Effect of Temperature on the rheological properties of bentonite-water suspensions

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Abstract:
The temperature and shear rate effects on rheological behavior of bentonite –water suspensions were investigated in this work. The model of Herschel-Bulkley was used to fit the shear rate dependence of the shear stress. The temperature increase induced not only on increase in yield stress but also an increase of the viscosity at zero shear rate and a decrease of pH of bentonite suspensions. An evolution of the viscoelastic moduli as a function of time for different temperature shows that the increase of temperature favors the kinetics of structuring.

Keywords: temperature, yield stress, viscoelastic moduli, viscosity, thixotropy, bentonite.

1. Introduction

The rheology of concentrates clay suspensions has been an object of interest for a rather long time because of the wide application of this type of suspension. Their flow properties are important in such varied fields as paint formulation, pharmaceutical suspensions, inks and drilling fluids.
As in other disperse systems, such properties are strongly correlated with the degree of flocculation between the particles and with the structure of the flocculi. In fact, the pioneering works of Norrish [3, 4] and Von Olphen [5, 6] already suggested that the mechanical strength of montmorillonite gels must be related to the formation of particle networks in wich individual clay particles are in contact with others, forming ribbon –like or scaffolding structure.
Drilling mud rheological and gel property changes due to elevated temperatures frequently cause problems in drilling deep wells.so it is desirable, to know the effects of time and temperature on the rheological properties of the drilling fluid in the hole.
At high temperature , the clay flocculates. The flocculation temperature depends on the concentration and type of solids in the suspension and the degree of chemical deflocculation. Gel strengths were found to be more sensitive than viscosities to changes in temperature and mud composition [1,2].

2. Materials and Methods

2.1. Bentonite

The clay used in this study is a calcic bentonite (B3378) its chemical formula is: $Al_2O_34SiO_2H2O$, had a pH = 9 and a density of $2.4 g/cm^3$.the chemical composition of this bentonite is given in the table**:**

Table 1: Chemical composition of bentonite (B3378)

Chemical element	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O
Concentration (%)	48.35	12.15	8.26	6.68	5.47	3.65

2.2. Samples Preparation

The bentonite preparations were performed by adopting the following experimental protocol: to the predetermined quantity of distilled water, the mass of bentonite (6%) was intimately added. Homogenization is obtained by stirring for 24 hours.

Before performing the rheological measurements on the Physica MCR301 rheometer, each sample is stirred to obtain an homogeneous suspension. To ensure good reproducibility of the measurements, all samples studied are subject to the same mechanical history.

The experiments were performed at different temperatures (25, 35, 45, 55 and 65 °C).

3. Results and Discussion

3.1 Flow Curves

The steady state test consists to apply a rising ramp of shear rate for bentonite sample at different temperatures.

The rheological behavior of the basic bentonite suspension (6%) at different temperatures remain shear-thinning with yield stress (Fig.1).

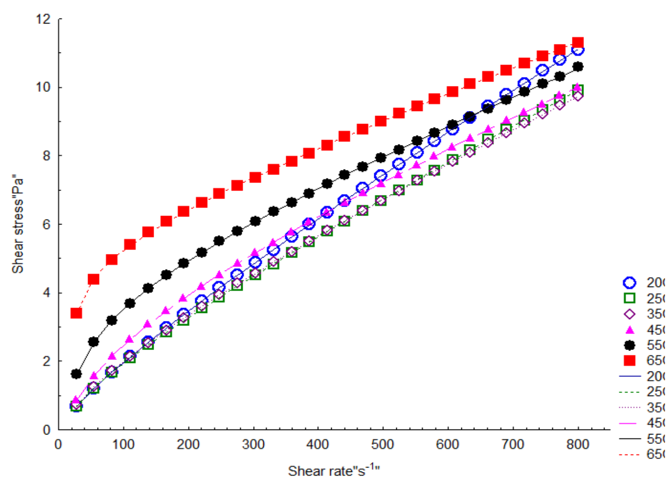

Fig .1 Flow curves for bentonite suspensions at different temperatures.

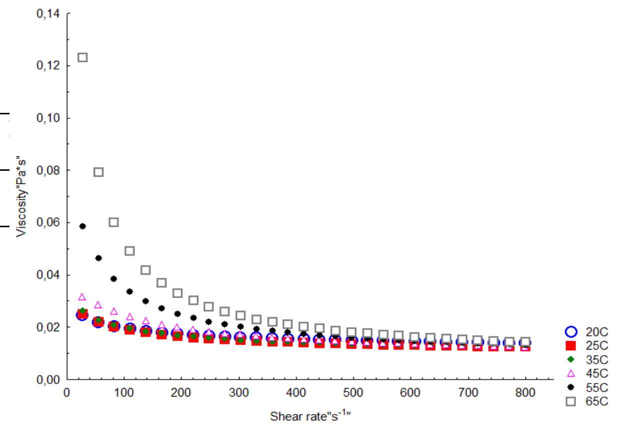

Fig.2 Viscosity curves for bentonite suspensions at different temperatures.

