Effect of UH Biosurfactant on the Rheological Properties of Acrylamide Polymer Modified Cement

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Abstract

In this study, the effect of UH Biosurfactant on the rheological properties with ultimate shear stress and initial resistivity of the oil well cement (class H) modified with acrylamide polymer was investigated. The Biosurfactant content was varied 0, 1 and 2 % by the weight of the cement. The UH Biosurfactant modification increased the yield stress (τ_0) and plastic viscosity (μ_p) based on the UH Biosurfactant content of the cement slurry. The shear thinning behavior of the cement slurry with and without UH Bio surfactant has been quantified using the Vipulanandan rheological model and compared with the Modified Bingham model. The Vipulanandan rheological model has a maximum shear stress limit were as the Modified Bingham model did not have a limit on the maximum shear stress. Based on the Vipulanandan rheological model the maximum shear stress produced by the 0%, 1% and 2% of Surfactant at the temperature at 25 ºC were 156 Pa, 172 Pa and 182 Pa respectively.

1. Introduction

Rheology is defined as the science of deformation and flow of materials in response to applied stresses. The rheological properties through equations giving the relation between shear stress and shear strain rate for concentered suspensions of cementitious materials (Mohammed, 2017). These are suspensions that rheologically behave mostly in a non-Newtonian way such as the deformation and flows of the suspicions depend on the applied stress in a non-linear way. Being able to predict the rheological behavior of cementitious suspensions is important for the design, execution, and evaluation of a primary cementing operation (Gopalakrishnan, et al., 2012). The power-law, Bingham, and Herschel-Bulkley models are the most commonly used in the well-cementing industry (Guillot, 1990).

2. Objective

The overall objective was to quantify the effect UH Biosurfactant on the electrical resistivity and rheological properties of Acrylamide polymer modified cement. The specific objectives are as follows:

1. Quantify the shear stress-shear strain rate relationship of Acrylamide polymer modified cement with varying amounts of UH Biosurfactant at 25 ºC temperature using the Vipulanandan rheological model and compare it to the Herschel-Bulkley model, Modified Bingham model.
2. Investigate the relationship between the shear stress limit of the cement slurry and the initial electrical resistivity.

3. Materials and Methods

In this study, oil well cement (Class H) with the polymer solution-to-cement ratio of 0.45 was used the polymer solutions was prepared with 2% monomer (AV100), 0.75 % Activator (AV101) and 0.3 % Initiator (AV102) Three series of oil well cement slurries were prepared with varying amounts of UH Bio surfactant up to 2% (by the weight of the cement) and the initial resistivity measurements were taken using conductivity probe. Rheology tests were performed by utilizing a rotational viscometer at the temperature of 25 ºC at rpms ranging from 0.3 to 600 rpm and related shear stresses were recorded. The viscometer was calibrated using several standard solutions. The rheological properties of the cement slurry modified with varying amount of UH Biosurfactant up to 2% by the weight of cement were measured.

4. Rheological Models

Modified Bingham Model

Different types of analytical models are available to calculate the rheological properties of cement slurries. One of them is the Bingham model ($\tau = \mu_p \dot{\gamma} + \tau_0$) that is usually used for defining the rheological properties of cement slurries. Plastic viscosity (μ_p) and yield stress (τ_0) are obtained from the shear stress versus shear rate curve. On the other hand, if highly pseudo-plastic and shear thickening behaviors disappear the yield stress calculated by using the Bingham model is lower than true yield stress. Because of this situation, yield stress and plastic viscosity are estimated by using modified Bingham model. Modified Bingham model is described as second order polynomial equation and following equation is given below (Yahia & Khayat, 2001).

$$\tau = \tau_0 + \mu_p \dot{\gamma} + C\,\dot{\gamma}^2$$

where τ = shear stress (Pa), τ_0 = yield stress (Pa), μ_p = plastic viscosity (Pa.s), $\dot{\gamma}$ = shear rate (s^{-1}) and C = constant. The modified Bingham model presents a more certain solutions than the traditional Bingham model for the similar mixtures (Khayat & Yahia, 1997)

Vipulanandan Rheological Model (2014)

The Vipulanandan rheological model (Vipulanandan & Mohammed, 2014) was developed to satisfy the condition in Equations as follows:

$$\boldsymbol{\tau = \tau_0 \quad \text{When} \quad \dot{\gamma} = 0}$$

$$\tau = \tau_{max} = \tau_0 + \frac{1}{\mathrm{B}} \quad \text{When} \quad \dot{\gamma} \rightarrow \alpha$$

Based on the inspection of the test data the Vipulanandan rheological relationship was used to predict rheology of acrylamide polymer modified cement with UH Bio Surfactant.

$$\tau = \frac{\dot{\gamma}}{\mathrm{A+D}\,\dot{\gamma}} + \boldsymbol{\tau_0}$$

Where τ = shear stress (Pa), τ_0= yield stress (Pa); A $(Pa.s)^{-1}$ and B $(Pa)^{-1}$ = are model parameters and $\dot{\gamma}$ = shear strain rate (s^{-1}). Hence this model has a limit on the maximum shear stress ($\boldsymbol{\tau_{max}}$) the cement slurry will produce or tolerate at the relatively high rate of shear strains.

