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TESTING OF AN ENGINE FUELLED WITH RAPESEED OIL

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Abstract

Rapeseed oil in a few applications can be used as an engine fuel. Although it has worse properties than its methyl esters, it can be considered as an alternative fuel in engines adapted to its use. The article describes some problems resulting from the use of pure rapeseed oil as a fuel for compression ignition internal combustion engines. Differences between basic physical and chemical properties between diesel oil and rapeseed oil will be discussed and their impact on the theoretical engine performance and emission of pollutants from the exhaust system, with a focus on viscosity of rapeseed oil and the impact of this parameter on the fuel injection process. The basic changes in the engine design to be able to run on the rapeseed oil are discussed. The results of author's own tests of the engine adapted to operate on the rapeseed oil and its blends with diesel oil carried out on the engine dynamometer test bench are presented. The theoretical assumptions presented in the Introduction were tested experimentally in the dynamometric test. Combination of higher density of rapeseed oil and its smaller stoichiometric value caused by the presence of oxygen and a smaller share of hydrogen in the fuel, means that a larger mass of fuel can be injected into the charge compressed into the cylinder. Thanks to this, the engine powered by rapeseed oil and diesel oil can reach similar powers.

Keywords: *transport, road transport, combustion engines, air pollution, environmental protection, emissions testing*

1. Introduction

Vegetable oils are considered as good alternatives to diesel since their properties are similar to diesel oil. Thus, they offer the advantage of being able to be used in the existing diesel engines without any modifications. They have a reasonably high cetane number. The flash point of vegetable oils is high; hence, it is safe to use them. Vegetable oils typically have large molecules, with carbon, hydrogen and oxygen being present. They have a structure similar to diesel fuel, but differ in the type of linkage of the chains and have a higher molecular mass and viscosity. The presence of oxygen in vegetable oils raises the stoichiometric fuel air ratio. Contrary to fossil fuels, vegetable oils are free from sulphur and heavy metals. The calorific value is slightly lower than that of diesel. Transesterification of vegetable oils provides a significant reduction in viscosity; thereby enhancing the physical and chemical properties of vegetable oil to improve the engine performance and also the properties of the transesterified oil (Bio diesel) is almost identical to diesel. It has been reported that the methyl and ethyl esters of vegetable oil can result in superior performance than neat vegetable oils. However, vegetable oils may be used in rare cases as motor fuels. One of such fuels may be rapeseed oil.

The ideal diesel fuel is a saturated and non-branched hydrocarbon molecule with carbon number of 14, whereas vegetable oil molecules are triglycerides generally with non-branched chains of different lengths and different degrees of saturation with the carbon number of 18 to 57 and it depends on the type of vegetable oils. The vegetable oil contains a substantial amount of oxygen in its structure and so it is naturally oxygenated. The boiling point of hydrocarbons depends on the number of carbon atoms in the molecule.

The fuel oils containing 14 carbon atoms in the molecule boil at a temperature of 250-300ºC, while for heavier fuels containing 19 carbon atoms in the molecule, this temperature is higher by about 50ºC [5]. The distillation curves of diesel oil and rapeseed oil are quite different. The rapeseed oil distillation curve is almost a horizontal line showing that almost 80% of the rapeseed oil mass evaporates in a narrow temperature range between 320 and 350ºC [6]. Differences in the boiling points of light fractions of diesel oil and rapeseed oil reach 100ºC and decrease to zero at the end of distillation. These differences mean that heavier rapeseed oil is more difficult to evaporate in the engine's combustion chamber, especially when relatively low temperatures prevail in it (low engine loads, cold engine starting).

