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INVESTIGATION OF FLOWABILITY OF RAPESEED OIL AND DIESEL FUEL BLENDS IN WINTER CONDITIONS

RAPSŲ ALIEJAUS IR DYZELINIŲ DEGALŲ MIŠINIŲ TAKUMO ŽIEMOS SĄLYGOMIS TYRIMAS

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The main problems to use straight vegetable oil as a fuel are its kinematic viscosity and low temperature behaviour. If the viscosity is too high, the oil can’t pass the fuel circuit. In previous investigations at the Biofuels Research Laboratory (Latvia University of Agriculture) vehicles VW Golf 1.9TDi and MAN 19.464 were used as the study objects. There were no problems in the vehicle operation in warm weather conditions, but in winter time, when the air temperature dropped below -10°C, the use of vehicles, especially starting the engine, became problematical. As the kinematic viscosity is an indicator for low temperature behaviour, this investigation deals with the results of rapeseed oil flowability tests in winter conditions depending on the amount of mixed fossil fuel. The blends with 5%, 10%, 25% and 50% fossil diesel fuel (0^{th} and 2^{nd} arctic classes) admixture were tested. Besides kinematic viscosity the freezing temperature and cold filter plugging point of each blend was determined. Experiments proved that for the smooth operation of diesel engine under Latvian climatic conditions in winter time, the rapeseed oil and fossil fuel blends have to be used. Use of the second-class arctic diesel fuel for blends is better at lower temperatures because it provides a lower viscosity and using 50% mixture the engine operation is possible up to -30°C.

Rapeseed oil, diesel fuel, kinematic viscosity, cold filter plugging point.

Introduction

The main problems to use straight vegetable oil as a fuel are its kinematic viscosity and low temperature behaviour. For most vegetable oils kinematic viscosity is much higher than for diesel fuel. If it is too high, the oil can’t pass the fuel circuit. Heating is one of the possibilities to enable engines to run on vegetable oil. The low temperature behaviour is of importance for engine cold start and low load. In previous investigations at the Biofuels Research Laboratory (Latvia University of Agriculture) vehicles VW Golf 1.9TDi (rebuilt to run on rapeseed oil with a one-tank system) and MAN 19.464 (rebuilt to run on rapeseed oil with a two-tank system) were used as the study objects [1,2]. There were no problems in the vehicle operation in warm weather conditions, but in winter time, when the air temperature dropped below -10°C, the use of vehicles, especially starting the engine, became problematical [3]. Besides the viscosity an important parameter influencing usage of fuel in winter months is the cold filter plugging temperature or point (CFPP, °C) [4]. CFPP is the highest temperature, at which a given volume of fuel fails to pass through a standardized filtration device in a specified time when cooled under certain conditions. This test gives an estimate for the lowest temperature that a fuel will give trouble to free flow in certain fuel systems. This is important as in cold and temperate climate countries a high cold filter plugging point will clog up vehicle engines more easily.

Literature analysis

Most of the companies that offer equipment to adapt vehicles to run on vegetable oil, give some guidance to the choice of conversion kits and vegetable oil and fossil fuel blend proportions. As an example the companies *Green Bull Motors GmbH* recommendations are shown in Table 1 [5].

Table 1. Recommendations of *Green Bull Motors GmbH* for operating diesel engines on vegetable oil.
1 lentelė. "Green Bull Motors BmbH" firmos rekomendacijos variklio darbui augaliniu aliejumi.

Vegetable oil, %	Fossil diesel fuel, %	Diesel engines with prechamber and wirl chamber, older engines	Diesel engines direct injection SDI Bosch VP37-VP44, Bosch VE, Multijet, mechanical rotary pump, TDI Diesel-Kiki, Nippon-Denso or Zexel
100	0	One-tank system in summer or two-tank system all the year	Two-tank system all the year
50	50	One-tank system all the year	One-tank system in summer or two-tank system all the year
30	70	One-tank system all the year	One-tank system in summer or two-tank system all the year
20	80	One-tank system all the year	One-tank system all the year

Unfortunately, these suggestions are very approximate, so the use of vegetable oil as a fuel at the specific climatic conditions requires for more detailed studies.

