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FLOW BEHAVIOR OF PETROL, BIO-ETHANOL AND THEIR BLENDS

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Abstract

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The objective of this article deals with the flow behavior of bio-ethanol, conventional petrol and their blends (E15, E85). The temperature dependence density and kinematic viscosity of the liquids have been measured. The densitometer Densito 30PX with the scale for measuring fuels has been used to the measuring temperature dependence of the density of fuels and their blends. The rotary viscometer Anton Paar DV-3P has been used to the measuring temperature dependence of kinematic viscosity of fuels and their blends. For all samples has determined that the temperature has increased the density and kinematic viscosity of fuels and their blends has decreased. The range of temperature measurement has been from –10°C to 40°C. The mathematic models have been compiled (polynomial and exponential) according to the general shapes. The coefficients of determination R^2 have achieved high values from 0.98 to 0.99 for temperature dependence of density of fuels and their blends and from 0.86 to 0.96 for temperature dependence of kinematic viscosity of fuels and their blends. The mathematical models could be used to the prediction flow behavior of petrol, bio-ethanol and their blends.

bio-ethanol, petrol, kinematic viscosity, density, temperature, modeling

Currently, bio-fuels are the subject of much used by experts in the field of ecology, chemistry and technology of processing of agricultural products. It is necessary viewed from the perspective of engine designers (with no differences in the type of fuel used – gasoline or diesel). Experts are not fully in consensus on the effectiveness, timeliness and extent of use of motor bio-fuels, but despite these has been approved the promotion of energy from renewable sources, which establishes conditions and target utilization of renewable energy, including biodiesel. It was approved by the European Parliament and Council 2009/28/EC in April 2009 (Souček, 2009).

From June 2010 ruled in Czech Republic that in the petrol must be 4.1% of bio-components (for example bio-ethanol) and in the diesel must be 6% of bio-components (for example RME). From 2020 will be in fuels about 10% of bio-components (2009/28/ES).

Modern motor units are equipped with highly accurate and precise technique of working, than we must know physical properties of blends of fuel and bio-fuel. In this article it was influenced of the concentration of bio-ethanol in petrol to its temperature dependence of selected physical properties. Selected properties were measured temperature dependence of kinematic viscosity and density of blends of petrol and bio-ethanol.

MATERIALS AND METHODS

Temperature dependent was measured with rotary viscometer Anton Paar DV-3P. It was used standard LCP spindle, which is the most suitable to measuring low viscosity liquids. 100 *rpm* and frequency 1 *Hz* was set. For temperature measuring was used sensor Pt100.

Temperature dependent was measuring with digital densimeter Densito 30 PX with a scale for measuring petroleum products and integrated temperature sensor.

The blends of petrol and bio-ethanol were mixed in precisely defined conditions with a total sample volume of 500 *ml*. Other information is in Tab. I.

I: *The blends of petrol and bio-ethanol*

Number of sample	Petrol (Natural 95)		Bio-ethanol	
	ml	%	ml	%
1	500	100%	0	0%
2	425	85%	75	15%
3	75	15%	425	85%
4	0	0%	500	100%

First the blends were cooled to –10 °C and then were heated to 40 °C for measuring temperature dependent of density and kinematic viscosity.

Mathematical models have been created with use of software Microsoft® Excel 2002 (10.6856.6856) Service Pack 3.

RESULTS AND DISCUSSION

Results and discussion of measurements of temperature dependence density and kinematic viscosity of the blends of petrol and bio-ethanol were further processed and divided into subsections.

Temperature dependent density of blends of petrol and bio-ethanol

By measuring was demonstrated the temperature dependent of density of prepared blends. With increasing temperature of blends the density was decreasing. It is shown in Tab. II and in Fig. 1. Similar results were seen for motor oil in the publication (Kumbar *et al.*, 2011a).

The temperature dependencies of the density were created mathematical models (polynomial 2nd degree). Similar methods authors described in the publication (Severa *et al.*, 2009).

