Bulletin of the *Transilvania* University of Braşov • Vol. 2 (51) - 2009
Series I: Engineering Sciences

MODELING RHEOLOGY PROPERTIES OF WATER-FUEL OIL EMULSIONS AND WATER-COAL FUEL SUSPENSION

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Abstract: *Study viscosity - coefficient of internal friction at the movement and deformation of substance who belongs to rheology domain. Synthetic fuels based on petroleum and coal products, prepared in the form of emulsions and suspensions with water, manifested an non-newtonian rheological behavior, shear stress of them is not directly proportional with the velocity of deformation at shearing. In this moment did not exist an exactly theory of viscosity liquids. From existing theories for establish the temperature dependence of viscosity it was taken first of all on the relationship Frenkel in the presentation of Andrade. Rheological models the oil-water emulsions and the water-coal fuel suspension were established in the mechanical-electrical analogies, drawing- equivalent electric schemes, where inertial element is modeled with an inductance, the disipativ element - with a resistance and the elastic element -with a capacity.*

Key words: *Suspension rheology, rheological structure of relationships, rheology bubble suspension, viscosity; visco-elasticity, time-dependent flow*

1. Introduction

It was shown that there are fluids whose viscosity is dependent on the parameters of demands and sometimes by time. These real fluids have been called abnormal viscous fluids or non-newtonian fluids. There are situations where even an newtonian fluid, such as water, with mechanical particles (coal dust), is forming an fluid with an non-newtonian behavior. Moreover, a number of real fluids, besides the essential attribute of the fluid state, viscosity, can manifest in a certain weight and specific properties of solids such as elasticity and plasticity, under the aspect of ther deformation at the action of an external solicitation, is called rheological behavior. Current research in in the domain of synthetic fuels has caused an new interest in this problem, because the rheological properties of these fuels are first important. From particular fuels artificial are interesting, first of all primarily the physical properties wich affect the storage, the transporting and the atomizers of it (the degree of dispersion, viscosity, stability, density and freezing temperature) and, secondly, the energetical propreties such as mass heat, thermal conductivity, burning heat, flammability and ignition temperature.

Even from the begining of electrotechnics like discipline has been used widely electrical schemes as objects of study for some phenomenons. Because the electrical schemes are more clear in presentation and more studied results that,

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because of the uniqueness of equations that describes objects of diverse physical study of phenomenons in a non-electric system may be replaced with the study of analogical processes in a electrical circuit.

2. Rheological characteristics of synthetic fuels based on oil and coal.

Commonly, non-newtonian fluids are those who don't have direct proportionality between unit efforts and the velocity of deformation. [1]

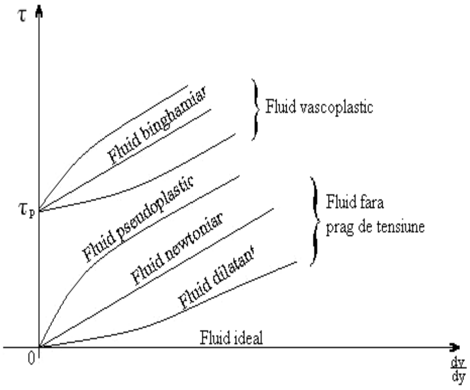

Fig. 1. *Types of fluids non-newtonian.*

An model of non-newtonian fluid, hit is often find in practice with a behavior very close to that monoplastic, is that plastic fluid Bingham or binghamian, which contains two rheological constants: threshold of flow τp, which is the unitar tangential effort under whose value does'nt appear velocity of deformation, and plastic-viscosity (structural) µp.

$$\tau = \tau_p - \mu \frac{dv}{dr}$$

It was demonstrated that it is possible to describe viscometric the properties of synthetic fuels by treating them in terms of rheological behavior using power law fluids [2]

$$\tau_{yx} = K\left(\frac{dV_x}{dy}\right)^n = K \cdot \dot{\gamma}_{yx}$$

$$\eta_a = \frac{\tau_{yx}}{\dot{\gamma}_{yx}} = K \cdot \dot{\gamma}_{yx}^{n-1}$$