Analyzing the fossil and biofuel blend studies performed in other countries, Cold Filter Plugging Point and viscosity quality assurance is highlighted as one of the most significant factors in biofuel application efficiency. For instance, in China an artificial neural network model is established to predict CFPP of the blended diesel fuels, using input parameters of kinematical viscosity, density, refractivity intercept, CFPP and weight percentages of constituent diesel fuels [6]. Most of investigations in this field are carried out to investigate fossil diesel and biodiesel blend properties. For example, in order to exploit the proximity of South Asian and South-East Asian countries, blends of Jatropha and Palm biodiesel have been examined in India to study their physical-chemical properties and to get an optimum mix of them to achieve better low temperature properties with improved oxidation stability [7].

Very large-scale studies have been conducted in Lithuania where the comparative bench testing of a direct injection diesel engine operating on ethanol, petrol and rapeseed oil blends was performed [8]. One of the purposes of this research was to examine the effect of ethanol and petrol addition into rapeseed oil (RO) on the biofuel kinematical viscosity. Adding into RO from 2.5 to 7.5% of ethanol and petrol its viscosity at ambient temperature of 20°C was diminished by 9.2 to 28.3% and 14.1 to 31.7%, respectively. Heating up to the temperature of 60°C the viscosity of pure rapeseed oil, 2.5 – 7.5% ethanol-RO blends and 2.5 – 10% petrol-RO blends further was decreased 4.2, 3.9 – 3.8 and 3.9 – 3.6 times. The same authors investigated also diesel engine operating on rapeseed oil and its blends with diesel fuel [9]. Experiments confirmed that mixing of RO with diesel fuel improves filtration through a fine porous paper element and flow capacity for blends with 25 to 75% admixture of diesel fuel increases 1.7 to 11.8 times.

Purpose of the research and objectives

To ensure the reliable operation of the diesel engine using vegetable oil as a fuel for the entire year, but especially in winter time when the ambient air temperature falls up to -25°C, it is important to develop an optimum ratio rapeseed oil and arctic diesel blends to be used as a fuel in winter conditions. As vegetable oil fuel use mainly depends on two key parameters – viscosity and CFPP temperature, to achieve the target the following tasks were set for this investigation:

- preparing of rapeseed oil and diesel fuel (up to 50%) blends, using the 0^{th} and 2^{nd} arctic class diesel fuel;
- determination of the viscosity of blends at different temperatures and their freezing temperature;
- evaluation of the CFPP changes depending on diesel fuel content in rapeseed oil and diesel fuel blend.

Subject and test methodology

The following rapeseed oil blends with fossil diesel fuel were tested:

- rapeseed oil with 5% 0th arctic class diesel fuel mix (in the following tables and figures marked with RO+5%D);
- rapeseed oil with 10% 0th arctic class diesel fuel mix (RO+10%D);
- rapeseed oil with 25% 0th arctic class diesel fuel mix (RO+25%D);
- rapeseed oil with 50% 0th arctic class diesel fuel mix (RO+50%D);
- rapeseed oil with 5% 2nd arctic class diesel fuel mix (RO+5%D2);
- rapeseed oil with 10% 2nd arctic class diesel fuel mix (RO+10%D2);
- rapeseed oil with 25% 2nd arctic class diesel fuel mix (RO+25%D2);
- rapeseed oil with 50% 2nd arctic class diesel fuel mix (RO+50%D2).

Determination of the cold filter plugging temperature CFPP was performed according to the method of the standard LVS EN 116+AC:2002 at the Latvian Certification Centre. Kinematic viscosity measurements at various temperatures were performed under field conditions. Viscosity was determined using a glass capillary viscometer ВПЖ-2 (Figure 1) with a capillary diameter 2.37 mm.

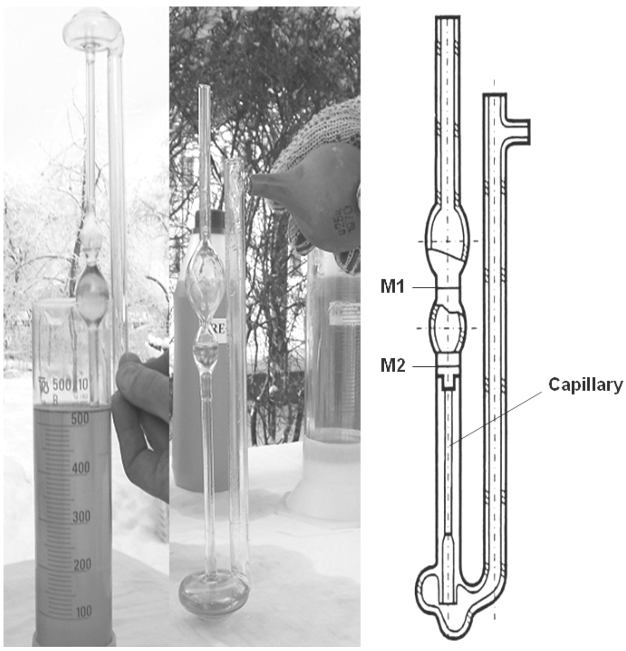

Fig. 1. Viscometer ВПЖ-2
1 pav. Viskozimetras ВПЖ-2

Viscometer consists of a U-shaped tube with a built-in capillary. Viscosity determination method is based on a time measurement when a fixed quantity of fluid from the reservoir flows through the capillary. The time T in which the mixture flows through the capillary from the mark M1 to the mark M2 was fixed.

