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O. F. JOEL AND A. A. UJILE

PERFORMANCE EVALUATION OF SPACER FORMULATION FOR EFFICIENT MUD REMOVAL AND IMPROVED CEMENT BOND

By

*O. F. JOEL, **A. A. UJILE
*Department of Petroleum and Gas Engineering,
Faculty of Engineering, University of Port Harcourt, Nigeria
**Department of Chemical/Petrochemical Engineering,
Rivers State University of Science and Technology, Port Harcourt

ABSTRACT

This work details the performance evaluation of different spacer formulations and determination of their compatibility tendencies with mud and cement for efficient mud removal and improved cement bond.

Compatibility tests of mud and cement recipes at different ratios and temperatures were carried out with spacer formulation.

The rheological properties and the shear-stress and shear- rate behaviour of the mixtures at different temperatures were determined. In all the tests performed with mud/cement mixtures, incompatibility phenomenon was evident as indicated by higher rheological values of the mixtures.

However, in the tests with spacer/mud, spacer/cement mixtures, the incompatibility was less pronounced.

Therefore, to avoid incompatibility and make for efficient mud removal and improved cement bond, the choice of spacer formulation as well as ensuring that spacers are pumped ahead of cement is imperative.

Keywords: compatibility, spacer, mud, cement, emulsion, rheology

INTRODUCTION

The problem of obtaining a good cementing job is one of displacing substantially all of the drilling fluid in the annulus with the cement composition. Unfortunately, many of the drilling fluids employed are not compatible with oil well cements so that when the cementing composition comes into contact with the drilling fluids the mixture of cement and drilling fluid may flocculate or gel to form a material of complex chemical composition which is extremely viscous such that it becomes substantially unpumpable with conventional pumps and thereby prevents pumping of all the cement out of the interior of the casing and into the annulus[1].This can result in plugging of the interior of the well casing or, at the very least, channelling of the cement in the annulus so that the cement does not form a continuous phase completely around the annulus. Also, this gel can plug the annulus causing a build up of pressure by the cement composition behind it to a degree sufficient to fracture the formation and pump cement into the formation. If the mud is not properly displaced, channels and or pockets of mud may be left in the cemented annulus, which can lead to inter-zonal communication and corroded casing.

Assuming adequate bulk displacement has taken place, bonding of the cement to the pipe can be less than desirable should the said surfaces not be conducive to cement bonding. Coatings from mud additives (polymers, corrosion inhibitors, etc) and non-aqueous mud systems can interfere with the bonding between the cement sheath and the pipe surface. Such poor bonding is typically reported as a micro-annulus as viewed by a cement evaluation log and is often blamed for poor zonal isolation. The ultimate consequence is substantial economic and drilling efficiency loss. In order to alleviate the problems which occur when well cement is allowed to contact or otherwise admix with drilling mud, of either the water base or oil base variety, spacer compositions have been used. Basically, the function of the spacer composition is to insulate, and act as a barrier between, the drilling mud present in the borehole and the cement composition. Thus, spacers are pumped into the borehole prior to introduction of the cement composition but after the drilling mud being employed. The requirements for spacer compositions include compatibility with both drilling mud and well cement compositions.

Compatibility may be defined as the capacity of forming a fluid mixture that does not undergo undesirable reactions There should be neither sludge formation nor separation in the process.

Compatibility test of the mixture of the fluids with the spacer must be conducted to ensure there will be no incompatibility when pumped into the well bore.

One of the aspects of ensuring an annular seal during a cementing operation after achieving bulk displacement of the drilling mud is bonding of the cement to the formation and wellbore surfaces. The most important factor in obtaining a good primary cement job is properly displacing the drilling fluid[2,3].

Spacers and flushes are effective displacement aids because they separate unlike fluid such as cement and drilling fluid, and enhance the removal of gelled mud allowing a better cement bond [4,5]

Special formulations are designed to provide better mud displacement resulting in improved cement bond logs and zone isolation, lost-circulation control effects; faster slurry gelation after the slurry is in place, and fluid loss control[6,7,8].

A basic understanding of emulsions as they relate to drilling mud and spacers is fundamental to understanding the processes that occur when designing a surfactant package for a cementing spacer used to displace a non-aqueous mud.[10] Synthetic, mineral, and oil-based drilling muds are oleaginous or oil-external fluids.

These fluids consist of oil or synthetic continuous phase and an internal aqueous phase usually containing $CaCl_2$ up to saturation.

The emulsification process of oil phase and water phase is shown on figure 1 below.[8,9]

The objective of this project was to evaluate the compatibility of the spacer with mud and cement mixtures for improved cement bond.

