

Effect Concentration and Temperature on the Rheological Behavior of Copolymer Polyethylene-Propylene Solutions

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Abstract: In this paper I undertook to determine the rheological characteristics of the copolymer polyethylene-polypropylene solutions. I have studied the 3, 6, 10, and 12% concentrated solutions for a temperature interval from 40°C and 90°C in 10 degree steps, and for the shear rate from 3 to 1312 s⁻¹ in the second domain. The measurements were performed using a Haake VT 550 rotational rheometer with a HV₁ sensor. The rheology of the solutions has been impacted by the shear rate, the temperature and the concentration of the copolymer polyethylene-polypropylene. I have found two models that successfully describe the rheological behaviour of the solutions compared to other models that do not consider the copolymer's concentration.

Keywords: copolymer solutions; rheology; rheometer

1. Introduction

The knowledge of the rheological behaviour of copolymer solutions provides information for the polymer processing industry. The rheological behaviour is important in terms of the processing methods of copolymers, such as extrusion, injection moulding, blow moulding, calendaring and fibre spinning [1-3]. The viscosity of the polymer solution depends on a number of factors. These factors are molecules' shape, molecular weight, hydrophilic nature, and interaction of polymer molecules with the solvents. The solution viscosity depends on the concentration of the dissolved polymer. In good solvents the polymer segments prefer to be surrounded by solvent molecules rather than by other polymer segments [4-6]. The in poor solvents, the polymer molecules try to minimize the area of contact with the solvent molecules, the extension of the polymer molecules depends on the interaction of the polymer solvent, which directly affects its size and the viscosity of the solutions.

The most polymer solutions behave non-Newtonian which demonstrates that the viscosity depends on the shear rate and other factors. The viscosity of the polymer solution decreases as shear rate and temperature increases and this can be explained by the alignment of polymer molecules in shear application. The aligning

molecules allow their easy flows that reduce the viscosity at high shear rates.

The dependence of viscosity η on absolute temperature could be described by the Arrhenius equation (1):

$$\eta = k_1 \exp(E_0/RT) \quad (1)$$

where k_1 is constant, R is gas constant and E_0 is activation of energy.

The other model describing the dependence of the viscosity of solutions of polymers is temperature and shear rate [7]:

Raman

$$\eta_1 = \eta_v \exp(E_2 - E_1/RT) \quad (2)$$

Dunn

$$\eta = A \exp(Q/RT) \quad (3)$$

Frenke

$$\eta = XT \exp(U/RT) \quad (4)$$

Madge

$$\eta = A \exp(B/T)/(T-C) \quad (5)$$

Andrade

$$\eta v^{1/3} = A \exp(B/T_v) \quad (6)$$

Silverman

$$\eta=(A/T^{0.5})exp(B/T-ct) \quad (7)$$

Eyring

$$\eta=(A/V)exp(B/T)b/T \quad (8)$$

Gornlissen and Waterman

$$\eta=exp(B+A/T_C) \quad (9)$$

Agrawal and Thodes

$$\eta+k=aexp(m/T_r) \quad (10)$$

were η – dynamic viscosity, A, B, C, k is constants, R is gas constant and E_1 , E_2 , U is activation of energy.

The pseudo plastic polymer solutions are in general non-Newtonian, where viscosity decreases with increasing shear rate, with the result of the thinning of the solution occurs at high temperatures [8-15].

In this paper I undertook to determine the rheological characteristics of the copolymer polyethylene-polypropylene. I have studied the 3, 6, 10, and 12% concentrated solutions for a temperature interval from 40°C and 90°C in 10 degree steps, and for the shear rate from 3 to 1312 s⁻¹ in the second domain. The measurements were performed using a Haake VT 550 rotational rheometer with a HV₁ sensor. The rheology of the solutions has been impacted by the shear rate, the temperature and the concentration of the copolymer polyethylene-polypropylene. I have found two models that successfully describe the rheological behaviour of the solutions compared to other models that do not consider the copolymer's concentration.

