Rheology of Smart Cement as a Function of Temperature

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Abstract: In this study, smart cement rheology was tested with temperature, the temperature was increased up to 70°C. The rheological data was modeled using Bingham plastic model and compared to Vipulanandan Rheological model. Results showed that Vipulanandan rheological model better predicted the behavior of smart cement under high Temperatures and high shear rates.

1. Introduction: With the current Challenging HPHT conditions and especially unconventional wells, cement mixing and design is of utmost importance in order to ensure the integrity of the cement for the life of the well. This is especially critical in deviated and horizontal wells (Murtaza et. al. 2019). With Vipulanandan's Smart Sensing Cement, cement performance could be monitored during placement and as long as the well remains in service. Rheological properties should be predicted properly as overestimation or underestimation could be critical especially in high-temperature and high-pressure operations (Sutton et. al 1990). The effect of pressure was proved to not effect the rheological properties of cement by (Sutton et. al. 1990). Therefore, in this study the rheological behavior of Smart Cement with no additives was modeled in order predicted the behavior with increasing temperatures and shear rates.

2. Objective: The specific objectives of this study are the follows:

a) Test the rheological behavior of Smart Cement under high temperature.
b) Compare Bingham Plastic model and Vipulanandan rheological model.

3. Materials and Method:

Class H cement 0.38 water to cement ration (w/c) using (350 g) cement and (132 mL) of water and conductive fillers. Commercially available viscometer with a heated cup was used to perform the tests and heat up the samples to the desired temperatures. Viscometer was calibrated before the testing using 100 cp viscosity calibration fluid. Testing was done in accordance with API-RB10 testing standards and procedures by dispersing conductive fillers in dry cement and then pouring into the API blender cup containing the mix water while spinning under 4000 rpms within 15 s then mixed at 12000 rpm with constant speed mixer for 35 s. The samples then were mixed and conditioned to the desired testing temperature for a total of 30 minutes.

4. Results and Discussion: Smart cement shear stress curves increases with increasing temperatures. This is evident from the trends observed in Fig 1. Bingham plastic model was compared to Vipulanandan model in Table 1 and Table 2 with the hyperbolic showing low RMSE values at higher shear rates..

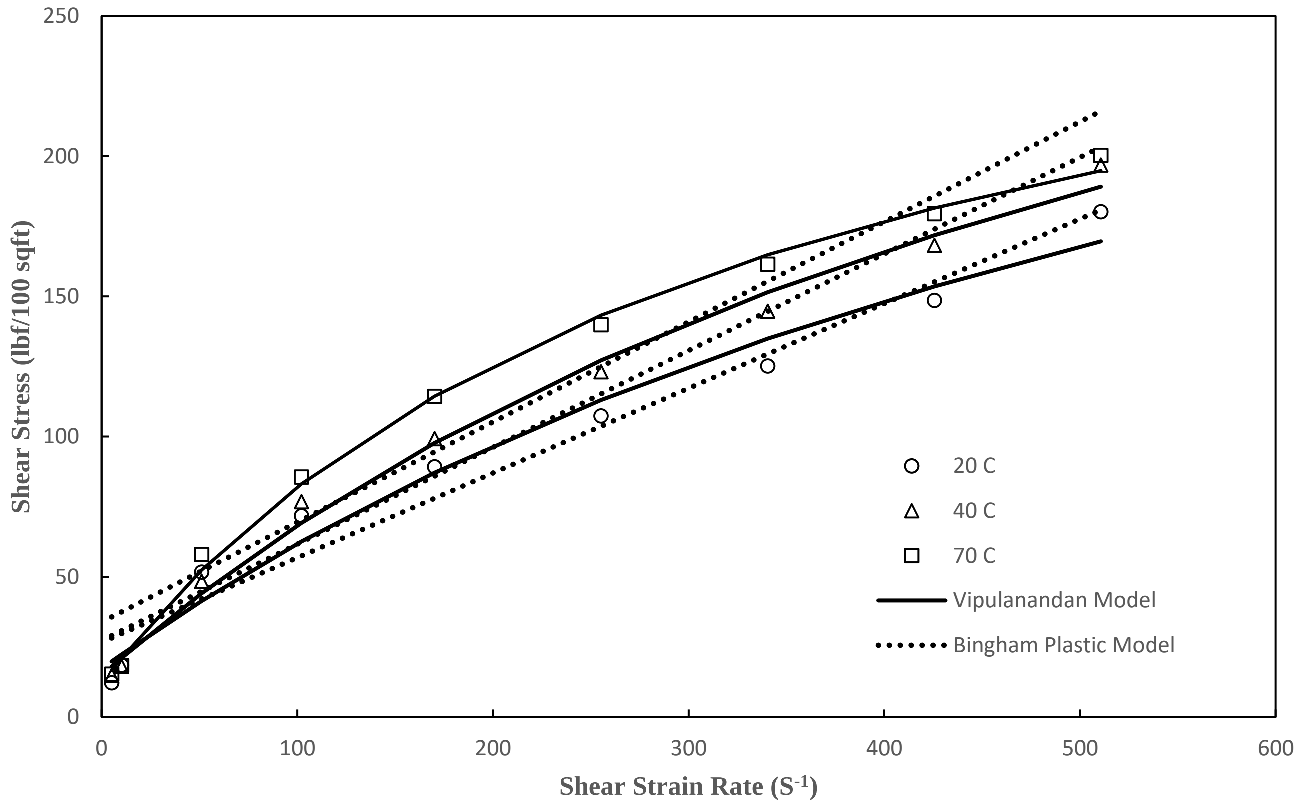

Figure 1. Rheological Behavior of Smart Cement under Varying Temperatures

Table 1. Bingham Plastic Model Parameters

Test Sample	K	n	R^2	RMSE(lbf/100sq.ft)
20 C	26.6	0.302	0.966	9.86
40 C	27.2	0.345	0.973	9.99
70 C	33.9	0.357	0.946	14.88

Table 2. Vipulanandan Rheological Model Parameters

Test Sample	τ_0	A	B	τ_{max}(lbf/100sq.ft)	R^2	RMSE(lbf/100sq.ft)
20 C	17.28	1.978	0.00269	389.01	0.980	7.67
40 C	14.90	1.616	0.00258	403.16	0.993	5.08
70 C	12.07	1.096	0.00333	312.76	0.997	3.37

5. Conclusion:

1. Smart Cement showed shear thinning behavior and shear stress increased with increasing temperature.
2. Vipulanandan model provides both shear stress at shear rate equal to zero and a maximum value of shear stress at infinite shear rates.
3. Vipulanandan model gave lower RMSE and higher R^2 numbers if compared Bingham plastic model.
4. Vipulanandan model better predicted initial shear stress values at lower shear rate values (3 rpm) than Bingham plastic model.

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