ECONTECHMOD. AN INTERNATIONAL QUARTERLY JOURNAL – 2019, Vol. 08, No. 4, 3 – 7

Determining the effect of the addition of temperature on the rheological properties of biofuels FAME and RME

[1] *G. Wcisło,* [2] *B. Pracuch,* [3]*P. Łagowski,* [3]*D. Kurczyński,* [4]*A. Leśniak* [5]*V. Tomyuk*

[1] *Faculty of Production Engineering and Power Technologies*

University of Agriculture in Krakow, Poland

e-mail: Grzegorz.Wcislo@ur.krakow.pl

[2] *BioEnergia Małopolska Centre for Renewable Energy Sources, Poland*

e-mail: gwcislo@bioenergia.com.pl

[3]*Kielce University of Technology*

Department of Automotive Vehicles and Transportation, Poland

[4]*Krakow University of Economics*

[5]*Department of Computer Aided Systems*

Lviv Polytechnic National University, Ukraine

e-mail: vasyl.v.tomiuk@lpnu.ua

Received January, 01 2019: accepted January, 21 2019

Abstract. The aim of the study was to compare the impact of dynamic viscosity of two biofuels. One was a mixture of 50% (m / m) SBME and 50% (m / m) RME of own production. The mixture was conventionally called FAME. The second biofuel was commercial RME from a gas station. Dynamic viscosity as a function of temperature from -20 to 50°C was tested. The main device used at the measuring stand was ReolabQC rheometer manufactured by a German Anton Paar GmbH company. Dynamic viscosity especially grew rapidly after cooling biofuels to temperatures below -5°C. Dynamic viscosity FAME biofuels produced from pure vegetable oil (soybean oil and rapeseed oil) in a temperature range of 50 to -20°C has a value of c.a. 9 to 53[mPa·s]. Dynamic viscosity of Biofuel FAME produced from mixtures of vegetable oils it was on average lower by about 1 to 8 [mPa·s] of RME shopping from a gas station.

Keywords: Biodiesel, FAME - Fatty Acid Methyl Esters, RME - Rapeseed Methyl Esters, diesel engine, dynamic viscosity, shearing rate, biofuel mixture

INTRODUCTION

Quality standards PN-EN 590:2006 for diesel fuel and EN ISO3104 for FAME fuel determine only kinematic viscosity. No obligatory norm has been introduced so far for determining dynamic viscosity. Kinematic viscosity is a parameter describing the resistance of fluid flow due to gravity forces. Analysis of the subject literature shows various values of RME kinematic viscosity, which according to some authors at the temperature of e.g. 20°C ranged from 6 to 2000 [mPas] [1,9,11]. In recent years a rapid development of injection apparatus based on pump-injectors or common rail has been observed, where very high pressure occurs. In this situation it is most important to determine the fluid flow resistance under dynamic, not static conditions. It is the more important when type "B" fuels with biocomponent supplement of higher viscosity are used for self-ignition engine feeding.

Therefore, dynamic, not kinematic viscosity should be determined most precisely.

Dynamic viscosity is a measure of fluid's resistance to flow or fluid deformation - Polish standard PN-EN ISO 3104. It also affects the injection course, stream range and fuel spraying in the engine combustion chamber. It influences lubrication properties, which is particularly important in the case of rotational injection pumps because in the pumps of this type the pump elements are lubricated with diesel oil. So far dynamic viscosity has not been determined separately, only obtained from kinematic viscosity. It was due to a lack of proper tools which were relatively expensive. However, a dynamic development of rheometers in recent years, particularly dynamic types, allowed for a most precise determination of dynamic viscosity. Moreover, for a better assessment of fuel mechanical properties the influence of many rheological parameters on the behaviour of fuels or biofuels may be also tested [5,6]. It may be the reason why one sometimes encounters the opinion that small viscosity and resulting good flow properties are more important for the engine start up than the cetane number [2,3,4]. There is also a strict relationship between viscosity, temperature and shearing rate. Another problem is wrong separation of ester from glycerine phase, since even trace amounts of glycerine phase left over lead to a considerable increase in viscosity. As results from the Author's own research, viscosity of properly separated glycerine phase obtained after rapeseed oil methanolysis at 20ºC is about 940[mPas], whereas in diesel fuel about 8 [mPas], RME esters about 13 [mPas], whereas rapeseed oil about 70[mPas]. It results from the data given above that at 20oC oil viscosity is 5,5 times higher and viscosity of glycerine phase by over 72 times higher than RME viscosity [10].