2. Materials

The copolymer polyethylene-propylene is physical and chemical properties: physical state – solid, form – bales and granulate, colour – natural opaque, brown in case of oil extended grades, odour – weak paraffinic, pH value – n/a, relative density – 860 – 900 kg/m³, bulk density – depending on bale or granulate structure, melting point/range – n/a, softening point/range – n/a, boiling point/range – n/a, vapour pressure – n/a, vapour density – n/a, avaporation rate – n/a,

volatile matter (wt %) – 0.3, solubility in water – insoluble. Soluble in hydrocarbons such as: alkanes – hexane, heptane, octane, decane, dodecane, iso-octane, isododecane, cycloalkanes – cyclo-octane, decaline, cyclododecane, aromatic substances – butylbenzene, octylbenzene, oil – paraffinic oil, naphthenic oil, to a lesser extent in aromatic oil, flash point – non oil-extended polymers >370°C, oil extended polymers >360°C. Dust explosion is unlikely, because the product is not supplied in small particle sizes (>500µm) can take place. Dust formation is unlikely to occur. During grinding of the bales or granules dust explosion danger can arise when particles smaller than 500µm are formed. Whenever small particles are transported (pneumatic transport systems, ventilation systems) apply proper local grounding to prevent build-up of static electricity. At high temperatures inert gases should be applied in order to strongly reduce oxygen concentrations. Flammable gases are formed only at higher than usual processing temperatures.

Do not exceed 300°C. Long term high temperatures will cause degradation of the material with changes of ignition. On thermal degradation, reaction products is CO, CO₂, H₂O, low molecular products, various hydrocarbons can be formed. Although highly dependent on temperature and environmental conditions, a variety of decomposition products may be present, ranging from simple hydrocarbons to toxic and/or irritating gases. Degradation will occur only at extreme temperatures (above the decomposition temperature).

The oil SAE 10W is physical and chemical properties: form - homogeneous liquid, yellow-brown, odor - characteristic, density (15°C) – 0.875-0.910 kg/m³, kinematics viscosity to 40°C - 90 cSt, kinematics viscosity to 100°C - 8 cSt, dynamic viscosity (20°C) - 65 cP, viscosity index – 70 -100, solubility in organic solvents, petroleum, fat, water-insoluble, flash point > 200°C, melting point - (-10) ÷ (-15)°C, amount of coke – 0.03 – 0.5 %. The SAE 10W oil is used so predominantly paraffinic hydrocarbons containing 75% saturated. The solutions of concentration 3 %, 6 %, 10 % and 12 % were prepared at room temperature for several weeks under continuous stirring.

The for rheological characterization of concentrated polymer solutions was used Haake VT 550 viscometer rotating cylinder equipped with additional focus. The principle consists in determining the existence of two parts, one fixed and one mobile that moves beyond the first. These parts include: cylinder concentric, cone and plate, parallel plate, disc, or rotor blade rotating in a cylinder. The rheological behaviour of the copolymer in SAE 10W oil was studied using a Haake VT 550 viscometer equipped with HV₁ sensor, which allows the application of shear rates between 3 and 1312 s⁻¹ in the temperature range of 40 - 90°C.

3. Results and discussions

The 3 %, 6 %, 10 % and 12 % concentrated solution investigated non-Newtonian behaviour as indicated by the decrease of dynamic viscosity of the solution increases as the shear rate and temperature. The dynamic viscosity of the solution decreased to low shear rates, from 3 to 48.6 s⁻¹ shear rate higher than between 145.8 and 1312 s⁻¹. As the temperature increased, the dynamic viscosity of the solution decreased. As the polymer concentration has increased dynamic viscosity of the solution increased as well. At high concentrations the polymer is cut your temperature range at which you can make determinations and considerably lower shear rate. The solutions of lower concentrations are studied at higher shear rate.

Figure 1 shows the dependence temperature versus dynamic viscosity at a shear rate 437.9 s⁻¹, 729 s⁻¹ and 1312 s⁻¹ in 3 % concentration solution. The graph is observed exponential decrease of dynamic viscosity with temperature solution studied.

