Prediction of Smart Cement Rheological Behavior Modified with Latex Polymer Additive using Vipulanandan Model

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Abstract: In this study, smart cement rheology was tested using oilfield viscometer. The rheological data was modeled using both Bingham Plastic and Vipulanandan Hyperbolic models. Results showed that Vipulanadan's rheological model better predicted the behavior of smart cement modified with latex polymer under high shear rates.

1. Introduction: Cement mixing and design is very critical for the cement performance. This is due to the time dependency of the cement properties which would make the repeatability of tests especially rheology difficult. In order to ensure both the reliability and repeatability of cement rheology testing, a new method for quality assurance and quality control for cement mixing and rheological testing is presented with resistivity added as a new parameter. This could be a valuable parameter to the API procedures as currently API only considers one or a few points of time during the setting process and resistivity is a material property (Vipulanandan 2015). Also, in this study, rheological properties of smart cement modified with latex polymer is investigated and modeled using Vipulanandan's Rheological model. Latex polymers are often used in oil well cementing to prevent gas migration and increase the fluidity as well as improve the workability and durability of the cement. The reported shear rate readings are the average of the hysteresis loop which shows a trend of decreasing shear rate with the addition of more polymers.

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

c) Test the rheological behavior of smart cement modified with up to 5% latex polymer.
d) Present a new method for cement mixing quality control using resistivity.
e) Compare Bingham plastic rheological model to 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. Latex polymer additive added as (1%, 2%, 3%, 5% BWOC) (Carboxylated styrene butadiene latex XSBR). The tests were done under ambient temperature and atmospheric conditions. The machine was calibrated before the testing using 100 cp viscosity calibration fluid. Testing was done in accordance with API-RB10 testing standards and procedures by mixing the polymer with water first then cement with 0.1% conductive filler dispersed inside was poured into the blender while spinning within 15 s. Density and weight measurements of the samples were made after 35 s of mixing. Then mixing for 30 minutes is resumed before the rheology test begins. As for the resistivity measurements, a conductivity probe was used to measure the conductivity of the slurry which was then converted to resistivity.

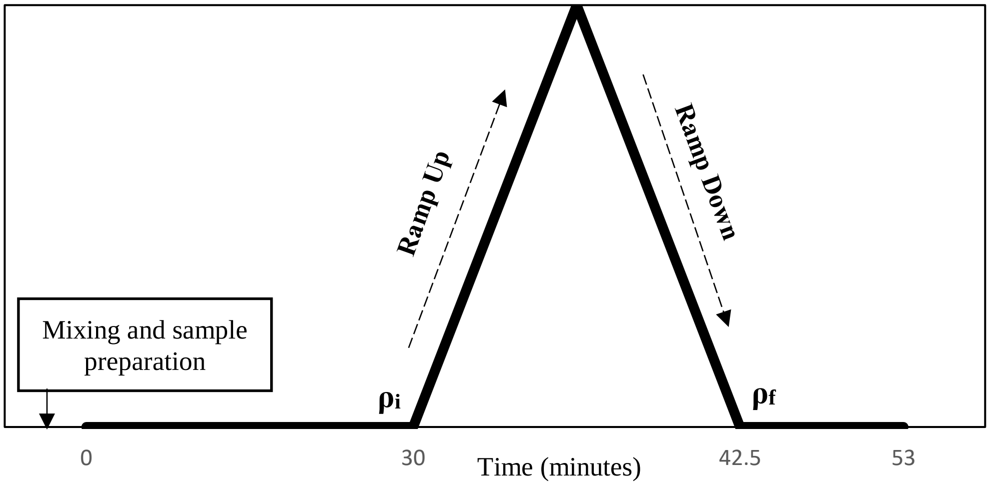

Figure 1. Rheological Test Design of Smart Cement and Hysteresis Loop

4. Results and Discussion: Smart cement modified with polymer showed shear thickening behavior and with the introduction of higher percentages of latex polymer, the density of the samples decresed along with the precence of foaming which becomes more apparent at higher polymer content. It was also observed that the initial resistivity $\boldsymbol{\rho_i}$,which was recorded after 30 minutes of mixing and right before the test, increased with increasing percentage of latex polymer. Similar fashion was observed with the final resistivity $\boldsymbol{\rho_f}$ taken at the end of the test with the resisitivity decreasing from initial to final. Results are summarized in **Table 1** and rheological properties are shown in **Table 2** and **Fig 2**.