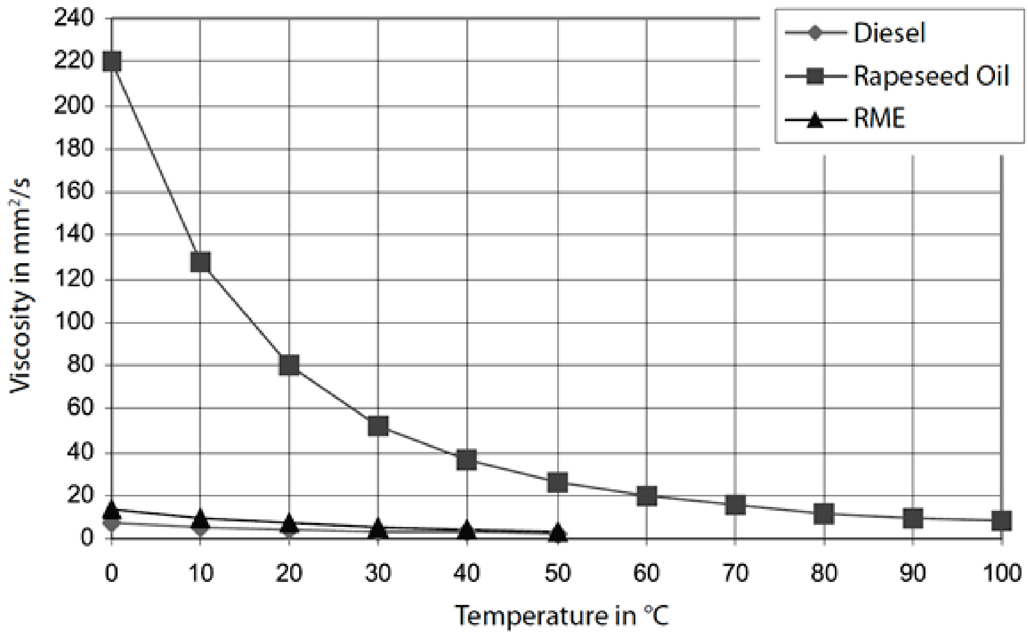

Fig. 1. Viscosity of rapeseed oil, diesel oil and RME [4]

Due to the distinctly higher kinematic viscosity of rapeseed oil compared to diesel fuel, it needs to be heated before it can be used as a fuel for engines. Rapeseed oil reaches the kinematic viscosity level of diesel from a temperature level of approx. 100ºC. In general, rapeseed oil is not heated higher than 70ºC, due to polymerisation, which starts at approx. 75ºC. This clearly implies that for the atomization process the temperature level is a significant influencing variable. Apart from this, the flashpoint of rapeseed oil is also very different to that of diesel. This behaviour can be attributed to the different saturated liquid line. The decelerated evaporation of rapeseed oil leads to a delayed fuel mixing process in the combustion chamber of the engine. Hence, problems with the combustion in low load operation can be expected, which can result in higher CO emissions.

2. Engine testing

The theoretical assumptions presented in the Introduction were tested experimentally in the dynamometric test. A Farymann Diesel 18 W type engine was used for the tests (Fig. 2), the basic technical data of which is shown in Table 2.

When using rapeseed oil and its mixtures with diesel oil, the engine uses a fuel heating system that maintains the fuel temperature at 55ºC.

Tab. 1. Fuel properties of diesel and rapeseed oil [1]

Physical property	Unit	Diesel	Rapeseed oil
Density (15ºC)	kg/m^3	835	920
Kin. viscosity (20ºC)	mm^2/s	3.08	78.7
Kin. viscosity (40ºC)	mm^2/s	3.2	33.1
Surface tension (40ºC)	mN/m	27	33
Gross caloric value	MJ/kg	42.6	37.7
Volumetric caloric value	MJ/dm^3	35.6	34.7
Cetan number	–	50-54	39-44
Flashpoint	ºC	64	230
Sulphur	%m/m	0.035	>0.001
Content of carbon	%	86	78
Content of hydrogen	%	14	10
Content of oxygen	%	–	12