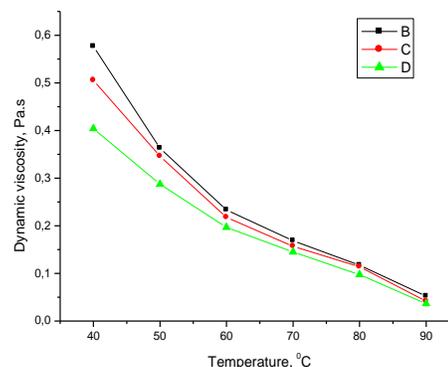


Fig. 1. The dependence temperature versus dynamic viscosity for the 3 % concentration solution at a shear rates: B – 437.9 s⁻¹, C – 729 s⁻¹ and D – 1312 s⁻¹

The 3 % concentrated solution was studied in the temperature range of 40 - 90°C and shear velocities 145.8 s⁻¹, 243 s⁻¹, 437.9 s⁻¹, 729 s⁻¹ and 1312 s⁻¹ in domain 2. The shear rate 145.9 s⁻¹ and a temperature of 40°C solutions is dynamic viscosity 0.6416 Pa.s. Increased temperature of 10°C, but at the same shear rate viscosity solution lowers the value 0.3888 Pa.s. Because there were only two values of dynamic viscosity at this shear rate, we have not plotted.

The shear rate 243 s⁻¹ and a temperature of 40°C of 3 % concentration solution is the dynamic viscosity 0.49 Pa.s. A temperature of 50°C and constant shear rate viscosity solution decreases the value 0.385 Pa.s is almost insignificant, and at 60°C to value 0.2333 Pa.s. Table 1 shows the shear rate, the parameters A, B, C and correlation coefficients obtained by polynomial fitting of experimental curves and determined statistically.

The values of parameters A, B and C and the correlation coefficients were obtained by fitting polynomial curves dynamic viscosity versus temperature applying equation (11). The last column of Table 1 shows the values of correlation coefficients statistically derived equation (12):

$$\eta = A + Bt + Ct^2 \quad (11)$$

$$R = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{(n\sum x^2 - (\sum x)^2)(n\sum y^2 - (\sum y)^2)}} \quad (12)$$

where the parameters A, B, C depend on the chemical composition of the polymer and oil, η - dynamic viscosity, t - temperature in degrees Celsius.

In Table 1 the parameter A decreases with increasing shear rate of 3 % concentrated solution. The parameter B increases with increasing shear rate and of C decreases with increasing shear rate. Correlation coefficients determined by equation (11) are close to unity, which proves that the dependence temperature of dynamic viscosity shows a decrease described by polynomial equations. Obtained correlation coefficients show statistically much lower than those determined by a polynomial equation as dynamic viscosity - temperature dependence is not linear.

The parameters A, B and C are dependent on the chemical structure of the obtained polymer, depending on its behaviour at high temperatures and high shear rates.

Figure 2 shows the dependence dynamic viscosity versus shear rate in the temperature range of 40 - 90°C to the 3 % concentrated solution. The dynamic viscosity of the solution shows a linear dependence of shear rate.

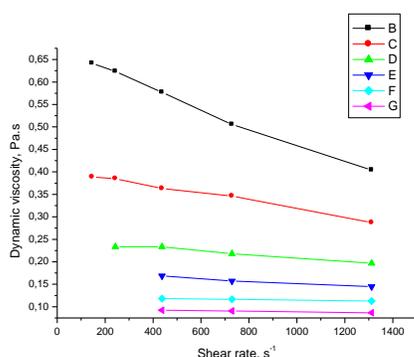


Fig. 2. The dependence dynamic viscosity versus shear rate for the concentration solution 3 % at a temperatures: B – 40°C, C – 50°C, D – 60°C, E – 70°C, F – 80°C and G – 90°C

The linear dependence of the dynamic viscosity versus shear rate of the concentration solution 3 % is described by equation (13):

$$\eta = A + B\dot{\gamma} \quad (13)$$

where A and B are parameters that depend on the equation of the chemical composition of the polymer and oil composition, η - dynamic viscosity (Pa.s) and $d\gamma/dt$ - shear rate (1/ s).