METHODS OF RESEARCH

Measuring set with two coaxial cylinders was applied in the rheometer. Beside the cone/plate viscometer it is one of the most precise devices for measuring dynamic viscosity of fuels and biofuels. Figure 1 shows the schematic diagram of the measuring set with marked parameters which served to formulate the main relationships: for tangent force, oscillating torque, shearing force and dynamic viscosity [7,8]. Assuming that the tested sample has the height *H*, tangent force in the fluid at the distance *r* from the rotation axis may be expressed by the formula 1. Considering rotating frequency of the spinning element and outer diameter of the spinning element $R_1$and inner diameter of cylinder sleeve R_2 filled with the tested fluid, we may derive formula 2 describing the relationship for shearing force. If oscillating torque caused by tangent force is equal it may be generally written as $M=F\cdot r$. On the other hand, for the set applied in the rheometer, i.e. measuring set with coaxial cylinders, the oscillating torque may be shown by formula 3. Tangent friction forces transferred by the fluid to the inner cylinder cause the described oscillating torque *M*. Considering the above mentioned assumptions the formula for dynamic viscosity using coaxial cylinder set may be described using formula 4.

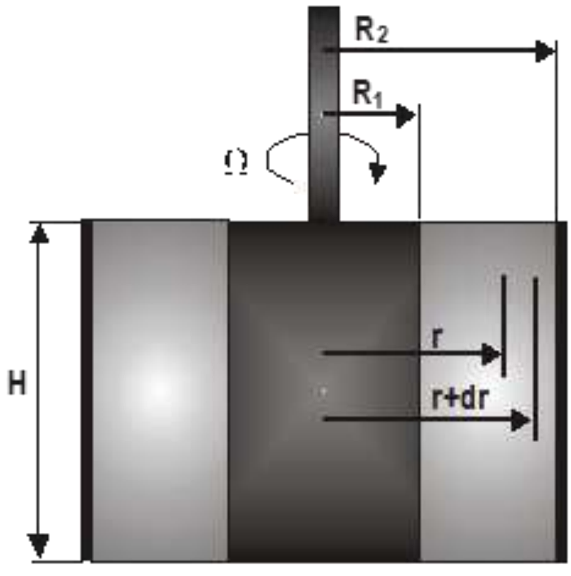

Fig. 1. Measuring set with coaxial cylinders

$$F_r = 2\pi r H \tau_r \quad (1)$$

$$\lambda = \frac{2\Omega}{1-\frac{R_1^2}{R_2^2}} \quad (2)$$

$$M = \frac{4\pi\eta H\Omega}{\frac{1}{R_1^2}-\frac{1}{R_2^2}} \quad (3)$$

$$\eta = \frac{1}{4\pi H}\left(\frac{1}{R_1^2}-\frac{1}{R_2^2}\right)\frac{M}{\Omega} \quad (4)$$

where *Ω* is a rotating frequency of the spinning element, *M* is an oscillating torque acting on spinning element axis, *H* is a height of biofuel sample, *r* is a distance from rotation axis, R_1 is an outer radius, R_2 is an inner radius of cylinder sleeve.

AIM AND SCOPE OF RESEARCH

The research aimed at determining the effect of temperature on dynamic viscosity of Biodiesel FAME and RME type biofuels. for comparison, the viscosity of commercial diesel was also determined.