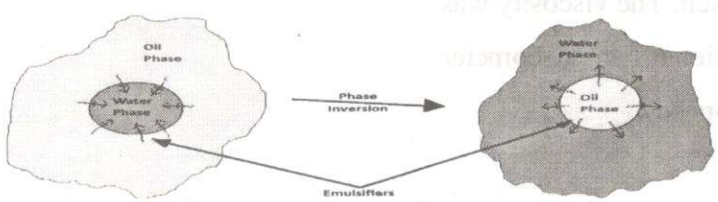

Fig.1: Emulsification process between oil/water phases at phase inversion and introduction of emulsifier[8]

FLUIDS COMPOSITION AND WEIGHT

a. The mud was oil-base, with specific gravity of 1.60 .

b. The spacer blend was made up of fresh water, barite and surfactant, with specific gravity of 1.75

c. Cement slurry was made of fresh water, cement, fluid loss additive and retarder with specific gravity of 1.90

RESEARCH METHODOLOGY

The spacer was mixed with the mud and cement recipes at different ratios and temperatures (table 1, figures 2-5) to determine their rheological properties.

The mixtures were conditioned for 20 minutes in an atmospheric consistometer at test temperature before rheological measurements were taken. The viscosity was measured using a rotational Fan Viscometer (115 Volts / 50 Hz, 6 Speed).

The test fluid was contained in the annular space or shear gap between the cylinders.

The outer cylinder was rotated through precision gearing at known velocities. The viscous drag exerted by the fluid created torque on the inner cylinder or bob. When the torque was transmitted to a precision spring, the spring's deflection was measured and then related to the test conditions.

Readings were taken at 300, 200, 100, 6 and 3 rpm respectively and recorded in Centipoises (cP) [10,11,12,13].

RESULTS

Table 1 and figures below present rheological values for the different mixtures of mud/spacer, Mud/cement and cement/spacer respectively for compatibility evaluation conducted.

TABLE 1: RHEOLOGIES FOR SPACER AND MUD MIXTURE AT 113^{O}F

MUD Vol(%)	SPACER Vol(%)	TEMP (^{O}F)	300rpm (cp)	200rpm (cp)	100rpm (cp)	6rpm (cp)	3rpm (cp)	PV (cp)	YP (lbf/100(ft^2)
100	0	113	27	22	16	5	4	16	11
90	10	113	22	18	14	5	4	12	10
75	25	113	16	13	9	3	3	11	5
50	50	113	9	8	5	2	2	6	3
25	75	113	4	3	2	1	1	3	1
10	90	113	3	2	2	1	1	2	1
0	100	113	2	2	2	2	2	0	0

The results obtained for spacer and cement slurry at temperature of 113 ^{O}F is shown in figure 2 below.