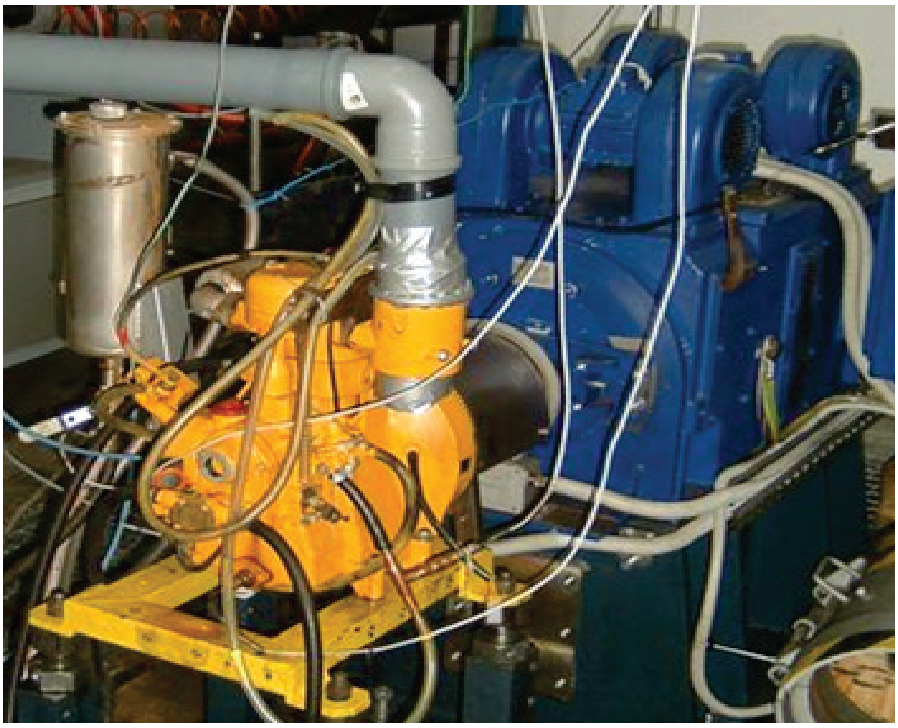

Fig. 2. Engine of 18 W type installed on test bench

Tab. 2. Data of the engine under test

Engine type:	Farymann 18 W
Displacement [dm^3]:	0.290
Number of cylinders:	1
Maximum power output [kW]:	4.7
Rated speed [RPM]:	3000
Cooling system:	water cooling
Ignition type:	self-ignition
Pollutants emission reducing devices:	none
Fuel injection type:	direct injection
Fuel system type:	heated with an external heat exchanger

Accidental combination of higher density of rapeseed oil and its smaller stoichiometric value caused by the presence of oxygen and a smaller share of hydrogen in the fuel, means that a larger mass of fuel can be injected into the charge compressed in the cylinder. Thanks to this, the engine powered by rapeseed oil and diesel oil can reach similar powers. The decisive factor limiting engine power, however, is exhaust opacity – higher in the case of an engine running on rapeseed oil (Fig. 4a). It is characteristic that differences in opacity increase with decreasing engine loading, which would indicate deterioration of mixing fuel with air under conditions of lower temperatures prevailing at low engine load. Higher differences in exhaust opacity at low engine loads are accompanied by greater differences in CO and NOx emissions (Fig. 3). This is evidence of poor mixing of fuel with air, as a result of which there are fuel-rich areas inside the cylinder, where fuel is not completely burned due to local lack of oxygen, and the slowdown resulting from this process is characterized by low intensiveness, resulting in low emissions NOx.