The yield point evolution as function as temperature is illustrate on Fig . 3

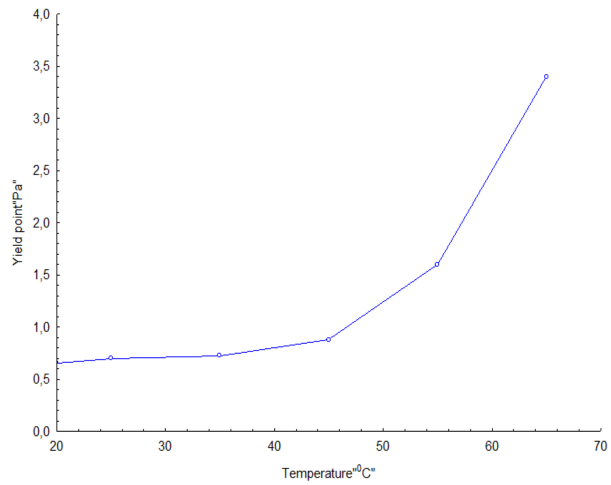

Fig.3 Variation of yield point of bentonite suspensions as function of temperature.

The rheological behavior of the basic bentonite suspension (6%) at different temperature remain shear-thinning with yield stress (Fig.1). the suspension becomes more non Newtonien, more shear thining as the temperature is increased. This change is characteristic of a flocculation process in which the yield point greatly increased [1, 2, 9].

3.2 Modeling of flow curves

In this study, the Herschel-Bulkley model [10] is used for the correlation of experimental results in simple shear:

$$\tau = \tau_c + k\dot{\gamma}^n$$

Where τ is the shear stress (Pa) and $\dot{\gamma}$is the shear rate (1 / s) and the rheological parameters of the model to identify are: yield stress (Pa), the consistency k andn index of flow**(Fig.4).**

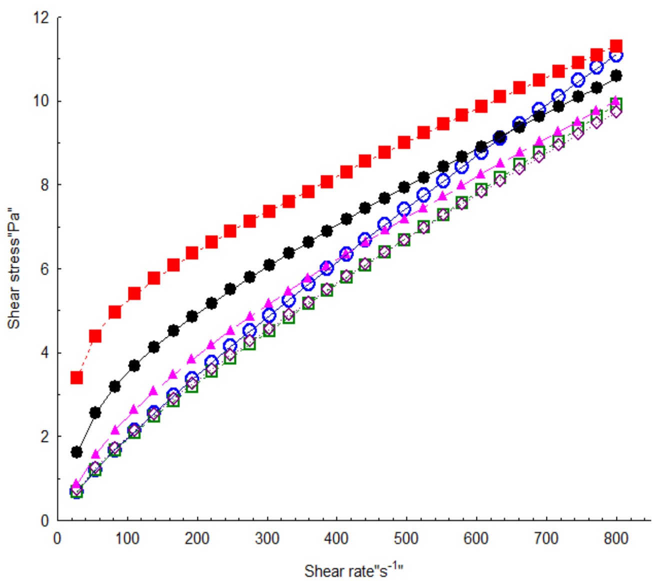

Fig .4 Prediction of flow curves for bentonite-water suspensions with HB model.

3.3 Dynamic tests

To make the connection between the suspension structure and its rheological behavior, we performed tests in stress and frequency sweep; the results are shown in Figures 5 and 6.

The results obtained revealed that the storage modulus G 'are greater than the loss modulus G" for every temperature, it is the viscoelastic solid behavior [8, 9]. Any time the modulus G' and G" of suspensions are increasing as the temperature is increased.

