Dynamic viscosity dependence of the shear rate of polyethylene-polypropylene solutions concentrated

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Abstract: In this article we determined the rheological characteristics of polyethylene-propylene copolymer solutions. The 3, 6, 10 and 12 % copolymer polyethylene-propylene solutions concentration were studied. The temperature range studied was 40 – 90 ^{o}C, from 10 to 10 degrees to the shear in the range 3 - 1312 s^{-1} in domain 2 and speed measurements were made with a rotation viscometer Rheotest type RV 550 coaxial cylinder sensor and VH_1. The rheology solutions are affected by concentration, temperature, shear rate and shear stress. The empirical relationship found, the dependence of the logarithm of dynamic viscosity according to the logarithm of the shear rate accurately describe the rheological behavior of the solutions studied in comparison with other models in the literature include the concentration of the solution.

Keywords: concentration; copolymer; dynamic viscosity; relationship

1. Introduction

In industrial practice, the behavior of bodies subject to external mechanical application of interest, of particular importance fluid flow. The study requests and response bodies handle requests rheology, which establishes mathematical models of response function of a body subjected to stress [1-5].

A force or system of forces applied to the body leads to its movement, which may consist of successive displacements or deformations. In general, the movement does not change the relative position of the elements of the body, but change its position relative to an external reference [6, 8]. The movement consists of the translation or rotation of the body. In other conditions, by applying a force or system of forces, the body may be deformed, which causes change position relative to the constituent elements. A body is deformed under the action requests when they change shape or volume [7-11].

In the case of fluids, if the deformation is produced by applying a strong anisotropic and inhomogeneous deformation they do not reach equilibrium, but the degree of deformation continuously changes over time [12, 14].

Fluid resistance small deformation and internal friction that arise during flow, reduces deformation force [13-17]. Under the action of a strong, fluid deformation rate increases until equilibrium is established with the friction, then remains constant. The main property of fluids is the viscosity [18, 20].

Flow is a key process in the most specific operations of synthesis and processing technologies of macromolecular compounds. Calling rheology is indispensable; given its contribution to elucidate flow behavior in various systems composed of macromolecular compounds.

Shear stress applied to a polymer concentrated solutions will cause the destruction of certain structures present in solution and the orientation of macromolecules and the elements resulting from the dissolution of associations [19-22].

In literature there are many empirical relationships describing the dependence of viscosity solutions of temperature, shear rate and shear stress and very little dependence describing logarithm of dynamic viscosity logarithm of shear rate [23-27].

This article proposes an empirical relationship of dependence of logarithm of dynamic viscosity according to the logarithm of the shear rate. This relationship has the form:

log η = log η₀ + b log(dy/dt) + c [log (dy/dt)]² (1)

$$\log \eta = \log \eta_0 + b \log(dy/dt) + c\,[\log (dy/dt)]^2 \quad (1)$$

where $\log \eta_{0,}$ b and c characteristic parameters of the solution are studied. They depend on the temperature, concentration of the solution, the nature of the polymer and solvent.

2. Materials

The copolymer polyethylene-propylene is Paratone 8900 commercialized by Exxon Chemical. The properties physical and chemical are**:** 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 · m^{-3}.

The oil SAE 10W is physical and chemical properties: form - homogeneous liquid, yellow-brown, odor - characteristic, density (15^{o}C) – 0.875-0.910 kg · m^{-3}, kinematics viscosity to 40^{o}C - 90 cSt, kinemetics viscosity to 100^{o}C - 8 cSt, dynamic viscosity (20ºC) - 65 cP, viscosity index – 70 -100, solubility in organic solvents, petroleum, fat, water-insoluble, flash point > 200ºC, melting point - (-10) ÷ (-15)ºC, 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 apparatus used for plotting curves rheological is a rotation viscometer (Rheotest) RV 550 type coaxial cylinder sensor and VH_1. In this viscometer has connected a thermostat to raise the temperature of the sample. Cylinder S_1 was used for the constant is 5.67 and worked with a speed concentrates were studied in the temperature range 40 – 90^{o}C and shear rates between 3.3 and 1312 s^{-1}.

3. Results and discussion

Figure 1 shows the dynamic viscosity dependence of the logarithm according to the logarithm of the shear rate for the of 3 % copolymer polyethylene-propylene solution concentration.