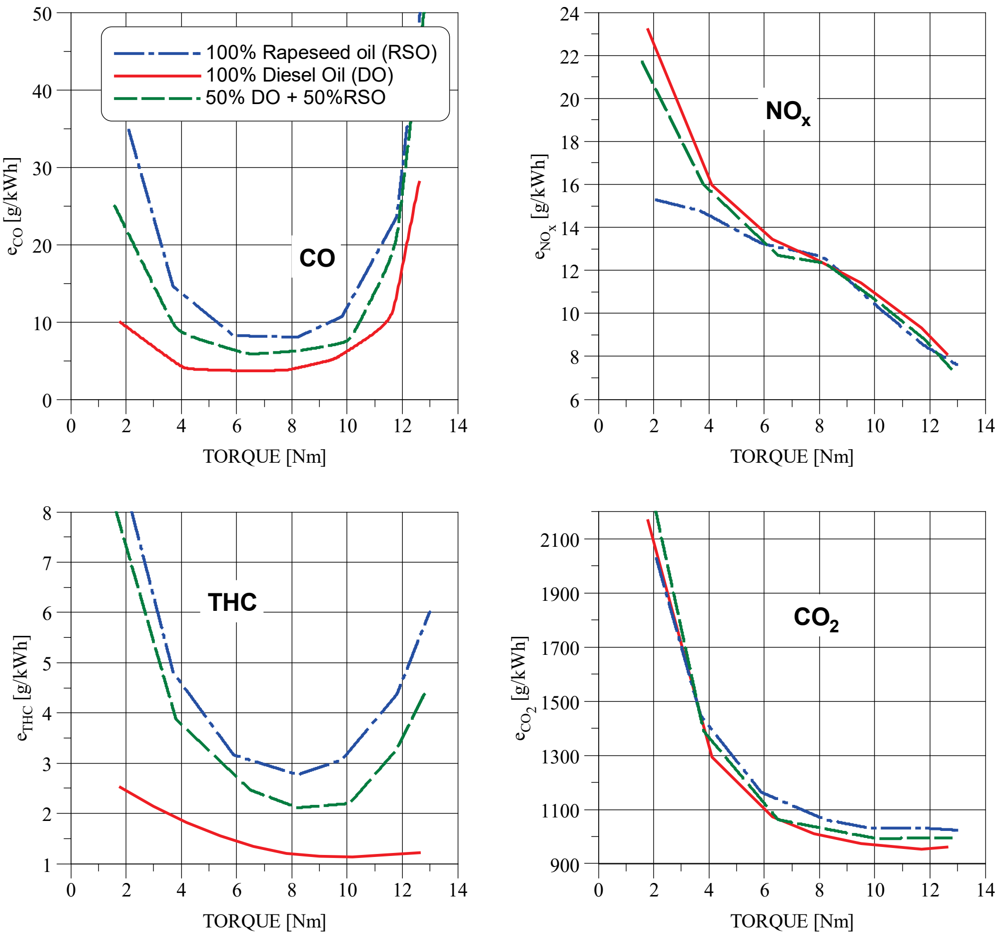

Fig. 3. Specific emissions for various fuels on the engine load characteristics at a speed of 2,500 rpm

Rapeseed oil causes an increase in exhaust opacity. Intending to keep the same opacity value when using rapeseed oil as fuel, the engine power should be reduced by 2-5%. In the case of blends of diesel oil with rapeseed oil, the percentage of rapeseed oil in the fuel is accompanied by the opacity increase.

The use of rapeseed oil causes an increase in CO_2 emission on average by approx. 7%, CO and THC by approx. 100% with the simultaneous decrease of NOx emission by 10-25%.

The use of rapeseed oil caused an increase in the exhaust gas temperature of the tested engine by approx. 300ºC (Fig. 4b), which means that the combustion process of this fuel has been extended in relation to diesel oil. Rapeseed oil is characterized by a lower value of cetane number in relation to diesel oil and, consequently, longer period of self-ignition delay. The course of specific emissions (Fig. 3) and the increase in the exhaust gases temperature in the case of rapeseed oil (Fig. 4b) show that in the engine under test when rapeseed oil is used, we have a delayed process of the heat release. It would be desirable to increase the injection advance for rapeseed oil or to add a cetane number increasing substance to the fuel.