The general form of polynomial 2nd degree:

$$y(x) = a_2 \times x^2 + a_1 \times x + a_0, \quad (1)$$

to calculate the density apply:

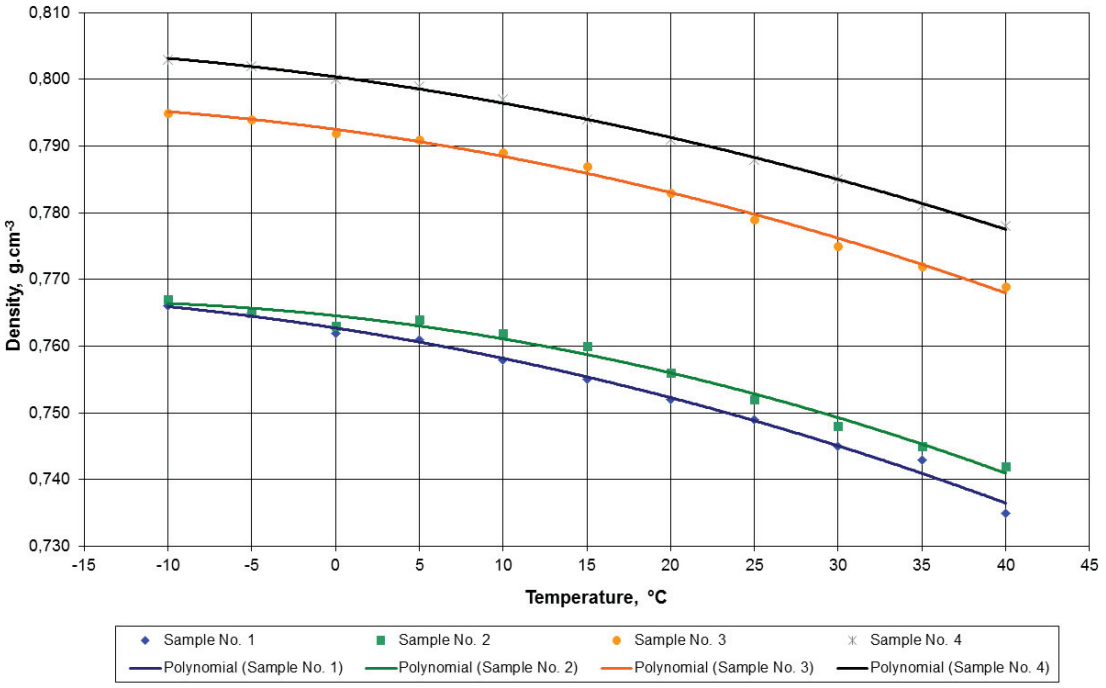
$$\rho(t) = a_2 \times t^2 + a_1 \times t + a_0; \text{ [kg.m}^{-3}\text{; °C]}. \quad (2)$$

All coefficients of determination R^2 reached very high values, from 0.98 to 0.99, which shows the appropriate choice of the type of mathematical model.

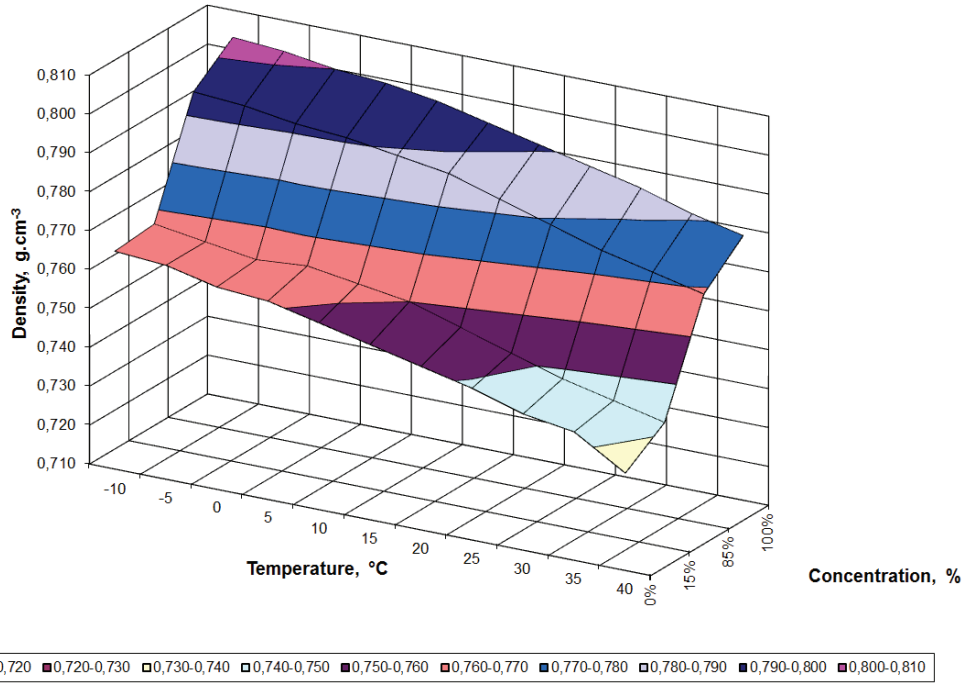
The results have shown that the density decreased less at a higher concentration of ethanol in petrol