Table 2 shows the parameters A and B obtained by linear fitting of the lines obtained experimentally obtained correlation coefficients with equation (13) and statistical correlation coefficients obtained from equation (12).

For the at 3 % solution value of the parameter A decrease with increasing temperature to a value of 0.6687 at 40°C, the value of 0.0951 for 90°C. The slope has the highest value at 40°C and the temperature ranges of 70-90°C slopes of the lines are close in order of magnitude. Correlation coefficients obtained by equation (2) are close to unity and has the value 1- 80°C. Statistical correlation coefficients obtained could be determined only at 40 and 50°C. For other temperatures could not be determined because they have been few readings (3 and 4 values of dynamic viscosity shear velocities).

Figure 3 shows the temperature dependency of the dynamic viscosity of the 6 % solution concentration. The solution was studied in the temperature range of 40-90°C for shear rates 9 s⁻¹, 16.2 s⁻¹, 27 s⁻¹, 48.6 s⁻¹, 81 s⁻¹, 145.8 s⁻¹, 243 s⁻¹, 437.4 s⁻¹, 729 s⁻¹ and 1312 s⁻¹.

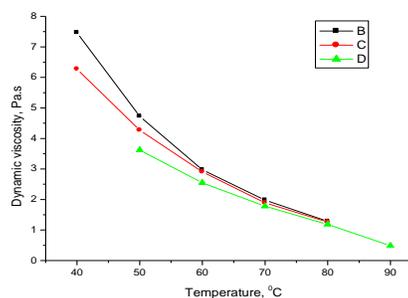


Fig. 3. The dependence dynamic viscosity versus temperature for the 6 % concentration solution at a shear rates: B – 48.6 s⁻¹, C – 81 s⁻¹ and D – 145.8 s⁻¹

The dynamic viscosity of the 6 % concentrated solution decreases with increasing temperature. At 9 s^{-1} shear rate and temperature of 40°C solutions is dynamic viscosity $9.261 \text{ Pa}\cdot\text{s}$. If the temperature remains constant but increases the shear rate 16.2 s^{-1} dynamic viscosity of the solution decreases the value $9.03 \text{ Pa}\cdot\text{s}$ and the 27 s^{-1} shear rate viscosity decreases further $8.673 \text{ Pa}\cdot\text{s}$ value.

If you increase the solution temperature 10°C and shear rate 16.2 s^{-1} dynamic viscosity of the solution decreases from $9.03 \text{ Pa}\cdot\text{s}$ to $5.075 \text{ Pa}\cdot\text{s}$. Maintaining constant temperature of 50°C but increasing shear rate 27 s^{-1} dynamic viscosity of the solution decreases the value $5.04 \text{ Pa}\cdot\text{s}$. At a temperature of 60°C and a shear rate of 27 s^{-1} of the dynamic viscosity of the solution drop to $3.15 \text{ Pa}\cdot\text{s}$. At higher shear rates and temperatures were determined values of the dynamic viscosity of the solution but could not be plotted. Thus, 243 s^{-1} shear rate and a temperature of 60°C the solution has a dynamic viscosity $2.28 \text{ Pa}\cdot\text{s}$. At a temperature of 70°C and the same shear rate viscosity of the solution reduces the amount of dynamic $1.575 \text{ Pa}\cdot\text{s}$. At a temperature of 80°C dynamic viscosities of the solution drops to $1.127 \text{ Pa}\cdot\text{s}$ and 90°C is $0.42 \text{ Pa}\cdot\text{s}$. For a shear rate of 437.4 s^{-1} dynamic viscosity was determined only at 80 and 90°C .

Than values are $0.9722 \text{ Pa}\cdot\text{s}$ and $0.3320 \text{ Pa}\cdot\text{s}$. The shear speed of 729 s^{-1} and 1312 s^{-1} dynamic viscosity of the solution concentration was determined only 6 % at a temperature of 90°C . These values are very close to the difference between them being $0.08 \text{ Pa}\cdot\text{s}$.