5. Results and Discussion

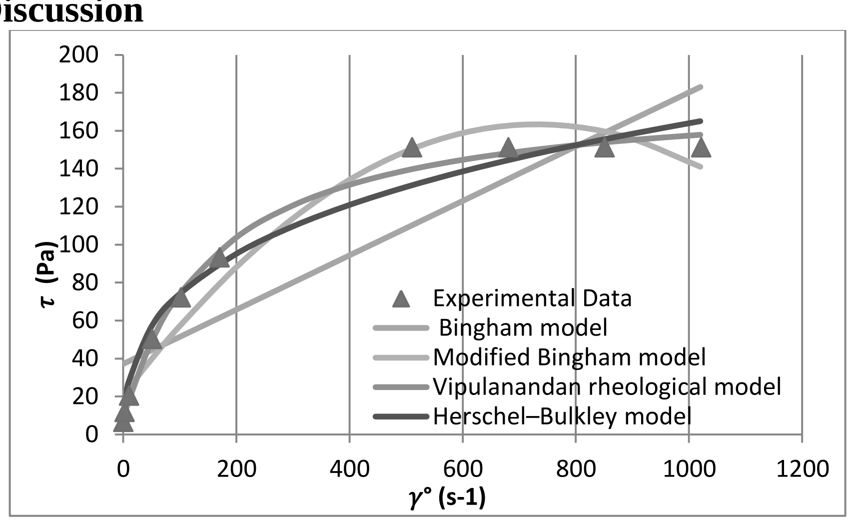

Figure 1. Predicted and measured shear stress-shear strain rate relationship for polymer modified oil well cement slurry with 1% UH Bio Surfactant

Table 1: Modified Bingham model parameters for the acrylamide polymer modified cement with UH Biosurfactant

UH bio (%)	τ_0	μ_p	C	R^2	RMSE
0	63.4	0.363	-0.00029	0.560	37.9
1	27.3	0.394	-0.00028	0.930	15.3
2	20.8	0.390	-0.00027	0.967	10.6

Table 2: Vipulanandan Rheological model parameters and resistivity for the acrylamide polymer modified cement with UH Biosurfactant

UH bio (%)	Resistivity (Ωm)	A	D	τ_0 (Pa)	R^2	RMSE	τ_{max} (Pa)
0	1.25	0.063	0.0066	5.97	0.962	11.2	156.4
1	0.96	0.656	0.0061	8.36	0.995	3.9	171.9
2	0.80	0.937	0.0057	7.91	0.994	4.7	181.8

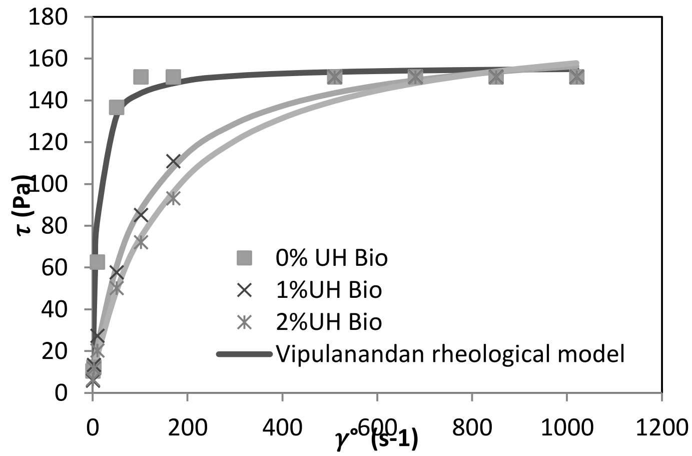

Figure 2: Experimental results and Vipulanandan model predictions

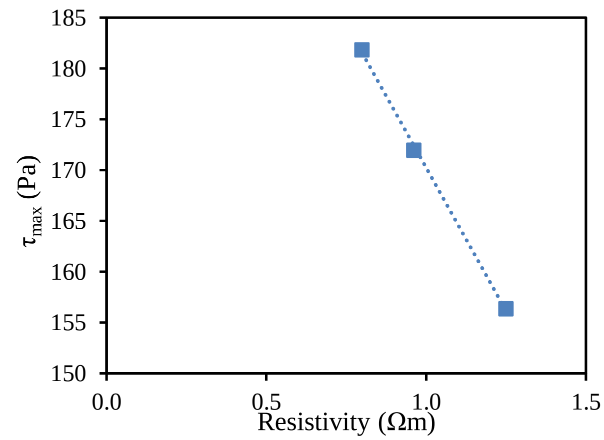

Figure 3: Correlation of electrical resistivity with τ_{max}

τ_{max} was correlated linearly ($\tau_{max} = -56.323\ \rho + 226.58$) with initial electrical resistivity of cement paste with a correlation coefficient of 0.999.

4. Conclusions

The investigation of rheology of polymer modified cement with UH Biosurfactant shows the following results:

1. UH Bio surfactant improved the workability of acrylamide polymer modified cement and showed 16% increase in the max shear stress.
2. Vipulanandan rheological model correlated well compared to the other available models used in cement testing based on the Root mean square error (RMSE).
3. Initial resistivity measurement was correlated with τ_{max} by using a linear line.

5. Acknowledgment

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6. References

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