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Rheological Behavior of Concentrated Solutions Depending on the Type of Polymer

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ABSTRACT

Rheology includes the laws of the behavior of the matter of a system (or of a body) under external demands and elaborates methods for researching the rheological behavior of matter. In article have followed concentrated solutions of polymers at temperatures between 40 and 100°C. Solutions with higher concentrations could not be studied at lower temperatures because they have high viscosity. We found a relationship of shear rate dependence on shear stress that can be successfully applied to all Infineum SV 260 and Keltan 4200 polymer solutions in SAE 10W oil.

Keywords: Solutions, Polymer, Rheology, Concentrated.

INTRODUCTION

Rheology includes laws of the behavior matter a system (or of a body) under external demands and elaborates methods for researching the rheological behavior of matter.

The response function (effect) of the requested material, expressed by the kinematic quantities (deformations, formation speeds of the body), is correlated with the dynamic quantities (forces, stresses, rates of variation of stresses, torsional moments which characterize the external stress in the form the rheological state equation (or constitutive equation). The rheological state equations allow the determination of the state of deformation of the bodies if the external stress and the previous evolution of the body are known.

The behavior of fluid bodies (deformation, flow) under the action of an external stress, different depending on the structure, called rheological behavior; of fluids are the basis of the rheological classification of fluids.

If an external stress acts on a fluid body, the corresponding energy of the applied force acts an external stress, the corresponding energy of the applied force is consumed partly for the deformation (volume variation) of the body and another part for the relative displacement of the fluid particles (flow).

Recently, rheology considers real fluid

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bodies in the category of viscoelastic bodies, thus simultaneously having those two unitary properties of matter: viscosity, the characteristic of the fluid state and elasticity, the characteristic of the solid state.

Under the effect of a system of forces, a viscoelastic body flows, but also deforms elastically. The energy transferred from outside, through the system of forces, a part is accumulated in the form of reversible deformation (elastic deformation) and a part is consumed to realize the flow (irreversible deformation), dissipating in the form of heat.

When the system of forces is removed, the viscoelastic fluid, due to the accumulated energy, tends to return to the initial, undeformed state, the partial elastic recovery of the deformation distinguishes the real viscoelastic fluid from the ideal viscous fluid. A fluid can be considered perfectly (ideally) viscous, if the effects of its elasticity property are negligible.

Ideal fluid bodies are classified by energy according to viscosity in:

-In viscid fluid body (Pascal fluid), an incompressible fluid that does not oppose any resistance to deformation (flow), therefore with zero viscosity;

-Viscous ideal fluid body, a fluid that opposes limited resistance to deformation, so with non-zero viscosity and zero elasticity., if the viscosity is constant independent of the shear stress value or its action time, the fluid is called a Newtonian fluid, and if the vacuum is not constant and depends on the voltage value or time, the fluid is called a non-Newtonian fluid.

The diverse rheological behavior of natural bodies under the action of external demands is explained by the fact that they simultaneously possess, and in different proportions, two properties: elasticity and viscosity. The evolution over time of the concepts regarding the rheological behavior of matter was expressed in relation to their state of aggregation, solid and fluid. The bodies: perfectly plastic solid (Hooke's body), inviscid fluid body -Pascal, perfectly viscous fluid body-Newton, perfectly plastic body-St.Venant, represent idealized concepts, because their behavior does not depend on time, so it does not depend on the history of requests. Real bodies are characterized by the fact that their rheological state at a given moment is influenced by previous stress states, so they have the "memory" of previous stress.

The rheological behavior of viscous and viscoelastic fluids is highlighted by simple stress experiments (shearing, unidirectional stretching); the graphic representations of the experimental results are called rheograms and represent the dependencies of the shear stresses on the ratios or time, for simple shear stress and of the time normal stresses or ratios on the flow direction, for the unidirectional stretching stress of viscoelastic fluid bodies.

The rheograms obtained for the 3%, 3.5%, 4%, 4.5%, 5%, 5.5%, 7%, 8%, 9%, 11%, 11.5%, and 12% Infineum SV 260 and Keltan 4200 solutions for shear rates ranging between 3 and 1312 s^{-1}:

Bingham:

$$\sigma = \sigma_o + \eta\gamma \quad (1)$$

Casson:

$$\sigma^{1/2} = \sigma_o^{1/2} + \eta^{1/2}\gamma^{1/2} \quad (2)$$

Ostwald-de Waele:

$$\sigma = k\gamma^n \quad (3)$$

and Herschel-Bulkley:

$$\sigma = \sigma_o + k\gamma^n \quad (4)$$

where σ is the shear stress, σ_o – yield stress, η- viscosity, γ- shear rate, n– flow index and k – index of consistency.[1-8].