II: *Density of blends of petrol and bio-ethanol*

t, °C	Density, g.cm^{-3}			
	sample No. 1	sample No. 2	sample No. 3	sample No. 4
–10	0.766	0.767	0.795	0.803
–5	0.765	0.765	0.794	0.802
0	0.762	0.763	0.792	0.800
5	0.761	0.764	0.791	0.799
10	0.758	0.762	0.789	0.797
15	0.755	0.760	0.787	0.794
20	0.752	0.756	0.783	0.791
25	0.749	0.752	0.779	0.788
30	0.745	0.748	0.775	0.785
35	0.743	0.745	0.772	0.781
40	0.735	0.742	0.769	0.778



1: *Mathematical models of temperature dependent of blends*



2: *3D graph of the influence of the concentration to the density of bio-ethanol in petrol*

(Fig. 2). For petrol decreased density when heated to 40 °C to 95% of value of the sample measured at –10 °C. For bio-ethanol decreased density when heated to 40 °C to 97% of value of the sample measured at –10 °C. Similar results have publicized authors in publications (Alptekin *et al.*, 2008) and (Murény *et al.*, 2012).

Temperature dependent kinematic viscosity of blends of bio-ethanol and petrol

By the measuring was demonstrated temperature dependent kinematic viscosity of blends of bio-ethanol and petrol. With increasing temperature of blends the kinematic viscosity was decreasing, which is shown in Tab. III and in Fig. 3. Similar results (but for engine oils) have publicized authors in publication (Kumbár *et al.*, 2011b).

The temperature dependencies kinematic viscosity was created mathematical model (exponential).

The general form of exponential:

$$y(x) = a_1 \times e^{a_0 \times x}, \quad (3)$$

to calculate the kinematic viscosity apply:

$$v(t) = a_1 \times e^{a_0 \times t}; [\text{mm}^2.\text{s}^{-1}; \text{°C}]. \quad (4)$$

All coefficients of determination R^2 reached very high values, from 0.86 to 0.96, which shows the appropriate choice of the type of mathematical model.

The results confirm that kinematic viscosity more decreased at higher concentration of bio-ethanol in conventional petrol. It is shown in Fig. 4.