Kinematic viscosity was calculated by the formula:

$$V = \frac{g}{9.807} \cdot T \cdot K \, , \tag{1}$$

where V – fluid kinematic viscosity, mm^2 s^{-1};
K – viscometer constant, 3.124 mm^2 s^{-2};
T – fluid flowing time, s;
g – gravity acceleration, m s^{-2}.

Results and discussion

The mixture kinematic viscosity was determined in the winter time, when air temperature reached -25°C. The measurement results are summarized in the Table 2 and Figure 2. Freezing temperatures were determined under laboratory conditions, because outdoor air temperature was not low enough to stiffen all the mixtures.

Table 2. Viscosity and freezing point measurement results.
2 lentelė. Klampos ir užšalimo taško matavimo rezultatai.

Rapeseed oil – diesel fuel mix	Viscosity, mm^2 s^{-1} at				Freezing temperature, °C
	-9°C	-15°C	-19°C	-24°C	
RO+5%D2	265.28	345.31	frozen	frozen	-19
RO+10%D2	224.99	246.25	580.92	frozen	-21
RO+25%D2	119.37	122.19	191.24	981.13	-27
RO+50%D2	46.87	47.19	53.44	119.99	-31
RO+5%D	290.62	390.62	frozen	frozen	-19
RO+10%D	237.50	261.87	384.37	frozen	-21
RO+25%D	134.37	143.75	160.84	790.77	-26
RO+50%D	59.37	59.06	79.06	200.94	-28

Experimentally was established that the kinematic viscosity of rapeseed oil have to be less than 1000 mm^2 s^{-1}, because such viscosity allows rapeseed oil freely flow through the fuel pipe with diameter 8 mm as it's recommended by *ELSBETT* (rapeseed oil conversion kit producer) for using a one-tank system. During viscosity measurements it was determined that a pure rapeseed oil reached the viscosity of 1000 mm^2 s^{-1} at -12°C, and, to operate a diesel engine at lower temperatures, it is necessary to make rapeseed oil and fossil fuel blends. Adding 5% of arctic diesel fuel to rapeseed oil, the limit of viscosity was reached at -17°C.

Forming 10% and 25% blends unusual occurrence was observed: mixed with 0th arctic class diesel fuel rapeseed oil viscosity decreased more intensively than in mixtures with the 2nd arctic class diesel fuel. However, reaching the temperature at limiting viscosity, the blend parameters became equal providing

1000 mm^2 s^{-1} viscosity for 10% mixtures at -20°C and for 25% mixtures at -24°C (Figure 2).

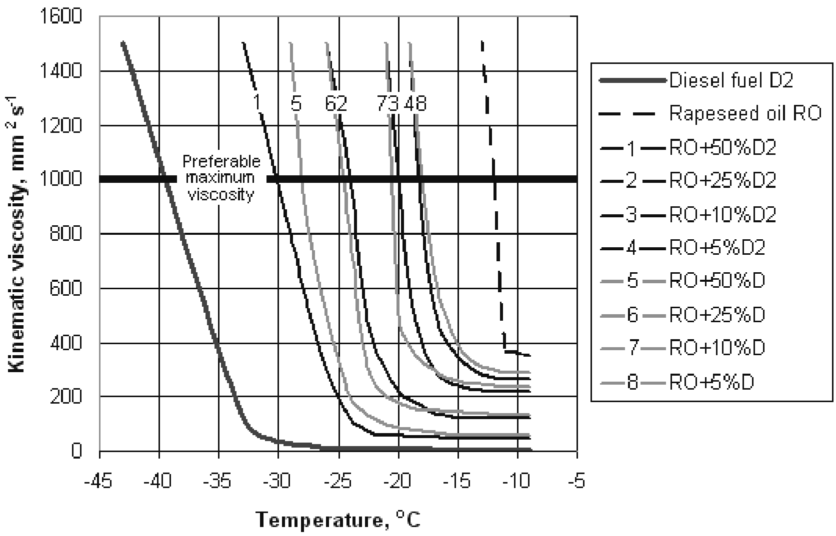

Fig. 2. Viscosity graphs of rapeseed oil and diesel fuel blends
2 pav. Rapsų aliejaus ir dyzelinių degalų mišinių klampos grafikai

Measurements of mixtures with 50% of arctic diesel fuel blend convincingly proved that the 2nd arctic class diesel fuel more effectively reduces the viscosity of rapeseed oil and the engine operation is possible up to -30°C.