Table 3 shows the shear rates which could plot of temperature dependence of dynamic viscosity of solution at 6 %, the parameters A, B, and C obtained by fitting a polynomial curve obtained by the correlation coefficients determined in equation (11) and coefficients statistically determined correlation equation (12).

As shown in Table 3, the parameter A decreases with increasing shear rate from 24.5066 to 10.3489 values. Parameter B increases with increasing shear rate of 6 % concentration solution and the parameter C decreases with increasing shear rate. Correlation coefficients obtained by equation (12) are close to unity which indicates that the temperature dependence

of dynamic viscosity shows a decrease by a polynomial equation.

Figure 4 shows the dependence of dynamic viscosity versus shear rate of the concentration solution 6 % in the temperature range of 40 - 90°C .

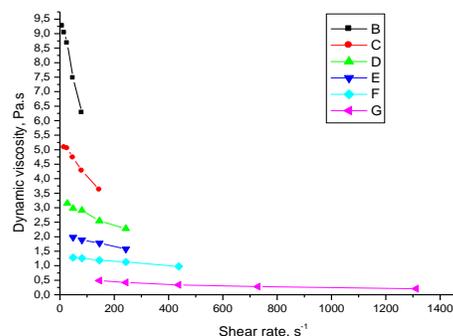


Fig. 4. The dependence dynamic viscosity versus shear rate for the concentration solution 6 % at a temperatures: B – 40°C , C – 50°C , D – 60°C , E – 70°C , F – 80°C and G – 90°C

As seen from Figure 4 there is a linear dependence of the dynamic viscosity versus shear rate for all temperatures studied. At high temperatures the slopes of the lines are close together.

Table 4 shows the temperatures at which the solution was studied parameters A and B obtained by linear fitting of the lines obtained correlation coefficients determined by equation (13) and correlation coefficients determined statistically equation (12).

In Table 4 the parameter A has the highest value at 40°C of 9.7006 and decreases with increasing temperature the value 0.4731 . Parameter B increases with increasing temperature, the slopes of the lines with values becoming smaller and very close to the temperatures of 80 and 90°C .

Figure 5 shows the dependence temperature versus dynamic viscosity of the 10 % concentrated solution only at the two shear rates 5.4 s^{-1} and 9 s^{-1} . The solution of the very viscous concentrated, 10 % could not be studied at a temperature of 40°C .

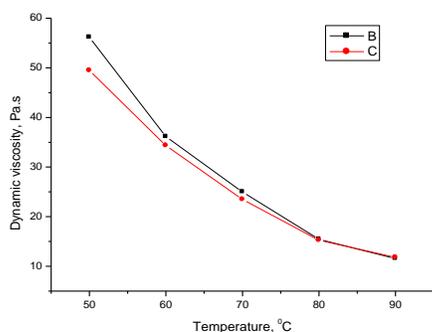


Fig. 5. The dependence dynamic viscosity versus temperature for the 10 % concentration solution at a shear rates: B – 5.4 s^{-1} and C – 9 s^{-1}

At 50°C and 3 s^{-1} shear rate viscosity of the solution is dynamic 64.26 Pa.s , 10°C temperature increase causes a decrease in dynamic viscosity of the solution which reaches the value of 39.69 Pa.s the same shear rate. Maintaining constant shear rate but still increasing temperature cause a decrease in dynamic viscosity of the solution 30.24 Pa.s value for the temperature of 70°C . At 80°C the dynamic viscosity of the solution decreases 16.065 Pa.s the same shear rate. All determinations were made on the two. Increasing shear rates the tightening of the range of temperatures at which measurements can be made. For shear rate 16.2 s^{-1} and a temperature of 60°C solutions is dynamic viscosity 30.45 Pa.s . If you increase the solution temperature 10°C , but maintain constant shear rate, dynamic viscosity becomes 22.82 Pa.s . At 80°C and the same shear rate, dynamic viscosity of the solution decreases further reaching 14.7 Pa.s and 90°C it reaches 10.15 Pa.s . If you increase the shear rate 27 s^{-1} solution can be studied throughout the temperature range, but only between $70\text{-}90^\circ\text{C}$. Thus, at the temperature of 70°C , the dynamic viscosity of the solution is 19.866 Pa.s at 80°C is 13.188 Pa.s and is 9.975 Pa.s at 90°C . The shear rate of 48.6 s^{-1} the viscosity of the solution at 80°C is 11.4683 Pa.s and 90°C is 8.8033 Pa.s .

