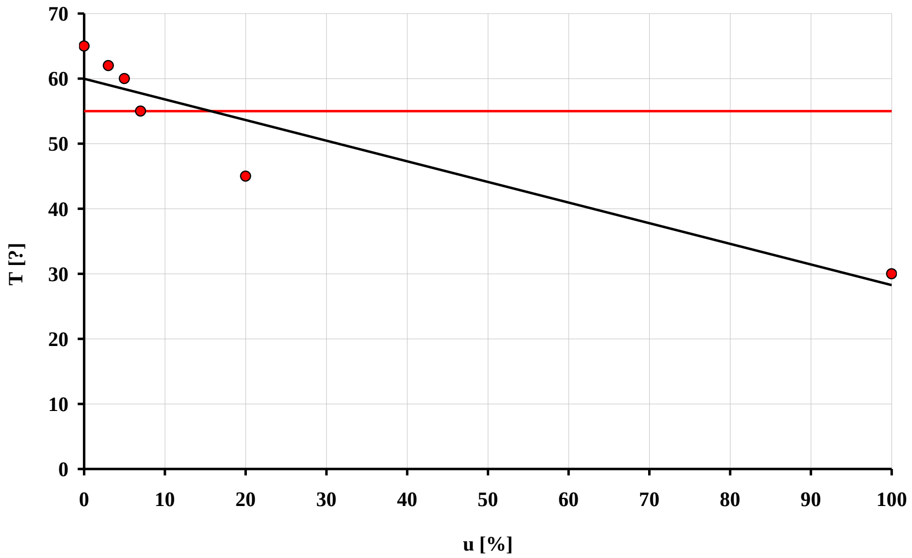

Fig. 4. Dependence of the ignition temperature on the concentration of synthetic fuel in the mixture

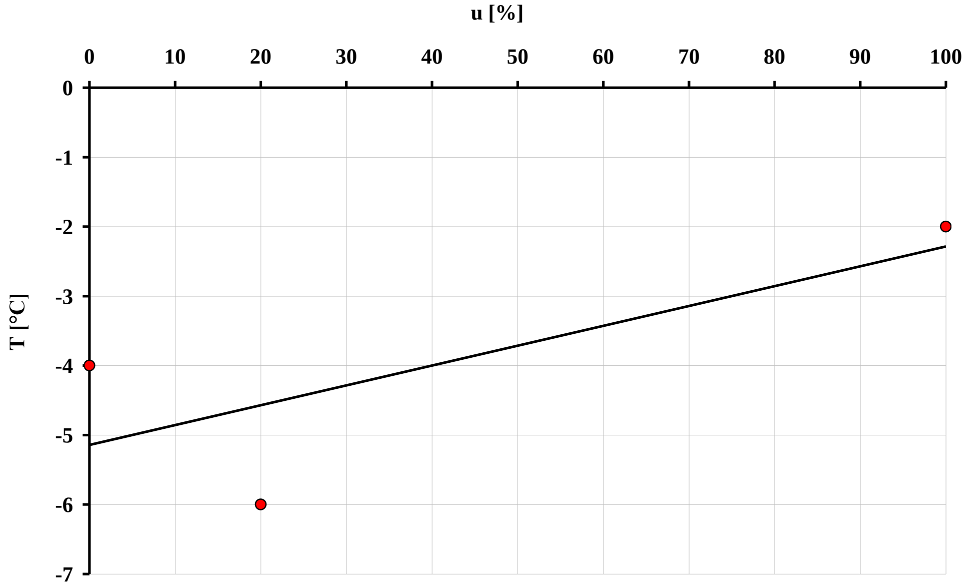

Fig. 5. The dependence of the cold filter plugging temperature on the concentration of synthetic fuel in the mixture

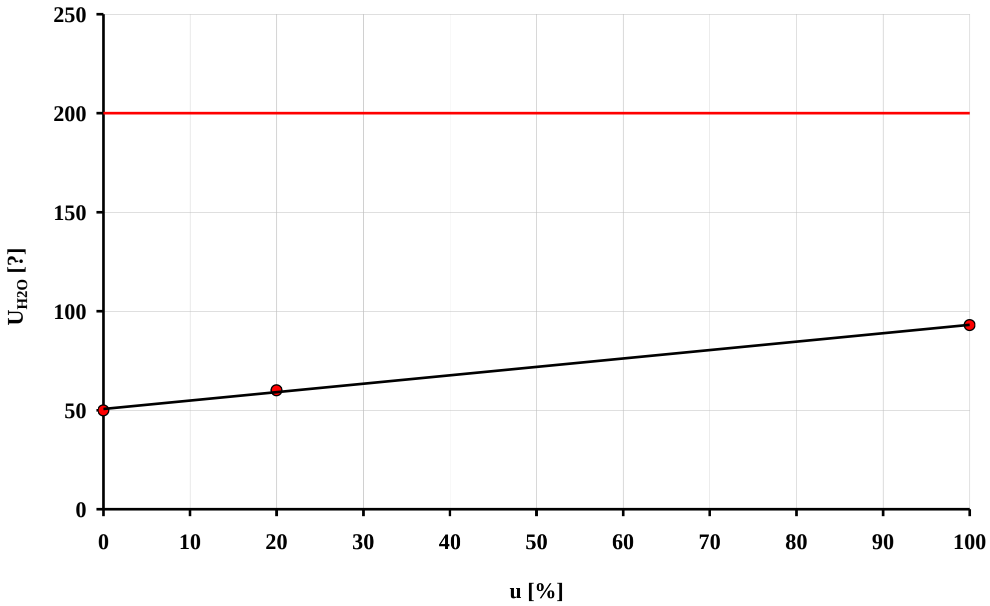

Fig. 6. Dependence of water content on the concentration of synthetic fuel in the mixture

Table 1 gives a summary of the physical parameters of petroleum-derived diesel oil, alternative fuel in the form of rapeseed oil methyl esters and the measurement results for a mixture of diesel oil and 7% synthetic polymer fuel additives.

Table 1

List of physical parameters of selected fuels [1,3]

		acc to PN-EN 690+A1:2011 DO "standard"	acc. to PN-EN 14214	acc to PN-EN 690+A1:2011 DO "standard"
kinematic viscosity in 400 C [mm^2/s]	min. max.	2.00 4.50	59 48	75 96
density in 15^0C	min. max.	820.0 845.0	860.0 900.0	830
cetane index	min.	46.0	-	-
cetane number	min.	51.0	51.0	57.0
sulfur content, % by weight	max.	0.001	0.001	-
flash-point, ^{0}C	min.	55.0	101.0	55.0
coking residue MCR in 10%, remaining ,% by weight	max.	0.30	0.30	0.08
cold filter blockage temperature, CFPP, ^{0}C	max.	0, -10, -20	0, -10, -20	-5.0

4. Conclusion

The analysis of the measurement results of the physical parameters of synthetic polymer fuels and their mixture with petroleum fuels allows the following conclusions to be drawn:

• virtually all physical parameters of both the mixture of synthetic fuels with petroleum oils and 100% synthetic fuel meet the standards for fuels for self-ignition engines,

• as shown by the results of tests on determining the flash point, the mixtures of petroleum oils and synthetic polymer fuels exceeded the permitted PN value of the flash point, and this applies to mixtures with synthetic fuels above 7%,

• the flash point measurement result corresponding to the 7% share of synthetic fuels in the mixture corresponds to the permitted content of additives to petroleum fuels, as in PN-EN590 concerning mixtures of petroleum fuels and fuels of plant origin.

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