Biofuel of the FAME Biodiesel was produced (composed of two biofuels) in a GW-200 reactor constructed by one of the authors (G.W) - Fig. 2. The process of transesterification was carried out in one stage and the obtained degree of oil transition into methyl esters was equal to 98.2%(m/m). The result has proved that the obtained FAME biofuel complies with EN 14214 standards of biofuel for a high pressure engine, as regards the ester content in FAME (Fatty Acid Methyl Esters).

The range of temperatures was assumed because due to the applied thermostatic bath it was impossible to lower the sample temperature below -20ºC. On the other hand raising the upper temperature above 50ºC was considered unnecessary because it does not generally affect a change of viscosity. In the test shearing rate of the rheometer spindle was constant 1050 [s^{-1}].

CHARACTERIZATION OF MEASURING STAND

The main device used at the measuring stand was ReolabQC rheometer manufactured by a German Anton Paar GmbH company - Fig. 3.

Fig. 2. Reactor GW 200 for production of Biodiesel FAME (FAEE)

Fig. 3. The researchers post was furbished with a reometer and tub thermostats

The rheometer is a devise designed for determining mechanical and rheological parameters of fluids and fuels. The device measures among others dynamic viscosity, surface tension, shearing forces, shearing rate, shearing tension, etc. The rheometer is also equipped with a temperature sensor and integrated system of time measurement. In order to determine the effect of temperature on the above mentioned parameters, the rheometer used at the measuring stand was additionally equipped with thermostatic bath made by an Austrian Grant company. The results of research using measuring system of the viscosimeter were sent to a computer and saved there to be subsequently processed using RHEOPLUS/32 V3.0.

The rheometer was equipped with internal memory and the system for research programme generation. Figure 3 presents the algorithm of the ReolabQC rheometer external control. The rheometer may be externally controlled by a computer which allows for creating and editing measuring programmes, which makes possible optional and multiple parameter setting and saving them without the necessity of deleting.

RESULTS AND DISCUSSION

Figure 4 show the results of research on determining the effect of temperature on dynamic viscosity.

Dynamic viscosity especially grew rapidly after cooling biofuels to temperatures below -5°C. Dynamic viscosity B100 FAME Biodiesel produced from pure vegetable oils in a temperature range of from 50 to -20°C has a value of c.a. 9 to 53 [mPa·s]. Dynamic viscosity B100 RME Biodiesel coming from the gas station in a temperature range of from 50 to -20°C has a value of c.a. 10 to 61 [mPa·s] For comparison, the dynamic viscosity Fuel Diesel in a temperature range of from 50 to -20°C has a value of c.a. 15 to 32 [mPa·s].

CONCLUSIONS

The test have shown that the dynamic viscosity of the biofuel FAME, RME and Fuel Diesel is temperature dependent.

Generally, the dynamic viscosity of FAME and RMR biofuels was higher in the whole range of temperatures tested.

Among the studied biofuels produced by the authors of the publication, FAME biofuel was characterized by a lower viscosity than RME biofuel from petrol stations. Dynamic viscosity especially grew rapidly after cooling biofuels to temperatures below -5°C.