Table 1. Summary of Density and Resistivity of Cement Slurry

BWOC	Density		Resistivity	
	ppg	g/cm3	ρ_i	ρ_f
0%	16.4	1.96	1.0	0.959
1%	15.8	1.89	1.01	0.965
2%	15	1.79	1.04	0.974
3%	14.1	1.69	1.10	0.983
5%	12.43	1.49	1.23	1.04

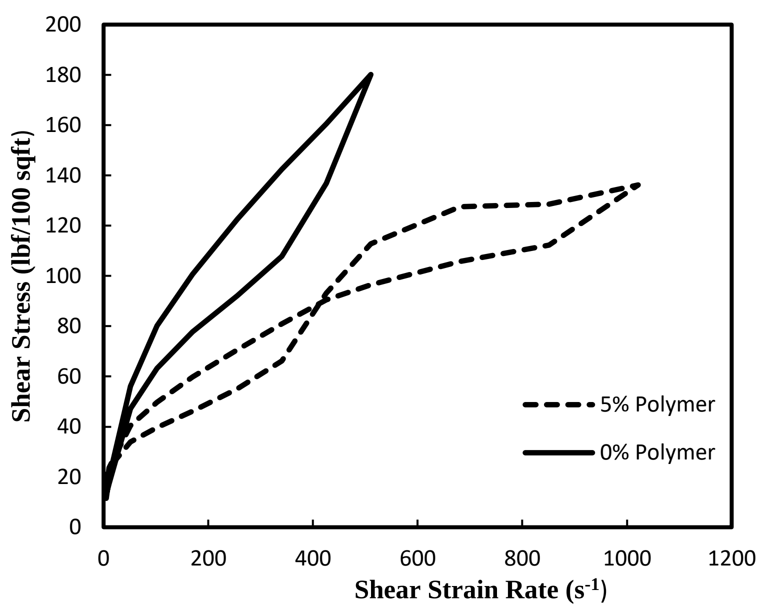

Figure 2. Thixotropic and antithixotropic behavior

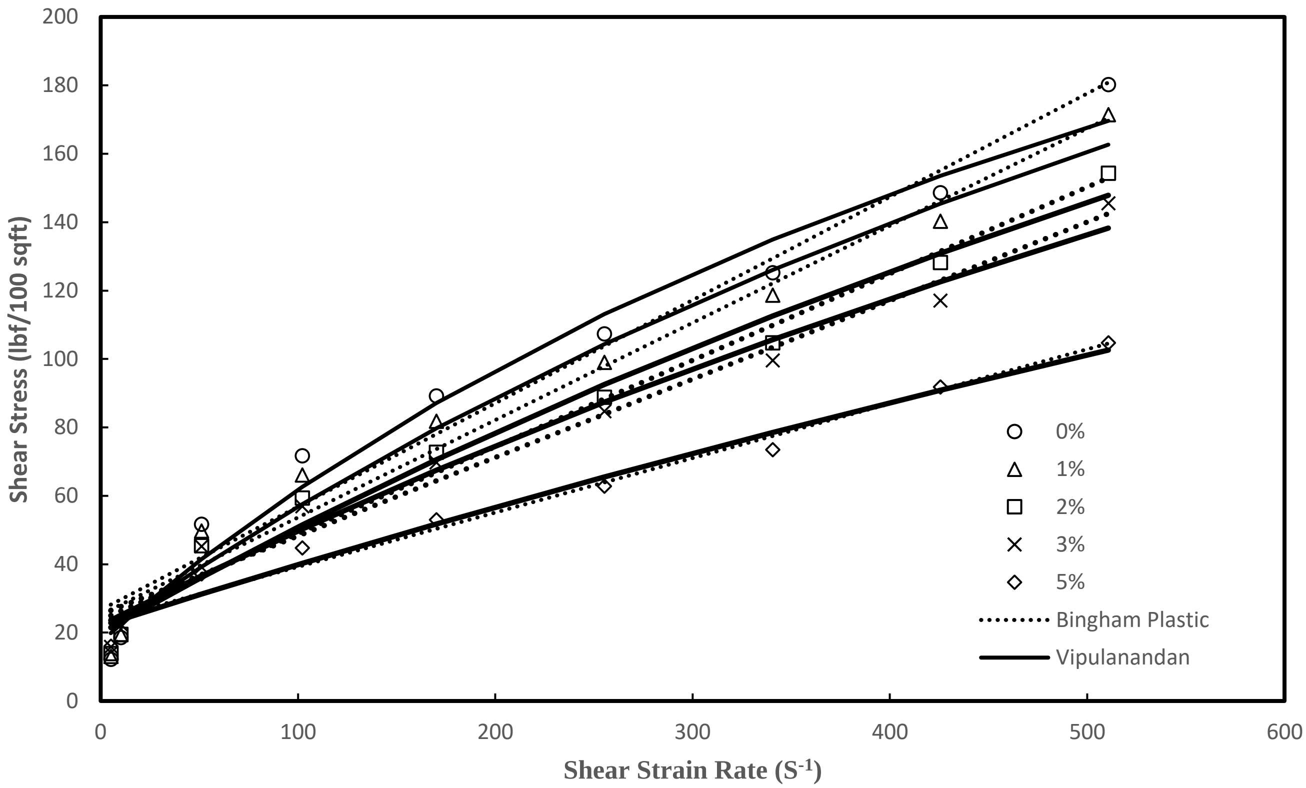

Figure 3. Rheological Behavior of Polymer modified Smart Cement at 300 RPM

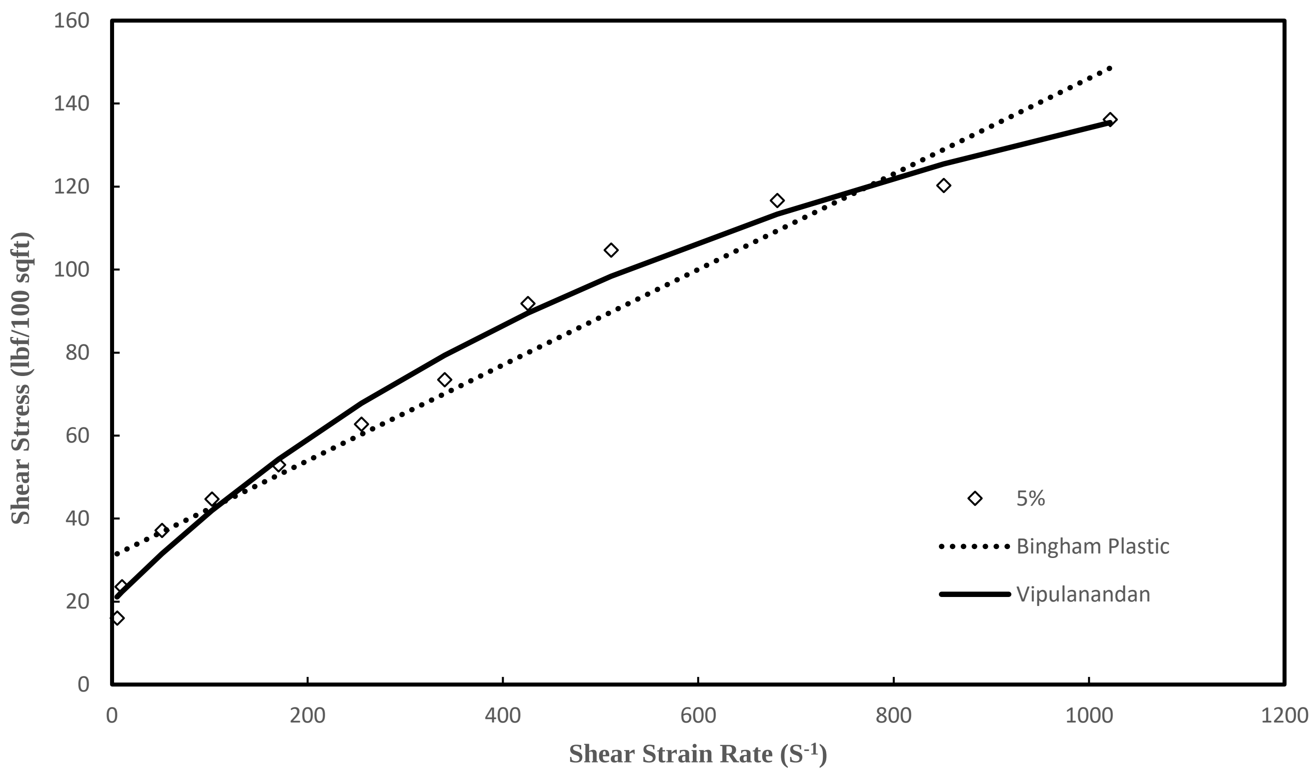

Figure 4. Rheological Behavior of Polymer modified Smart Cement at 600 RPM

Table 1 Rheological Model Parameters

BWOC	Bingham Plastic Model				Vipulanandan Model					
	K	n	R^2	RMSE (lbf/100sq.ft)	τ_0 (lbf/100sq.ft)	A	B	τ_{max} (lbf/100sq .ft)	R^2	RMSE (lbf/100sq.ft)
0%	26.63	0.302	0.966	9.86	17.28	1.98	0.00269	389.01	0.980	7.67
1%	25.28	0.284	0.973	8.29	19.15	2.44	0.00219	474.82	0.980	7.13
2%	23.70	0.253	0.977	6.79	19.84	3.04	0.00186	556.04	0.980	6.21
3%	25.28	0.230	0.976	6.34	22.11	3.43	0.00189	550.44	0.979	5.93
5%	23.30	0.159	0.979	4.11	21.8	5.38	0.00185	563.23	0.980	3.97

5. Conclusion:

5. Smart Cement modified with latex polymer showed favorable rheology when percentage of polymer increased (lower rheology) meaning the cement is more pumpable.
6. Density and specific gravity of samples decreased with increased percentage of polymers
7. Initial resistivity after 30 minutes increases with increasing polymer loading.
8. Final resistivity after the end of the test is lower than initial resistivity for each test sample.
9. Addition of 5% polymer increased the initial resistivity by 23%.
10. Vipulanandan model can predict both shear at zero shear rate and shear at infinite shear rate with both τ_0 and τ_{max} increase with polymer content.
11. Vipulanandan is better at predicting shear stress at high shear rates than Bingham Plastic model and as this is evident from root mean square error RMSE.

6. Acknowledgements: The study was supported by the CIGMAT (Center for innovative grouting materials and Technology) and Texas Hurricane Center for Innovative Technology (THC-IT) and support from industry.

7. References:

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