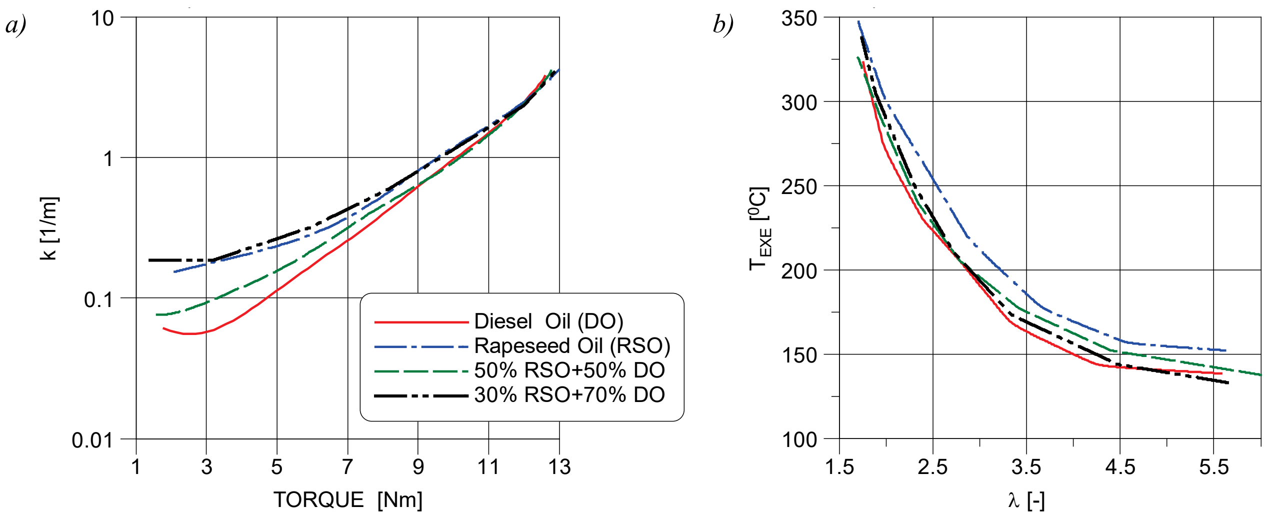

Fig. 4. The exhaust opacity (k) and the exhaust temperature (T_{EXH}) as a function of the torque (a) and the air-fuel ratio (b) at 2500 rpm

The ad hoc measures to accelerate combustion in the cylinder, such as increasing the injection advance or increasing the injector opening pressure, were not possible to achieve in the engine being tested, for technical reasons.

Increasing the injection advance would probably improve the efficiency of the engine, which would result in a decrease in fuel consumption and CO_2 and THC emissions as a result of earlier termination of the heat release process, but would lead to an increase in NOx emissions as a result of increasing the maximum temperature in cylinder.

In an engine with direct injection, the first phase of the combustion process, known as the premixed combustion, is usually responsible for the emissions of NOx, the course of which mainly affects the maximum temperature of the engine cycle. Its course is mainly influenced by the quality of fuel atomization and the quality of its mixing with air. In the case of a significant difference in the viscosity of diesel oil and rapeseed oil, which cannot be compensated for by the fuel heating, we are dealing with deterioration of fuel atomization, its worse evaporation, and mixing with air, which results in increased CO emission and extended combustion process. In the case of using rapeseed oil blends with diesel fuel, the differences are the more evident the higher the share of rapeseed oil in the fuel.

3. Conclusions

1) Due to a number of unfavourable properties, rapeseed oil is not a fuel that can replace diesel. It can be used as fuel in niche conditions in the engines specially adapted for that purpose.

2) The use of diesel fuel with the addition of rapeseed oil will increase the emission of CO, CO_2, THC and opacity of the exhausts as well as a decrease NO_x emissions.
3) In order to reduce the above differences, the engine fuel system should be heated in order to reduce the fuel viscosity containing rapeseed oil.
4) In the engines adapted to run on diesel fuel, it should be possible to adjust the injection advance to compensate for the delay of the heat release when rapeseed oil additive to fuel is used.
5) To maintain the same exhaust opacity at the rated speed, as in the case of diesel fuel supply, the engine power should be reduced by approx. 3%.
6) The use of rapeseed oil causes an increase of the fuel consumption by the engine from 6 to 13%.

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