MATERIAL AND METHODS

The rheological behaviour of the 3%, 3.5%, 4%, 4.5%, 5%, 5.5%, 7%, 8%, 9%, 11%, 11.5%, and 12% Infineum SV 260 and Keltan 4200.

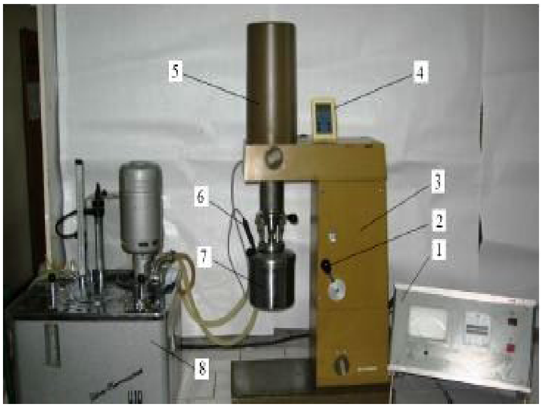

Fig. 1. Rheotest VT 550

Mainly, the Rheotest installation is composed of: 1-command and measurement module, 2-speed switch, 3-machine body, 4-electronic thermometer, 5-engine assembly, 6-thermometer probe, 7-enclosure for cylinders, 8-thermostatic bath.

Inside the enclosure (7) there are two coaxial cylinders, one fixed, integral with the body of the installation, the other mobile, driven by the motor shaft. The tested oil is inserted between the two cylinders. The resistance of the fluid against the rotational movement is transformed into an electrical signal, which is taken over by the electronic module, then it is compared in value based on the principle of voltage drop on a high-value electrical resistance and presented by the measuring instrument (1) in the form of important[9-11].

RESULTS AND DISCUSSION

Figures 2-5 show for solutions of concentration 3%, 3.5%, 4%, 4.5%, 5%, 5.5%, 7%, 8%, 9%, 11%, 11.5%, and 12% Infineum SV 260 and Keltan 4200 of the two polymers.

The Fig. 2, 11%, 11.5%, and 12% Infineum SV 260 and Keltan 4200 concentration solutions could not be studied at temperatures lower than 70°C, being very viscous. These were studied at shear speeds between 3 and 48.6 s^{-1} and shear stresses for Infineum SV 260 between 82 and 73Pa and for Keltan 4200 between 56 and 51Pa.

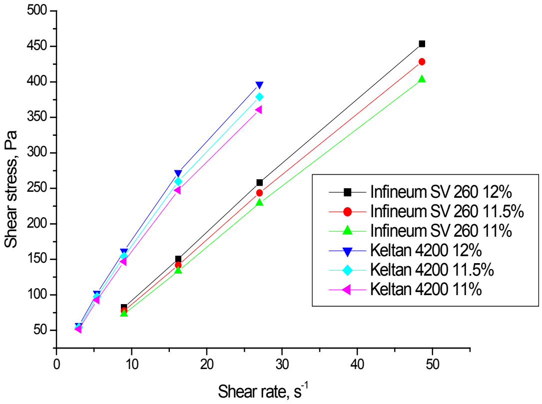

Fig. 2. Rheogram of concentration solutions at a temperature of 70°C

The drop in viscosity is more pronounced in the case of concentrated solutions of Infineum SV 260. Fig. 2 shows a decrease solutions. For concentrated solutions of 7%, 8%, 9% of Keltan 4200 and Infineum SV 260 polymers at a temperature of 700C (Fig. 3). These were studied at shear rates between 48.6 s^{-1} and 145.8 s^{-1} for Infineum SV 260 solutions and between 5.4 s^{-1} and 48.6 s^{-1} for Keltan 4200 solutions[12-18].

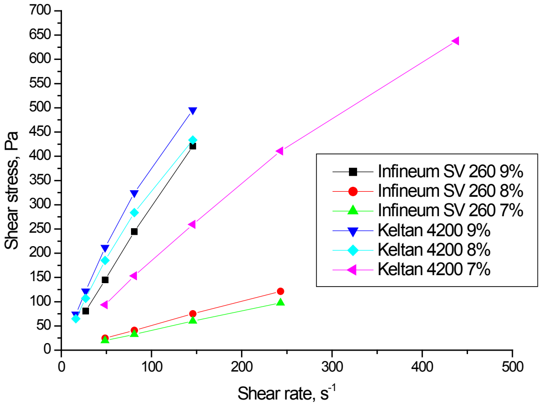

Fig. 3. Rheogram of concentration solutions at a temperature of 80°C

Figure 4 shows for concentrated solutions of 3%, 3.5%, 4% of Keltan 4200 and Infineum SV 260 polymers at a temperature of 40°C. These were studied at shear rates between 27 s^{-1} and 243 s^{-1} for Infineum SV 260 solutions and between 48.6 s^{-1} and 1312 s^{-1} for Keltan 4200 solutions.