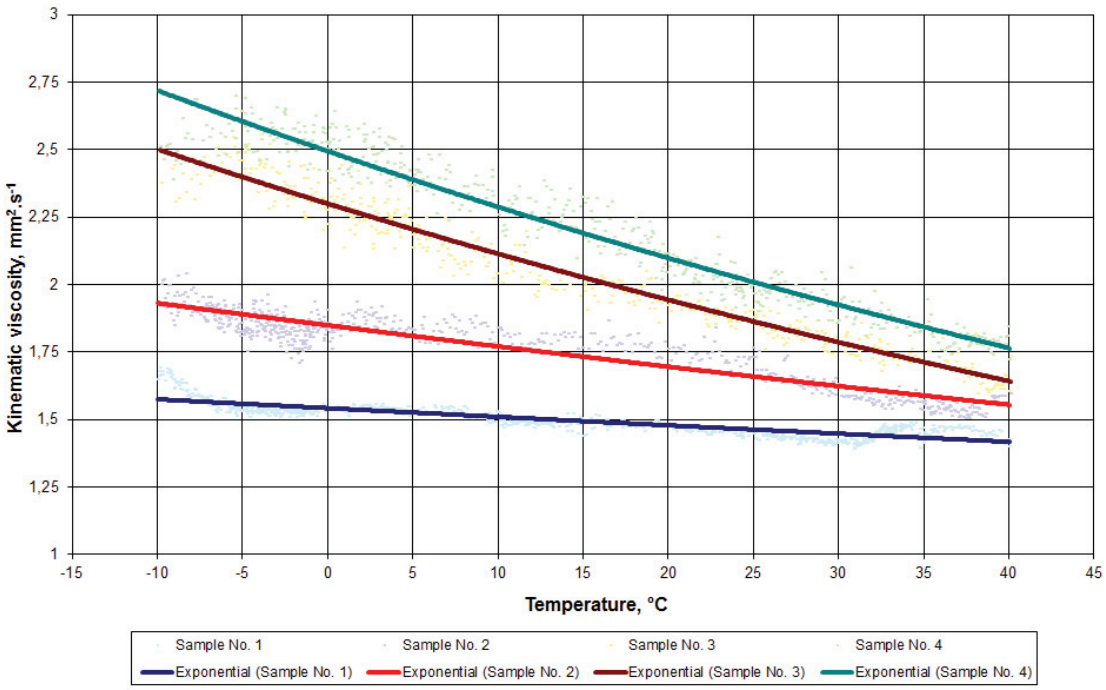
For petrol decreased the kinematic viscosity when heated to 40 °C to 89% of value of the sample measured at –10 °C. For bio-ethanol decreased density when heated to 40 °C to 70% of value of the sample measured at –10 °C. Behavior of the function was more non-linear with higher concentration bio-ethanol in petrol. Similar results have publicized authors in publications (Alptekin *et al.*, 2008), (Murphy *et al.*, 2012) and (Valente *et al.*, 2011).

III: *Kinematic viscosity of blends of bio-ethanol and petrol*

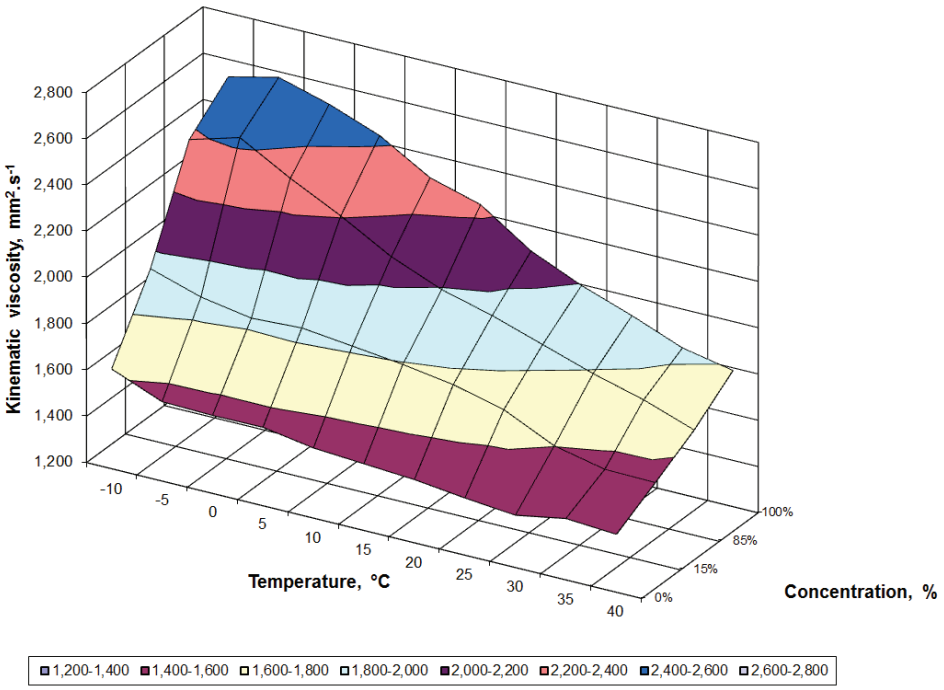
	Kinematic viscosity, $mm^2.s^{-1}$			
t, °C	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
–10	1.631	1.941	2.376	2.524
–5	1.543	1.872	2.438	2.575
0	1.537	1.834	2.315	2.512
5	1.539	1.845	2.206	2.430
10	1.503	1.820	2.083	2.301
15	1.488	1.794	1.994	2.238
20	1.473	1.760	1.935	2.091
25	1.447	1.705	1.863	1.995
30	1.426	1.602	1.791	1.918
35	1.465	1.554	1.731	1.832
40	1.450	1.550	1.654	1.788