Table 5 shows the range of shear rates which was the purpose of the studies of the 10 % solution of concentration, the parameters A, B and C obtained by curve fitting polynomial and the obtained correlation coefficient values

determined by the equation (11) and equation (12).

The values of parameters A, B and C, the correlation coefficients determined by equation (11) and of the statistically determined equation (12) are just two shear rates. A parameter decreases with increasing shear rate, the parameter B increases with increasing shear rate and the parameter C increases with increasing shear rate for the same solution. Correlation coefficients obtained by equation (11) are close to unity, the statistically determined are much lower for placing points on the graph is not linear.

Figure 6 shows the dependence dynamic viscosity versus shear rate of the 10 % concentration solution in the temperature range of $50\text{-}90^\circ\text{C}$. The solution with a high viscosity at 40°C could not make determinations of the two.

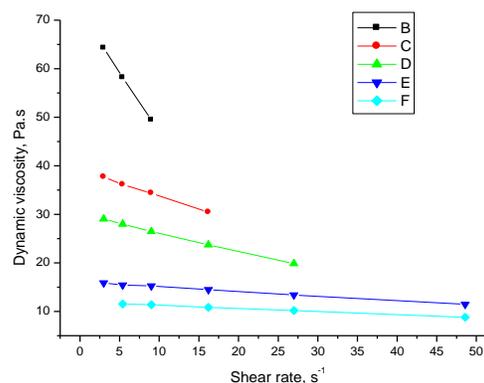


Fig. 6. The dependence dynamic viscosity versus shear rate for the 10 % concentration solution at a temperature: B – 50°C , C – 60°C , D – 70°C , E – 80°C and F – 90°C

As can be seen from figure 6 the dynamic viscosity of the solution decreases linearly with increasing shear rates. At 80 and 90°C slopes of the lines are very close, and the greater slope has the solution at 50°C .

Table 6 shows the temperatures at which they could make the determination, the parameters A and B obtained by linear fitting of the lines obtained correlation coefficients determined by equation (13) and correlation coefficients obtained by using equation (12).

Parameter A solution decreases with increasing temperature, parameter; B increases with increasing temperature. The slopes of the lines are very similar at 80 and 90°C . Correlation coefficients obtained using equation (13) are

close to unity, which shows that the dependence of dynamic viscosity shear rate is linear at all temperatures has been studied solution. Statistically determined correlation coefficient equation (12) could be determined only at 70, 80 and 90°C. The last solution studied was the concentration of 12 %. Figure 7 shows the dependence dynamic viscosity versus temperature for shear rate: 3 s⁻¹, 5.4 s⁻¹, 9 s⁻¹, 16.2 s⁻¹, 27 s⁻¹ and 48.6 s⁻¹. The 12 % concentrated solution could be studied at low shear rates, temperatures and domain 2. The dynamic viscosity of this solution decreases with increasing temperature.

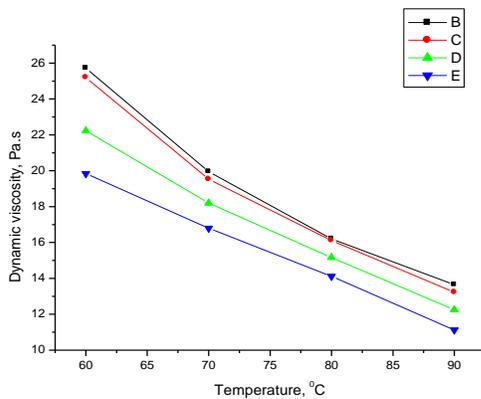


Fig. 7. The dependence dynamic viscosity versus temperature for the concentration solution 12 % at a shear rates: B – 5.4 s⁻¹, C – 9 s⁻¹, D – 16.2 s⁻¹ and E – 27 s⁻¹