Determining the CFPP temperature for the 2nd arctic class diesel it was -43°C, and for the 0th arctic class diesel fuel -33°C. To clarify, at what temperatures fuel filter is blocked, the CFPP measurements for blends were carried out (Table 3).

Table 3. CFPP measurement results.
3 lentelė. CFPP matavimo rezultatai.

Rapeseed oil – diesel fuel mix	CFPP temperature, °C
RO+5%D2	15
RO+10%D2	13
RO+25%D2	3
RO+50%D2	-20
100%D2	-43
RO+5%D	14
RO+10%D	12
RO+25%D	2
RO+50%D	-10
100%D	-33

As it is seen from the results (Figure 3 and 4), the CFPP temperature change in dependence from the mixed fossil fuel amount is nearly linear, and in the Latvian climatic conditions (except winters when the air temperature drops below -20°C) it's possible to run diesel engines with 50% blends without additional heating.

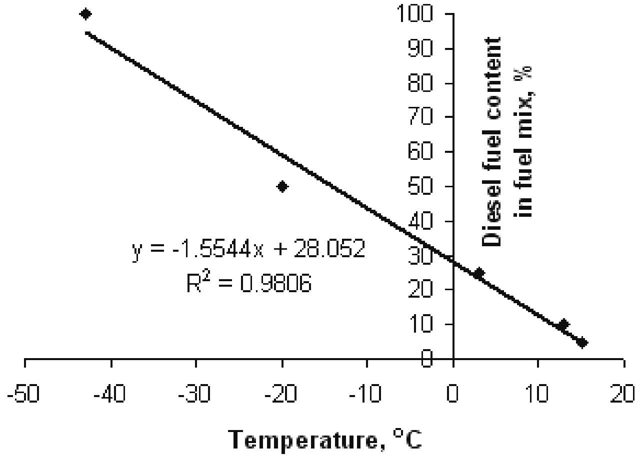

Fig. 3. CFPP temperature and diesel fuel content relationship for rapeseed oil and 2nd arctic class diesel fuel blends

3 pav. Rapsų aliejaus ir 2 klasės arktinių dyzelinių degalų mišinių CFPP temperatūros ir dyzelinių degalų kiekio sąryšis

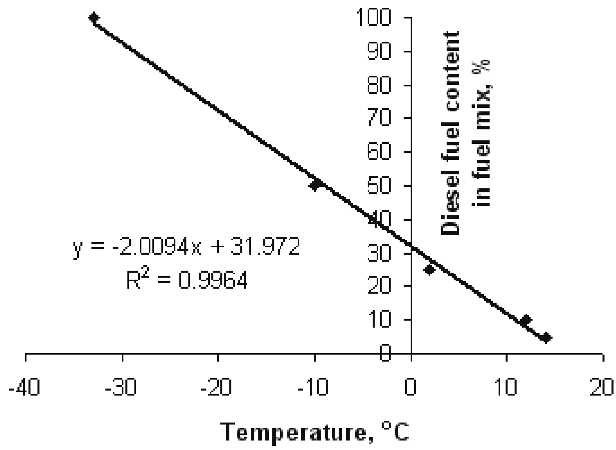

Fig. 4. CFPP temperature and diesel fuel content relationship for rapeseed oil and 0th arctic class diesel fuel blends

3 pav. Rapsų aliejaus ir 2 klasės arktinių dyzelinių degalų mišinių CFPP temperatūros ir dyzelinių degalų kiekio sąryšis

The difference is significant for mixtures with different arctic diesel fuel classes. If the 50% mixture with 2nd class arctic diesel fuel without a filter heating could be used up to -20°, then a 50% mixture with 0th class arctic diesel – only up to -10°C.