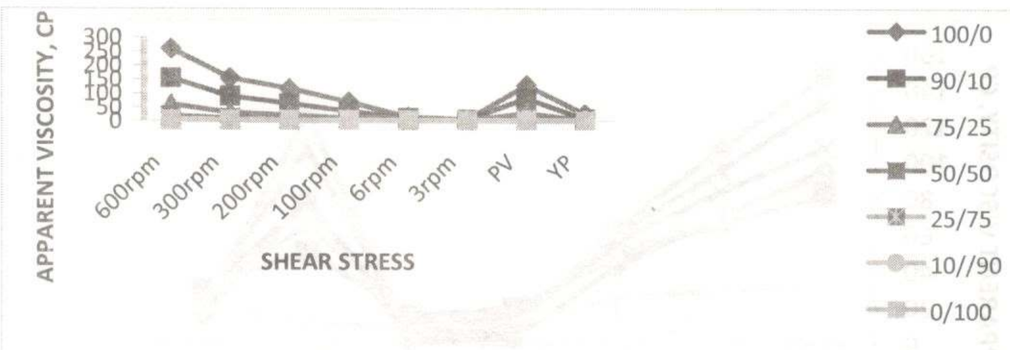

Fig. 2: Rheologies for spacer and cement mixture at 113^{o}F

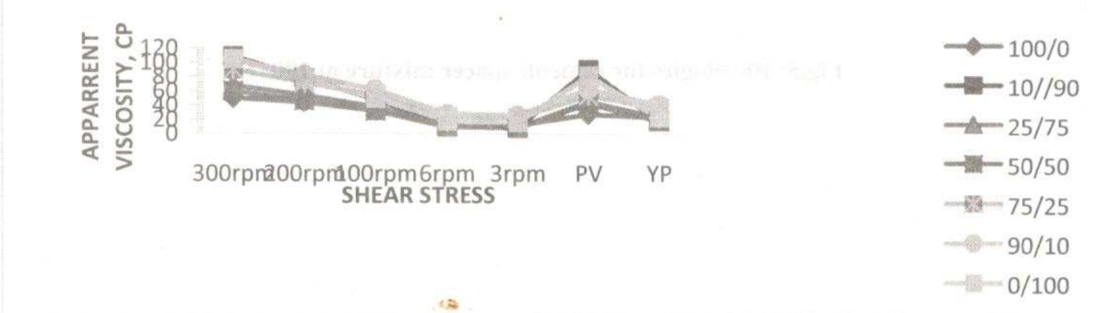

Fig.3: Rheologies for spacer/mud mixtures at 190 ^{o}F

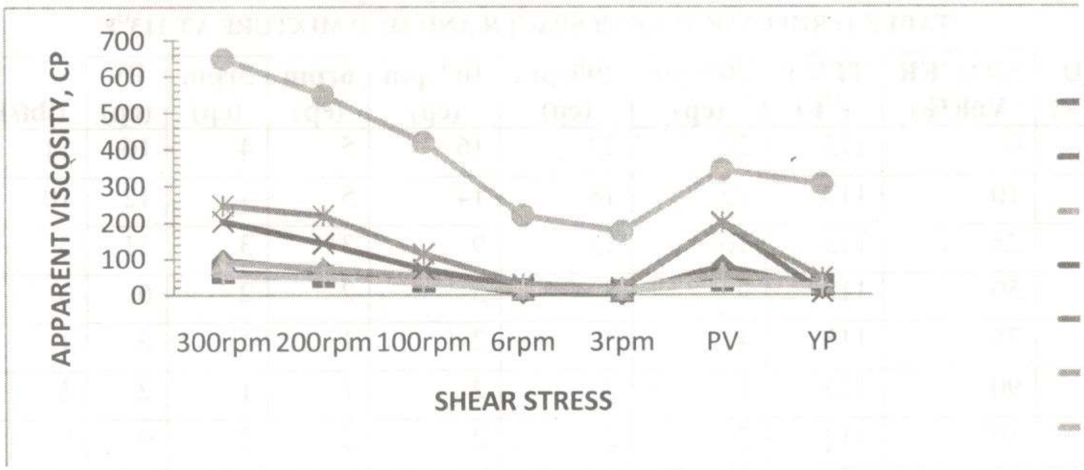

Fig. 4: Rheologies for cement/mud mixtures at 190 °F

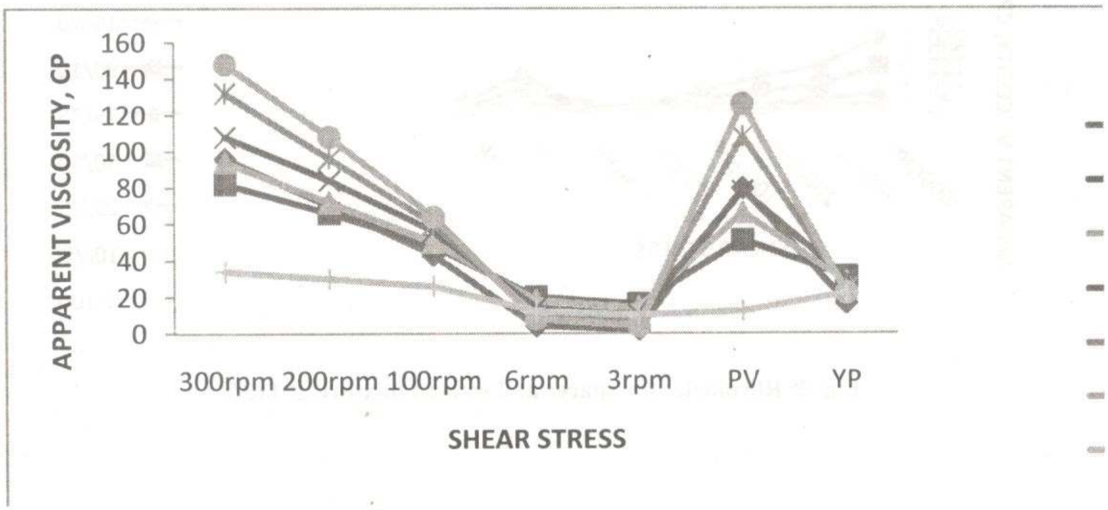

Fig.5: Rheologies for cement/ spacer mixture at 190 °F

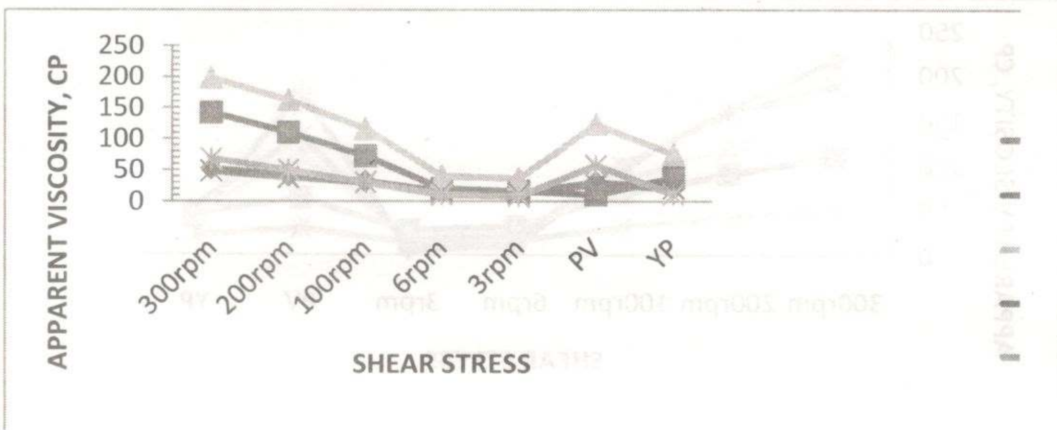

Fig. 6: Rheologies for spacer/mud mixtures at 150 °F

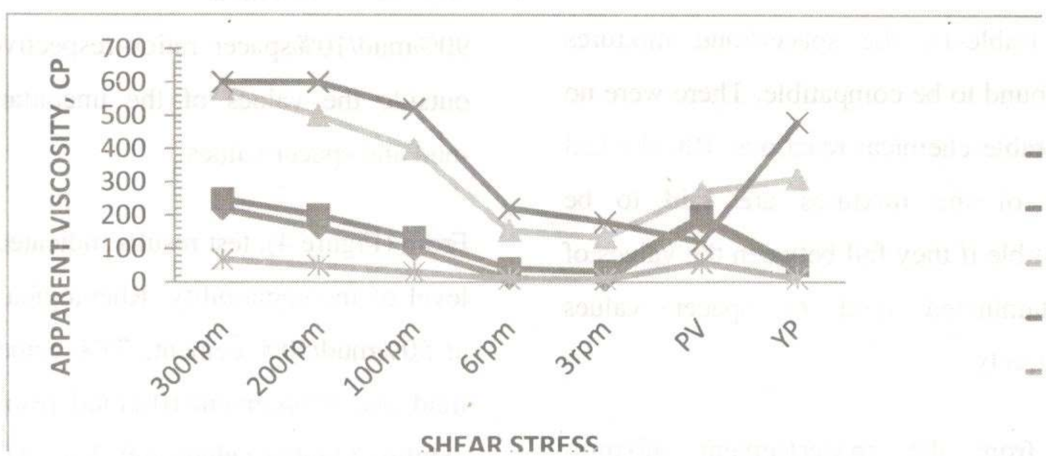