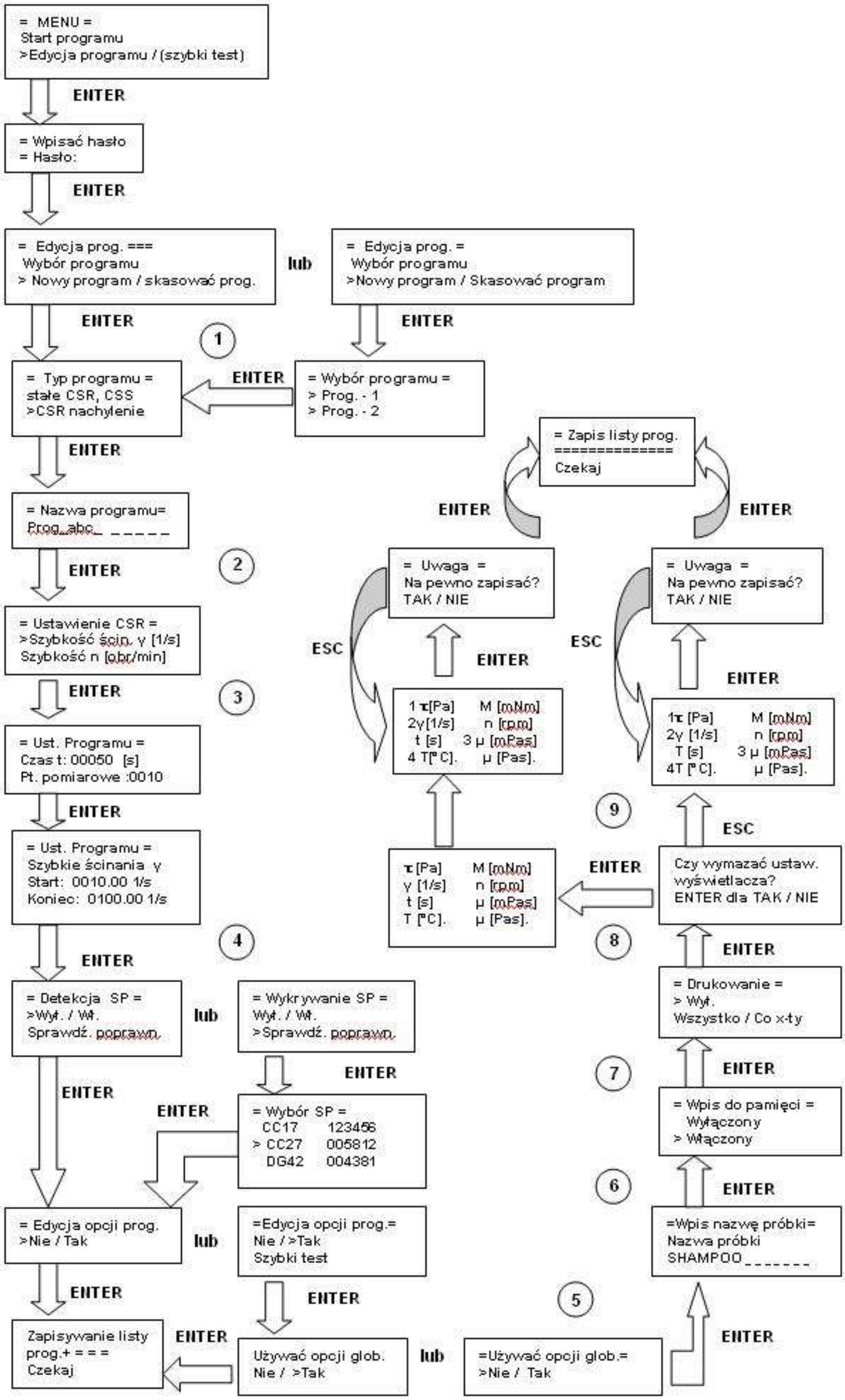

Fig. 4. The algorithmic work schemata is using the reometer ReolabQC

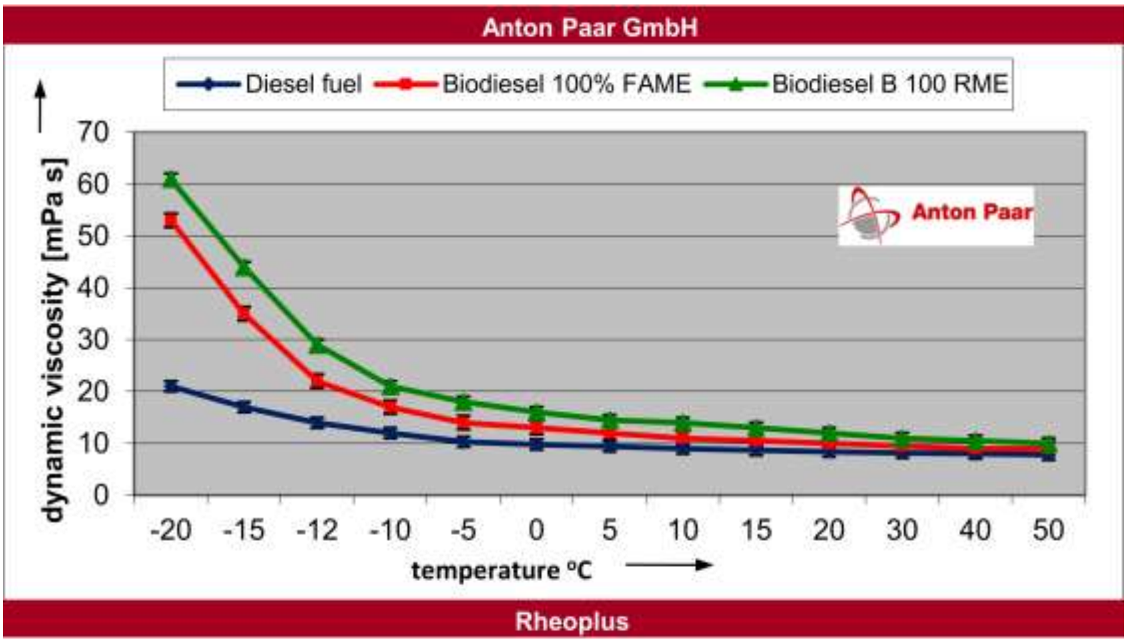

Fig. 5. Dynamic viscosity of biofuels containing FAME, RME and diesel fuel made of pure fat as a function of temperature

REFERENCES

1. **Cieślikowski B., Juliszewski T., Mazurkiewicz J.**, **2006**: Lepkość kinematyczna biopaliwa i fazy glicerynowej. Inżynieria Rolnicza, vol. 12, 59-65.
2. **Cisek J., Mruk A., Hlavňa V. 2011:** The properties of a HDV Diesel engine fuelled by crude rapeseed oil. Teka Komisji Motoryzacji i Energetyki Rolnictwa, Vol. XI, 29-39.
3. **Cisek J., Mruk A. 2012:** Właściwości silnika ZS zasilanego naturalnym olejem
4. rzepakowym. Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej z serii Mechanika Ekologia Bezpieczeństwo Mechatronika, Vol. 1(87)/2012, 5-16.
5. **Biodiesel 2006**, Handling and Use Guidelines. U.S. Department of Energy, Third Edition, September 2006.