Conclusions

1. In order to operate diesel engines using rapeseed oil as a fuel at air temperatures below -12°C, rapeseed oil and fossil fuel blends have to be used.
2. Adding 5% of arctic diesel fuel to rapeseed oil, the limit of viscosity can be lowered to -17°C, adding 10% – to -20°C, but using 25% blends – to -24°C.
3. Use of the second-class arctic diesel fuel for blends is better at lower temperatures because it provides a lower viscosity and using 50% mixture the engine operation is possible up to -30°C.
4. The CFPP temperature change in dependence from the mixed fossil fuel amount is nearly linear.
5. The CFPP temperature is not so much affected by crystal formation process, but by the rapeseed oil large viscosity, which hampers the fuel filtration process. So, to ensure the smooth operation of diesel engine under Latvian climatic conditions, the heating of rapeseed oil and diesel fuel blend before filtration is necessary, because only by the heating a rapid reduction in viscosity can be achieved.

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RAPSŲ ALIEJAUS IR DYZELINIŲ DEGALŲ MIŠINIŲ TAKUMO ŽIEMOS SĄLYGOMIS TYRIMAS

Reziumė

Gryno augalinio aliejaus naudojimo vietoj mineralinių degalų pagrindinės problemos yra jo kinematinė klampa ir kitos savybės esant žemoms temperatūroms. Jei klampa per didelė, aliejus negali tekėti degalų tiekimo sistema. Ankstesni tyrimai, atlikti Biodegalų tyrimo laboratorijoje (Latvijos žemės ūkio universitetas) su automobiliais VW Golf 1,9 TDi ir MAN 19.464 parodė, kad šiltomis oro sąlygomis automobilių varikliai veikia be problemų. Tačiau žiemos laikotarpiu, kai oro temperatūra nukrito žemiau -10°C, automobilių naudojimas buvo problemiškas, ypač variklio paleidimas. Šiame darbe pateikiami rapsų aliejaus ir jo mišinių su mineraliniais degalais takumo žiemos sąlygomis, priklausomai nuo įmaišytų mineralinių degalų kiekio, tyrimų rezultatai. Buvo tiriami mišiniai su 5%, 10%, 25% ir 50% mineralinių degalų kiekiu (0 ir 2 klasės arktinių degalų). Be kinematinės klampos buvo nustatyti ir šių mišinių užšalimo bei šalto filtro užsikimšimo temperatūros (CFPP)**.** Eksperimentai parodė, kad norint užtikrinti sklandų dyzelinio variklio darbą žiemos metu Latvijos klimato sąlygomis, turi būti naudojami rapsų aliejaus ir mineralinių degalų mišiniai. Mišiniams geriau naudoti antros klasės arktinius dyzelinius degalus, nes esant žemoms temperatūroms gaunama mažesnė klampa, o naudojant 50 % mišinį variklio darbas galimas iki – 30°C**.**

Rapsų aliejus, dyzeliniai degalai, kinematinė klampa, šalto filtro užsikimšimo temperatūra.

Илмарс Дукулис, Аиварс Бирквс, Гинтс Бирзетис

ИССЛЕДОВАНИЕ ТЕКУЧЕСТИ СМЕСЕЙ РАПСОВОГО МАСЛА И ДИЗЕЛЬНОГО ТОПЛИВА В ЗИМНИХ УСЛОВИЯХ

Резюме

Основные проблемы при использовании растительного масла как топлива, связаны с его кинематической вязкостью и поведением при низких температурах. При слишком большой вязкости масло не может протекать через систему топливоподачи. В Лаборатории исследования биотоплива (Латвийский сельскохозяйственный университет) результаты раннее проведенных испытаний на рапсовом масле работающих автомобилей VW Golf 1,9 TDi и MAN 19.464, показали, что нет проблем при работе двигателей в теплых условиях. Но зимой, когда температура воздуха упала ниже -10°C, использование автомобилей, особенно пуск двигателей, стало проблемным.

Целью этой работы являлось исследование текучести рапсового масла и его смесей с минеральным топливом в зимних условиях. Исследовались смеси с 5%, 10%, 25% и 50% содержанием минерального топлива (0-ого и 2-ого арктического класса). Кроме кинематической вязкости, определялись температура застывания и точка застопоривание холодного фильтра этих смесей. Эксперименты показали, что для надежной работы дизельного двигателя в Латвийских климатических условиях зимой, нужно использовать смеси рапсового масла и минерального топлива. При низких температурах для смесей лучше использовать дизельное топливо 2-ого арктического класса, так как достигается меньшая вязкость. При использовании 50% смеси, работа двигателя возможна до – 30°C.

Рапсовое масло, дизельное топливо, кинематическая вязкость.