The solution could not be studied at 40 and 50°C. At a temperature of 60°C and a shear rate of 3 s⁻¹ solution is dynamic viscosity 28.35 Pas. If you increase the solution temperature 10°C and maintain constant shear rate, dynamic viscosity of the solution decreases the value 18.9 Pa.s. For shear rate 48.6 s⁻¹ solution could be studied only at two temperatures: 80 and 90°C. At a temperature of 80°C the solution has a viscosity of 11.2 Pa.s, at 90°C and has a viscosity of 9.57 Pa.s.

Table 7 shows the shear velocities that could plot the dynamic viscosity with temperature, the parameters A, B and C determined by equation (11) and the correlation coefficients in the last column could not be determined. A parameter decreases with increasing shear rate, the

parameter B increases with increasing shear rate, the parameter C decreases with increasing shear rate. Correlation coefficients are close to unity for all shear rates.

Figure 8 shows the dependence dynamic viscosity versus shear rate of the concentration solution 12 % in the temperature range of 60-90°C. The slopes of the lines decrease with increasing temperature and shear velocities. At 80 and 90°C slopes of the lines are close together.

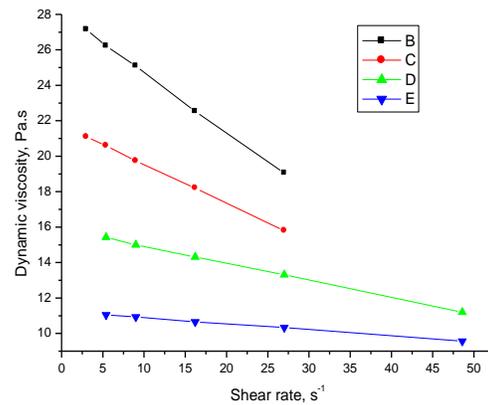


Fig. 8. The dependence dynamic viscosity versus shear rate for the 12 % concentration solution at a temperature: B – 60°C, C – 70°C, D – 80°C and E - 90°C

Table 8 shows the values of the parameters A and B obtained by linear fitting of the lines dynamic viscosity shear rate depending on the temperature range of 60-90°C, correlation coefficients obtained using equation (13) and correlation coefficients statistically determined using the equation (12).

As can be seen in Table 8 parametric solutions decreases with increasing temperature, so at 60°C has the highest value of 28.0882 and at 90°C has a value of 11.2297. Parameter B represents the slope decreases with increasing temperature and shear rate. At 80 and 90°C slopes of the lines are very close with small values.

Table 1. Shear rate, parameters A, B and C, correlation coefficients derived equation (11) and correlation coefficients statistically

Shear rate, s ⁻¹	A	B	C	Correlation coefficients, R ² equation (11)	Correlation coefficients, R ² equation (12)
437.9	1.6308	-0.0343	1.8887E-4	0.9873	0.9147
729	1.3465	-0.0268	1.3850E-4	0.9901	0.9403
1312	0.9689	-0.0175	8.0775E-5	0.9938	0.9667

Table 2. Temperature, parameters A and B, correlation coefficients and correlation coefficients obtained statistical

Temperature, °C	A	B	Correlation coefficients, R ² equation (13)	Correlation coefficients, R ² equation (12)
40	0.6687	-2.0656E-4	-0.9969	0.9938
50	0.4040	-8.7195E-5	-0.9958	0.9916
60	0.2452	-3.6738E-5	-0.9850	-
70	0.1785	-2.6278E-5	-0.9860	-
80	0.1209	-6.1743E-6	-1.0000	-
90	0.0951	-6.5614E-6	-0.9994	-

Table 3. Shear rate, parameters A, B and C, correlation coefficients determined with equation (11) and correlation coefficients statistically determined correlation equation (12)