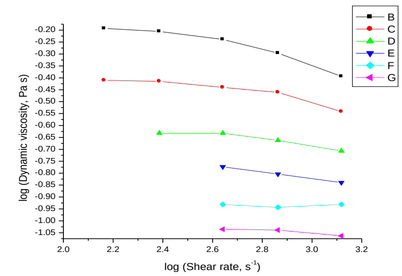

Fig. 1. Dependence log dynamic vicosity versus log shear rate of 3 % solution concentrated at temperatures: B – 40^{o}C, C –50^{o}C , D – 60^{o}C, E – 70^{o}C, F – 80^{o}C and G – 90^{o}C

Figure 2 shows the dependence of the logarithm of dynamic viscosity according to the logarithm of the shear rate to 6 % copolymer polyethylene-propylene solution concentration.

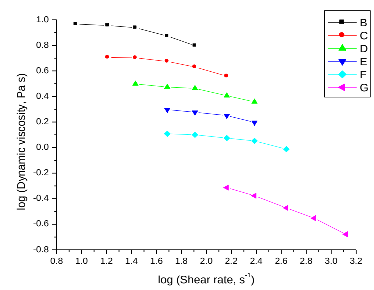

Fig. 2. Dependence log dynamic vicosity versus log shear rate of 6 % solution concentrated at temperatures: B – 40^{o}C, C – 50^{o}C , D – 60^{o}C, E – 70^{o}C, F – 80^{o}C and G – 90^{o}C

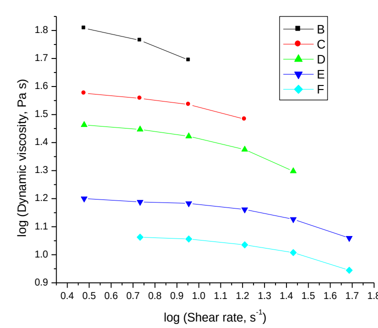

Fig. 3. Dependence log dynamic vicosity versus log shear rate concentrated solution 10 % at temperatures: B – 50^{o}C, C –60^{o}C , D – 70^{o}C, E – 80^{o}C and F – 90^{o}C

Figure 3 shows the dependence of the logarithm dynamic viscosity according to the logarithm of the shear rate to 10 % copolymer polyethylene-polypropylene concentration solution.

Figure 4 shows the dependence of the logarithm dynamic viscosity according to the logarithm of the shear rate to 12% copolymer polyethylene-polypropylene solution concentration.

Obtained lines are parallel to the axis which corresponds to the decimal logarithm of the shear rate at all temperatures to which the solution has been studied. Table 1 the temperature range that was studied solution parameter values obtained by fitting polynomial of the lines obtained correlation coefficients determined for each right.

As shown in Table 1 $\log\eta_0$ parameter is variable values, the lowest value is at most 90^oC and at 70^oC. These values depend on the structure of the copolymer and its behavior at elevated temperatures. The parameter b has only negative value at 70^oC and the highest value at 40^oC. The parameter c increases with increasing solution temperature, but it shows the highest value at 70^oC and lowest temperature of 40^oC. Correlation coefficients have values close to unity in the temperature range 40^oC – 60^oC and the value of one to the other temperatures.

The lines obtained for the solution concentration 6 % are substantially parallel to the axis of the corresponding logarithm of the shear rate. Only at 40^oC slope is much larger than the other temperatures at which the solution was studied.

With increasing solution concentration occurring interactions between macromolecules, which determine their association. Intensity depends on the macromolecular chains interactions SAE 10W oil and copolymer polyethylene-propylene. Increasing the solution concentration leads to interpenetration of macromolecules, causing portions of the chain cover. At higher concentrations the viscosity increases very rapidly and shear effects become important.

Table 2 temperature ranges that was studied solution at 6 % polyethylene-polypropylene copolymer, the parameter values obtained by fitting polynomial of the lines obtained correlation coefficients determined for each right.

The parameter values Log η_0 is positive in the temperature range 40^oC – 60^oC and negative for the other temperatures has been studied solution at 6 % polyethylene-polypropylene copolymer. The parameter b is variable values but the lowest value at 90^oC and largest at 40^oC. The parameter c decreases with increasing temperature the lowest value being at 90^oC. Correlation coefficients have values close to unity at all temperatures has been studied solution which demonstrates that math equation describes quite well the rheological behavior of the solution concentration 6 %.

As seen in chart logarithm of dynamic viscosity decreases with increasing shear rate logarithm of the solution concentration 10 % polyethylene-polypropylene copolymer.

At 40^oC slope has the highest value compared to the other temperatures at which the solution was studied.

Table 3 temperature ranges that was studied at 10% copolymer polyethylene-polypropylene solution, the parameter values obtained by fitting polynomial of the lines obtained correlation coefficients determined for each right.