Figure 5 shows for concentrated solutions of 4.5%, 5%, 5.5% of Keltan 4200 and Infineum SV 260 polymers at a temperature of 50°C. These were studied at shear rates between 27 s^{-1} and 243 s^{-1} for

Infineum SV 260 solutions and between 48.6 s^{-1} and 1312 s^{-1} for Keltan 4200 solutions.

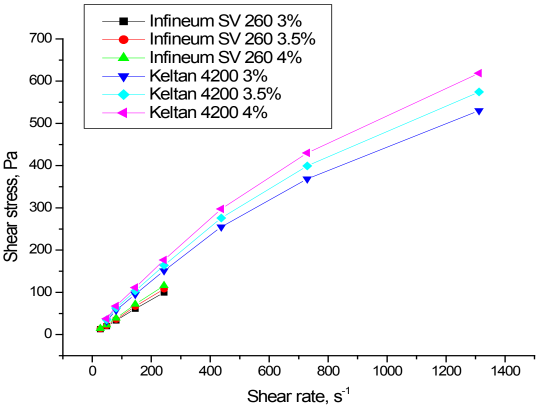

Fig. 4. Rheogram of concentration solutions at a temperature of 40°C

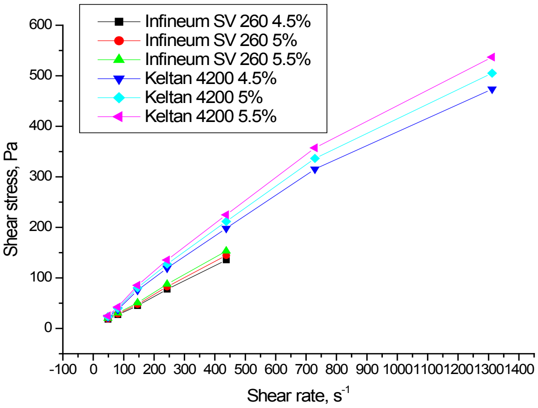

Fig. 5. Rheogram of concentration solutions at a temperature of 50°C

In this article we sought to find a polynomial relationship of dependence between shear rate and shear stress for the concentrated solutions of Infineum SV 260 and Keltan 4200 polymers.

$$\sigma = A + B_1\gamma^2 \quad (1)$$

Where A, B_1 and B_2 are the parameters of the equation that depend on the concentration of the solution, σ- shear stress and γ- shear rate.

Tables 1 and 2 present the correlation coefficients of equation (1) for different concentrations of Keltan 4200 and Infineum SV 260 polymer.

Applying relation (1) to the experimental data, it is observed that the correlation coefficients have values close to unity. The formula faithfully describes the rheological behavior of concentrated solutions of Infineum SV 260 and Keltan 4200.

Table 1: Correlation coefficients of equation (1) and temperature for different concentrations of Infineum SV 260 polymer

Concentration, %	Temperature, °C	A	B1	B2	Correlation coefficients, R^2
3	40	0.3711	0.4177	-3.6657E-5	0.9994
4	40	0.4329	0.4874	-4.2766E-5	0.9994
5	40	0.4948	0.5570	-4.8876E-5	0.9994
6	40	1.8915	1.6076	0.0016	1.0000
7	40	2.5219	2.1435	0.0021	1.0000
8	40	3.1525	2.6794	0.0027	1.0000
9	40	-17.1253	25.7155	-0.1952	0.9991
10	40	-19.2659	28.9299	-0.2196	0.9991
11	70	-9.3160	9.1705	-0.0139	0.9999
12	70	-10.4805	10.3168	-0.0157	0.9999

Table 2: Correlation coefficients of equation (1) and temperature for different concentrations of Keltan 4200 polymer

Concentration, %	Temperature, °C	A	B1	B2	Correlation coefficients, R^2
3	40	6.3920	0.6353	-1.8037E-4	0.9997
4	40	7.4572	0.7412	-2.1043E-4	0.9997
5	40	8.7196	0.8455	-2.3939E-4	0.9997
6	40	4.9489	9.3322	-0.0387	0.9995
7	40	6.5986	12.4430	-0.0516	0.9995
8	70	14.8907	20.3542	-0.2032	0.9994
9	70	17.0180	23.2619	-0.2323	0.9994
10	70	19.1453	26.1697	-0.2613	0.9994
11	70	-1.0902	18.1574	-0.1759	0.9999
12	70	-1.2240	19.9750	-0.1936	0.9999

Conclusion

In this article studied concentrated solutions of polymers at temperatures between 40 and 100°C. Solutions with higher concentrations could not be studied at lower temperatures because they have high viscosity. We found a relationship of shear rate dependence on shear stress that can be successfully applied to all Infineum SV 260 and Keltan 4200 polymer solutions in SAE 10W oil.

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Conflict of interest

The author declare that we have no conflict of interest.

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