- for n = 1, $\eta_a = k = const.$ and the fluid has Newtonian behavior;
- for n < 1, η_a - decrease with increasing of shear velocity and fluid has pseudo-plastic behavior;
- for n > 1, η_a - increases with velocity increasing of shearing and fluid has dilated behavior. In theory, in most practical suspensions such as those of coal-water some flocculation occurs due to interparticle attraction. For that reason only empirical equations are used to describe the relative viscosity of the concentrated suspension. Of these the Mooney equation (1951) and its modification by Doughety and Krieger (1969, 1972) are perhaps the most applicable for qualitative description of the bulk viscosity (η), volume fraction of the suspension φ relationship, the relationship between the bulk density (η) and the volume fraction of the suspension. These are given by equations:

$$\eta_r = \exp[\eta]\phi$$

$$\eta_r = \left[1 - \left(\frac{\phi}{\phi_p}\right)\right]^{[n]\phi}$$

where φ is the volume fraction of the suspension, φp is the so called packing fraction and K is the so called crowding factor (= 1/φp) Both equations predict a rapid increase in ηr with φ above a critical value. [3]

Viscosity is an determinant element of the stability of emulsions and suspensions at the given concetration of water and is always higher than the viscosity of each phase. For a value of shear rate, the ratio between stress and shear velocity defines the apparent viscosity of the non-newtonian fluid

$$\tau\left(=\frac{F}{S}=\eta\cdot\frac{dv}{dr}\right)=\eta\cdot G$$

where τ is the shear stress; G- shear rate (velocity) and η-dynamic viscosity. At those fluids the viscosity in isothermal conditions depends on the demands parameters and technologies of preparing so that the relationship between tensions and velocity gradient is more complex being non-linear. In relation with the viscosity of natural fuel, synthetic fuel viscosity increase with decreasing temperature. Both oil-water emulsions and water-coal suspensions are characterized by specific rheological behavior and the modification of rheological characteristics in time. Knowing the flow way of these fluids and their evolution over time represents an esential condition for leading to the optimal parameters of the preparation process and transport.

Beside some high values of viscosity suspension processed, it is characteristic to them the modification of type-flow, as a result of continuous accumulation phase, and because of the substrate consumed. For this reason, the values of rheological characteristics of suspensions (viscosity, shear stress, shear velocity, flow index, consistency index etc...). Achieved at a time is an indicator of the state in which the process is, being an element of control of development in the velocity of mass transfer and heat, under conditions in which it is made the mixing suspensions and subsequent filtering operations.

Viscosity decreases with the amount ofstress or rate of deformation, materials are flowing and become more pliable. This is explained by the alignment, the orientation of particles (asymmetric) in suspension, so it will oppose a lower resistance in flow process.[4]

Also, expansive behavior is frequently seen in suspensions and emulsions whose viscosity increases with the rate of deformation, Reynolds explain this behavior based on their porosity variation. At low velocity shearing porosity is low, but as the velocity of shearing increase, porosity increase too, intergranular space format is no longer filled with liquid, increase the number of points of contact between solid particles, which causes increased the internal friction forces and thus the apparent viscosity. Distribution of velocity, stress and deformation rates are shown in fig. 2.

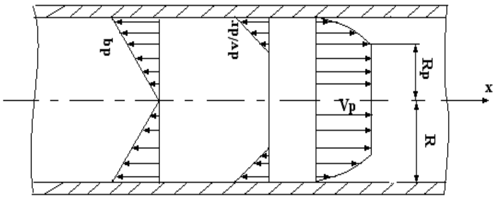

Fig. 2. *The distribution of velocity, stress and velocity of shearing deformation of the laminar flow through circular pipes fluids non-newtonian.*

Many non-newtonian fluids fall into the category of pseudo-plastic fluids, for them, the easier relationship between tangential unit effort and velocity of deformation is

$$\tau=k\cdot\left(-\frac{dv}{dr}\right)^{n}$$

and corresponds to Ostwald de Waele fluid model, which contains two rheological constants, k and n. The variation law of velocity in cross section, obtained by integrating the equation of motion in cylindrical coordinates for some limited conditions, is:

$$v = \frac{n}{n+1}\left(\frac{p_1 - p_2}{2kl}\right)^{\frac{1}{n}} \cdot \left[\left(\frac{d}{2}\right)^{\frac{n+1}{n}} - r^{\frac{n+1}{n}}\right]$$

and flow volume is calculated by the relationship:

$$Q = 2\cdot\pi\int_{0}^{\frac{d}{2}} v\cdot r\cdot dr = \frac{\pi\cdot n}{3n+1}\cdot\left(\frac{p_1 - p_2}{2kl}\right)^{\frac{1}{n}}\left(\frac{d}{2}\right)^{\frac{3n+1}{n}}$$

The degree of dispersion of synthetic fuel-based on oil or coal, is characterized by three dimensions: size (radius) of the drops, the reverse size of drop which usually is called refinement $F = 1/2\cdot a$, specific area S_{sp} of total surface by separation of equal phases with the ratio of total area of the drops in their volume.