6. **BRONIARZ-PRESS L., Różańska S., Kmiecik J.**, 2013: Analiza reologiczna paliw i biopaliw ciekłych. Ap. Chem. 52, 3, 159-16.
7. **Tys J. i in. 2003**: Technologiczne i ekonomiczne uwarunkowania produkcji biopaliwa z rzepaku. Instytut Agrofizyki im. Bohdana Dobrzańskiego PAN w Lublinie.
8. **Standard DIN 53019** - Układ pomiarowy reometru o cylindrach współosiowych.
9. **Standard PN-EN ISO 3104:2004**. Przetwory naftowe. Ciecze przezroczyste i nieprzezroczyste. Oznaczanie lepkości kinematycznej i obliczanie lepkości dynamicznej.
10. **Wcisło G. 2008**: Wyznaczenie wpływu temperatury na lepkość dynamiczną biopaliw roślinnych. Inżynieria Rolnicza, vol. 10 (108), 277-282.
11. **Wcisło, G. 2013**: Analiza wpływu odmian rzepaku na własności biopaliw RME oraz parametry pracy silnika o zapłonie samoczynnym. Monografia habilitacyjna. Wydawnictwo FALL, Kraków.
12. **Wcisło G. 2009**: Determining Rheological Properties of CSME Biodiesel Type Biofuels, „Combustion Engines“, Vol. 2009-SC1, 20–25.