Shear rate, s ⁻¹	A	B	C	Correlation coefficients, R ² equation (11)	Correlation coefficients, R ² equation (12)
48.6	24.5066	-0.5659	0.0035	0.9979	0.9299
81	18.2627	-0.3888	0.0022	0.9995	0.9571
145.8	10.3489	-0.1682	6.5636E-4	0.9971	0.9868

Table 4. Temperature, parameters A and B, correlation coefficients determined by equation (13) and correlation coefficients determined statistically equation (12)

Temperature, °C	A	B	Correlation coefficients, R ² equation (13)	Correlation coefficients, R ² equation (12)
40	9.7006	-0.0429	-0.9964	0.9928
50	5.2890	-0.0117	-0.9961	0.9922
60	3.2059	-0.0039	-0.9873	0.9748
70	2.0717	-0.0020	-0.9978	-
80	1.3176	-7.9450E-4	-0.9974	0.9948
90	0.4731	-2.2064E-4	-0.9432	0.8896

Table 5. Shear rate, parameters A, B C, correlation coefficients determined by the equation (11) and equation (12)

Shear rate, s ⁻¹	A	B	C	Correlation coefficients, R ² equation (11)	Correlation coefficients, R ² equation (12)
5.4	219.7312	-4.4929	0.0242	0.9978	0.9475
9	180.1497	-3.5415	0.0185	0.9998	0.9620

Table 6. Temperature, parameters A, B, correlation coefficients determined by equation (13) and correlation coefficients obtained by using equation (12)

Temperature, °C	A	B	Correlation coefficients, R ² equation (13)	Correlation coefficients, R ² equation (12)
50	71.5874	-2.4639	-0.9999	-
60	39.1949	-0.5412	-0.9994	-
70	30.0225	-0.3803	-0.9993	0.9986
80	16.0515	-0.0953	-0.9988	0.9976
90	11.9142	-0.0642	-0.9997	0.9994

Table 7. Shear rate, parameter A, B, C, correlation coefficients determined by equation (11) and correlation coefficients obtained by using equation (12)

Shear rate, s ⁻¹	A	B	C	Correlation coefficients, R ² equation (11)	Correlation coefficients, R ² equation (12)
5.4	93.2063	-1.6092	0.0081	0.9996	-
9	86.4488	-1.4415	0.0069	0.9982	-
16.2	57.0138	-0.7478	0.0028	0.9993	-
27	37.9913	-0.3127	1.6250E-4	0.9995	-

Table 8. Temperature, parameters A, B correlation coefficients determined by equation (13) and correlation coefficients obtained by using equation (12)

Temperature, °C	A	B	Correlation coefficients, R ² equation (13)	Correlation coefficients, R ² equation (12)
60	28.0882	-0.3369	-0.9997	0.9994
70	21.7576	-0.2206	-0.9999	0.9998
80	15.9006	-0.0967	-0.9998	0.9996
90	11.2297	-0.0341	-0.9996	0.9992

Both the correlation coefficients determined by equation (13) and those determined by equation (12) are close to unity which demonstrates that the dependence of dynamic viscosity shear rate is linear. As can be seen in Table 8 parametric solutions decreases with increasing temperature, so at 60°C has the highest

value of 28.0882 and at 90°C has a value of 11.2297. Parameter B represents the slope decreases with increasing temperature and shear rate. At 80 and 90°C slopes of the lines are very close with small values. Both the correlation coefficients determined by equation (13) and those determined by equation (12) are close to

unity which demonstrates that the dependence of dynamic viscosity shear rate is linear.

4. Conclusions

This work has shown polyethylene rheological behaviour of the solution - polypropylene at various concentrations, shear, and temperature. The dynamic viscosity decrease was more pronounced at lower shear rates than larger ones. The dynamic viscosity increases as temperature increases, as well as the solution concentration increases. However, the results show that the viscosity of the copolymer solutions was more sensitive to high temperatures.

The equations (11) and (13) provide the best correlation between dynamic viscosity and shear rate, concentration, and temperature. Calculate the parameter could be used to describe the rheology of solutions as a function of shear rate, concentration, and temperature.

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