These sizes are linked together:

$$F = 1/2\cdot a \ ;$$

$$S_{sp} = S/V = \pi(2\cdot a)^2/\left[\pi(2\cdot a)^3/6\right] = 3/a, \left[m^{-1}\right]$$

From these relations is observed that the finesse and specific area are inversely proportional to the average size of the drops. [5]

Density of synthetic fuels leads to a certain measure to their stability. It is clear that the values used in Romania

$$\rho^{0}_{10\left(15^{0}C\right)} = 900 - 1020\,kg/m^3 \ ,$$

sedimentation flows quite slowly even in case of emulsions with fine coarse. At densities close to water density the stratification becomes impossible. In usual limits of temperature variation of synthetic fuels, the density of continuous phase of them can be approximated by a linear relationship like:

$$\rho_1^0(t) = \rho_1^0(t_0)\left[1 - k_t(t - t_0)\right]$$

where $\rho_1^0(t)$ is the real density of the fuel at a temperature t, $\left[kg/m^3\right]$; $\rho_1^0(t_0)$ - fuel density at a reference temperature (in Romania $\rho_1^0(t_0)$ is determined to a temperature $t_0 = 15^o C$); temperature coefficient which is determined experimentally.[6]

The stability is an important characteristic for storage and transport of synthetic fuels. Volume fraction of water in synthetic fuel is calculated by the expression:

$$\theta = \frac{\rho - \rho_0}{\rho_2 - \rho_0}$$

where ρ is the density of synthetic fuel, $\left[kg/m^3\right]$; ρ_2- water density, $\left[kg/m^3\right]$; ρ_0 - emulsifying agent (stabilizer) density, $\left[kg/m^3\right]$.

3. The rheological model of syntetic fuels based on oil and coal.

In principle, if the constitutive equation of an certain fluid is known, the establish of the relationship flow-pressure drop is possible by integrating the equations of motion. Conversely, from data-flow pressure drop obtained in a capillary viscometer may calculate the rheological constants, with the condition of knowledge the type of flow. It happens relatively often, that it can not be correctly describe the behavior of a real nonewtonian fluid using a model from the categories listed in the speciality literature. Such situations appears when the rheological constants of the fluid are changing their values depending on the area of deformation speeds where the flow is going .[7]

First, it is necessary to establish some general relationships between flow and tangential unit effort. Metzner and Reed proposed a general procedure, valid for any type of fluid, which allows calculation of the fall of pressure through a pipeline, if it is available pressure-flow data measured in another pipe or an capillary viscometer.[8]

Thus, the term flow is written:

$$Q = 2\pi \int_0^{r_0} vr \cdot dr = \pi \int_0^{r_0^2} v \cdot d\left(r\right)^2 = -\pi \int_0^{r_0^2} r^2 \cdot dv$$

Because many fluids used in oil industry: drilling fluids, crude oils etc., are away from the law of composition of a newtonian fluid, especially at low speeds, the relations calculated establish are no longer fully available.

The problem of motion of a binghamian fluid that can be resemble a large part of the fluids encountered in industry has been studied, but nonstationary problem, at the start of moving or changing the regime, we try to determine that through a modern approach. Thus, the mechanical system of synthetic fuels is divided in such way so that each subsystem obtained is containing a focused mass. The number of subsystems must be equal with the focused mass of the mechanical system. Driving forces, acting on subsystem shows the circlets on the electrical scheme and it is presented as a source of FEM (electromotive force).

The forces of resistance acting on subsystem are noted on electric schemes in the form of tensions between those nodes.

Electrical items are noted with symbols, which are marked the analogic elements of mechanical system. For not introduce new notations, inductivities, capacities, fem, voltages and current intensities in analogic electric schemes we will note them with the symbols adopted in mechanical system. Table 1 presents, depending on the item, type of component equations obtained for the elements of dynamic systems by mechanical nature and electrical.

Table 1

Type of item	Mechanics (motion translation)	Electrical
Inertial	$F_i = m\dfrac{dv_i}{dt}$	$U_i = L \cdot \dfrac{di_i}{dt}$
Disipativ	$F_d = \mu \cdot v_d$	$U_d = R \cdot i_d$
Elastic	$F_e = c \cdot \int v_e dt$	$U_e = \dfrac{1}{C}\int i_e dt$

Topological equations of these systems are just completly analogical.