As shown in Table 3 parameter $\log\eta_0$ decreases with increasing temperature solution concentration 10% polyethylene-polypropylene copolymer. The parameter b is variable values in the range of temperatures at which the solution was studied, the lowest value being at 80^oC and largest at 90^oC. The parameter c is negative; the lowest value is at 50^oC and highest at 80^oC. The correlation coefficients have values close to unity at all temperatures studied that could be 10% concentration solution of the polyethylene-polypropylene copolymer.

As shown in Figure 4 at 12 % copolymer polyethylene-polypropylene solution was studied at high temperatures is very astringent. The dependence of the logarithm of dynamic viscosity by logarithm of the shear rate decreases with increasing temperature and shear rate, the slope has the largest solution at 40^oC.

Table 4 temperature ranges that was studied at 12 % copolymer polyethylene-polypropylene solution, the parameter values obtained by fitting polynomial of the lines obtained correlation coefficients determined for each right.

Table. The temperature, value of parameters of described by equation (1) and coefficient correlation for 3% solution concentrated

Temperature, ^0C	Value of parameters of the described by equation (1)			Correlation coefficient, R^2
	log η_0	b	c	
40	-1.3285	1.0324	-0.2349	0.9994
50	-1.3605	0.8329	-0.1825	0.9834
60	-1.7347	0.8965	-0.1819	0.9930
70	-0.4427	-0.1142	-0.0042	1.0000
80	-1.6474	0.5715	-0.1137	1.0000
90	-2.2615	0.9068	-0.1676	1.0000

Table 2. The temperature, value of parameters of described by equation (1) and coefficient correlation for concentrated solution 6 %

Temperature, ^0C	Value of parameters of the described by equation (1)			Correlation coefficient, R^2
	log η_0	b	c	
40	0.7151	0.4803	-0.2289	0.9973
50	0.4060	0.4727	-0.1859	0.9999
60	0.2827	0.3259	-0.1235	0.9885
70	-0.0846	0.4826	-0.1525	0.9913
80	-0.2757	0.4501	-0.1323	0.9918
90	-0.3160	0.2667	-0.1227	0.9993

Table 3. The temperature, value of parameters of described by equation (1) and coefficient correlation for concentrated solution 10 %

Temperature, ^0C	Value of parameters of the described by equation (1)			Correlation coefficient, R^2
	log η_0	b	c	
50	1.7798	0.2076	-0.3116	1.0000
60	1.5549	0.1089	-0.1382	0.9965
70	1.4126	0.1901	-0.1871	0.9956
80	1.1509	0.1503	-0.1197	0.9879
90	0.9678	0.2351	-0.1469	0.9967

Table 4. The temperature, value of parameters of described by equation (1) and coefficient correlation for concentrated solution 12 %

Temperature, ^0C	Value of parameters of the described by equation (1)			Correlation coefficient, R^2
	log η_0	b	c	
60	1.3796	0.1958	-0.1841	0.9949
70	1.2783	0.1651	-0.1528	0.9945
80	1.0796	0.2669	-0.1679	0.9926
90	0.9996	0,.1112	-0.0721	0.9939

As shown in Table 4 parameter log η_0 decreases with increasing temperature 12% copolymer polyethylene-polypropylene solution concentration. The parameter b is variable values in the range of temperatures at which the solution was studied, the lowest value being at 90^{o}C and largest at 80^{o}C. The parameter c is negative; the lowest value is at 60^{o}C and highest at 90^{o}C. The correlation coefficients have values close to unity at all temperatures studied that could be of the 12

% copolymer polyethylene-polypropylene concentration solution.

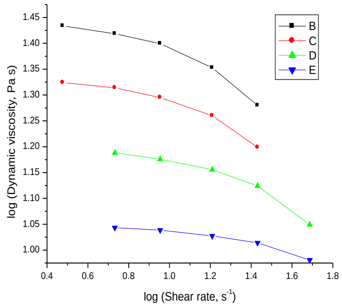

Fig. 4. Dependence log dynamic vicosity versus log shear rate 12 % solution concentrated at temperatures: B – 60°C, C –70°C , D – 80°C and E – 90°C

4. Conclusions

In this article we studied the rheological behavior of copolymer polyethylene-propylene solutions concentrated of at temperatures between 40 and 90°C and shear rates between 3 and 1312 s^{-1}. The rheology of the 3, 6, 10 and 12% solutions concentration are affected the temperature, shear rate, shear stress and the nature of the polymer and the solvent. Empirical relationship of dependence of logarithm of dynamic viscosity by logarithm of shear rate accurately describes the rheological behavior of these copolymer polyethylene-propylene solutions concentrated.

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