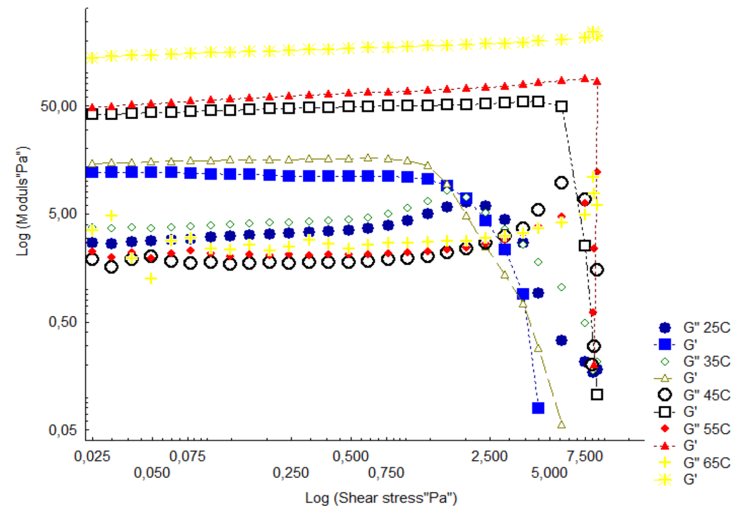

Fig.5. Elastic and loss modulus shear stress sweep as a function of temperature (ω = 10 1/s)

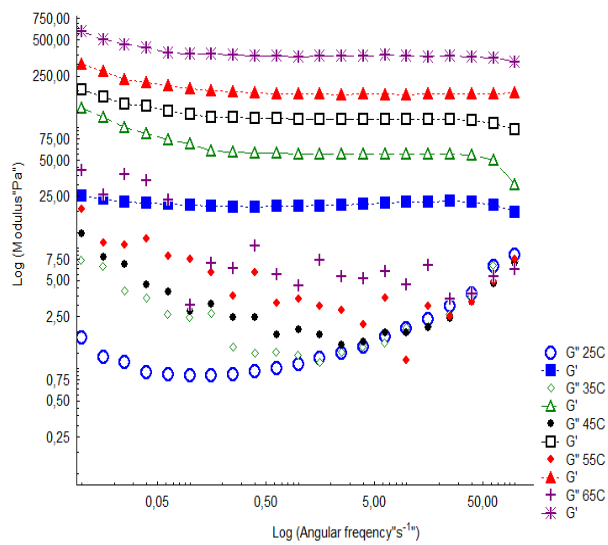

Fig.6.Elastic and loss modulus frequency sweep as a function of temperature (τ = 0.15 Pa).

3.4 Kinetic of Structure

To see the influence of the temperature on the gelation kinetics of our samples, measures of the temporal variation of the viscoelastic moduli G 'and G" for mild conditions were performed (Figure 7), an evolution versus time of the viscoelastic modulus was recorded. It is found that the bentonite-water suspensions have the same rheological behavior witch characterize the solid viscoelastic behavior at different temperature, but it is noted that the modulus increases at the rate as the temperature increases, which means that a gel time decrease (faster gelation depending on the temperature) which is accompanied by a decrease in pH (pH=9.01 at T=25°C to pH= 8.37°C), which means that the energy of interaction between particles increases with temperature, which gives a structure to attractive bonds.[7, 8, 16].

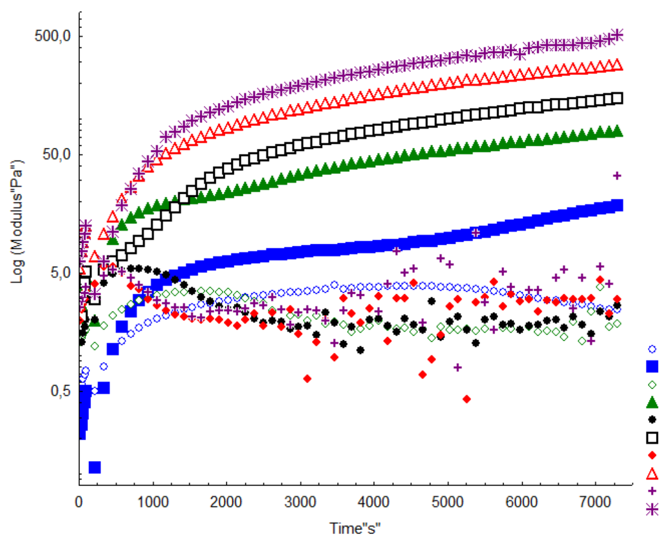

Fig.7. Elastic and loss modulus time sweep as a function of temperature (τ = 0.15 Pa, ω = 10 1/s).

Conclusion

In this study, we have shown the influence of temperature on the rheological properties of basic bentonite suspension. The results obtained allow us to conclude that the temperature has a flocculate effect on the bentonite suspensions it increase the rheological parameters of the suspension (yield stress, viscosity and viscoelastic modulus). The gel time of bentonite-water suspensions is also influenced by the temperature (decrease with increasing temperature).

There is a very good agreement between the results of tests in stationary regime and those under dynamic conditions.

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