This is the unique of the physical laws, even if there is a wide variety of natural materials.

Comparing the equations of system elements, it is easy to see dynamic analogies of all types of systems.

In table 2 are listed the variables with units of measurement for physical systems of different kind.

Table 2

Type of item	Physical nature of the system	
	Mechanics (motion translation)	Electrical
Type potential	Strength, F, [N]	Voltage, U, [V]
Type flow	Velocity, v, [m/s]	The current, I, [A]

In concordance with table 1 shall be drawn up equivalent electrical scheme (fig.4) of the mechanical system from figure3.

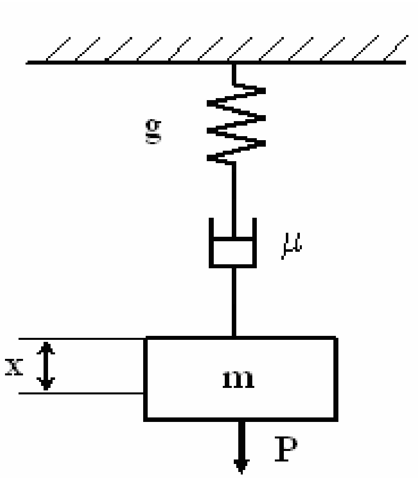

Fig. 3. *The equivalent mechanical rheological behavior.*

To determine the rheological characteristics of synthetic fuels based on oil and coal has been studied by analogy mechanical-electrical the behavior of RLC circuit alimentated in the DC under voltage U.

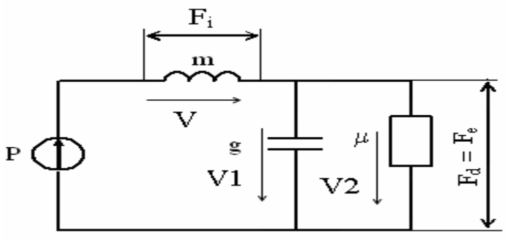

Fig. 4. *The equivalent electrical mechanical system.*

All the components used in electronic circuits have three basic properties, known as resistance, inductance and capacity.

In most cases, however, only one of these properties will be more widespread than the other two. Where as the fact that in direct current the coil`s behaivor is practically a short circuit, coil`s reactance does not change for different values of current (ex I0 = 0.2 ... 1.9 A, Io = Imax = 1.9 A), circuit`s analysis is riddled to the study of a parallel RC circuit in direct current.

Considering the current source of negligible resistance and condenser in the unladen condition, differential equation that describes the voltage at the terminals of condenser is:

$$RC\cdot\frac{du_c}{dt}+u_c=U_0$$

whose solution is:

$$u_c=U_0\cdot\left(1-e^{\frac{t}{\tau}}\right)$$

where τ = RC is time constant.

Current from circuit has a variation in time described by the equation:

$$i=\frac{U_0}{R}\cdot e^{\frac{t}{\tau}}$$

In the moment when the RLC circuit is powered with continuous voltage U0, condenser is loading almost suddenly, accruing power loads on his fittings, up to 99% for values of time after 5τ, but ulterior he discontinue the passing of electric current through the circuit .

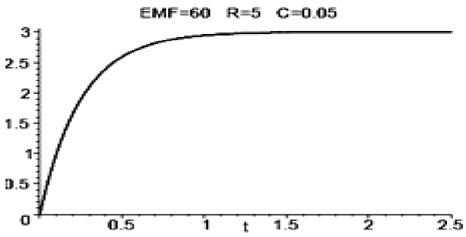

Fig. 5. *Loading condenser.*

For the situations when R a short circuit, respectively R in circuit , it is performing measurements and it is calculated voltages on the reactive elements and the impedance of them, same as the difference current-voltage, and it draws the graphs of variation .

Conclusions

1. Synthetic fuels based on oil or coal are characterized by specific rheological behavior and rheological characteristics changing over time.
2. Knowing how the flow of these fluids and their evolution over time is a prerequisite for running the optimal parameters of the process of preparation and transportation.
3. In addition to high values of viscosity synthetic fuels is the most characteristic type of flow modification as a result of the accumulation phase and substrate consumed.
4. The relationship betweenstress and deformation or deformation rate can be expressed through an equation dependent rheological analysis or a graphic-reograma.
5. In such fluid viscosity in isothermal conditions depends on the parameters so that requests the relationship betweenstress and velocity gradient is more complex as non-linear.
6. Function up with that change the apparent viscosity of a fluid non-newtonian may be independent or dependent.

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