CONCLUSIONS

The experiments confirm temperature dependent density of bio-ethanol, petrol and their blends. With increasing temperature of blends the density was



3: *Graphs of temperature dependent kinematic viscosity of blends of bio-ethanol and petrol*



4: *3D graph of the influence of the concentration to the kinematic viscosity of bio-ethanol in petrol*

decreasing. The density decreased less at a higher concentration of bio-ethanol in petrol. For petrol decreased density when heated to 40 °C to 95% of value of the sample density measured at –10 °C. For bio-ethanol decreased density when heated to 40 °C to 97% of value of the sample density measured at –10 °C.

The temperature dependencies of the density were created mathematical models (polynomial 2nd degree). All coefficients of determination R^2 reached very high values, from 0.98 to 0.99, which shows the appropriate choice of the type of mathematical model.

The experiments confirm temperature dependent kinematic viscosity of bio-ethanol, petrol and their

blends. With increasing temperature of blends the kinematic viscosity was decreasing. The kinematic viscosity more decreased at higher concentration of bio-ethanol in conventional petrol. For petrol decreased the kinematic viscosity when heated to 40 °C to 89% of value of the sample measured at –10 °C. For bio-ethanol decreased density when heated to 40 °C to 70% of value of the sample measured at –10 °C. Behavior of the function was more non-linear with higher concentration bio-ethanol in petrol.

The temperature dependencies kinematic viscosity was created mathematical model (exponential). All coefficients of determination R^2 reached very high values, from 0.86 to 0.96, which shows the appropriate choice of the type of mathematical model.

SUMMARY

The objective of this paper is find changes of the flow behaviour of the petrol if the bio-ethanol will be add. For the experiments has been created four blends of the petrol and bio-ethanol - pure petrol, pure bio-ethanol, E15 (15% bio-ethanol in petrol) and E85 (85% bio-ethanol in petrol). The temperature dependence of the density [$kg.m^{-3}$] has been measured in the range of –10 °C and +40 °C. The instrument Densito 30PX with the scale for measuring the engine oils has been used. The kinematic viscosity [$mm^2.s^{-1}$] has been measured in the range of –10 °C and +40 °C. The Anton Paar digital viscometer with the concentric cylinders geometry has been used. To the physical properties has been the mathematical models created. The density and the kinematic viscosity have been showed the significant temperature dependence. If the temperature increased, the density and the kinematic viscosity decreased. The density decreased from an average of the 783 $kg.m^{-3}$ at –10 °C to an average of the 756 $kg.m^{-3}$ at +40 °C. This decrease was almost non-linear. The coefficients of determination R^2 values ranged 0.98 to 0.99 (for the polynomial 2nd degree model). The kinematic viscosity decreased from an average of the 2.118 $mm^2.s^{-1}$ at –10 °C to an average of the 1.611 $mm^2.s^{-1}$ at +40 °C. The temperature dependence of the kinematic viscosity has been modelled by the exponential mathematical model. The values of the determination coefficient R^2 ranged 0.86 to 0.96. Knowledge of the density and kinematic viscosity behaviour of fuels (petrol, bio-ethanol and their blends) as a function of its temperature is of great importance, especially when considering running efficiency and performance of combustion engines. Proposed models can be used for description and prediction of flow behaviour of petrol, bio-ethanol and their blends.

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