Fig. 7: Rheologies for cement/mud mixtures at 150 °F

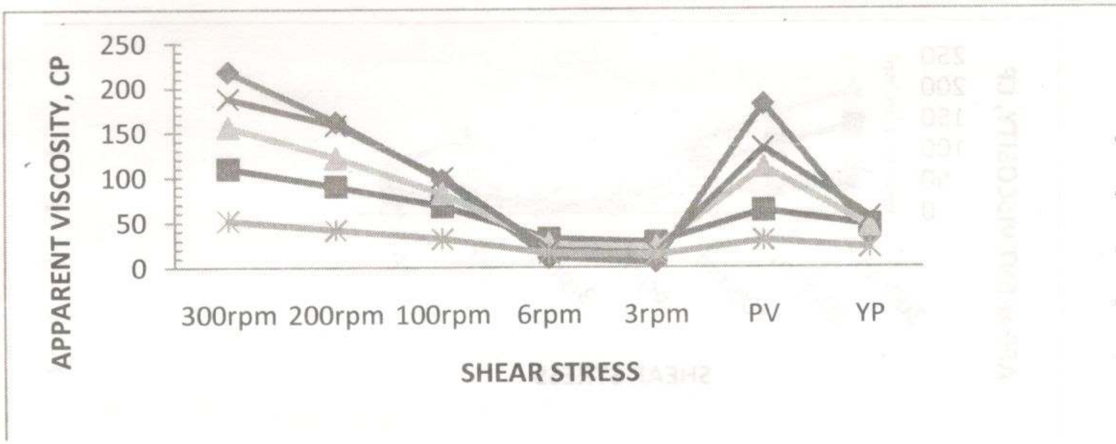

Fig. 8: Rheologies for cement/spacer mixtures at 150 °F

DISCUSSION

From (table-1), the spacer/mud mixtures were found to be compatible. There were no undesirable chemical reactions. Rheological values of the mixtures are said to be compatible if they fall between the values of uncontaminated mud or spacer values respectively.

Also from the spacer/cement mixtures (figure 2), the rheological values indicated that there was no incompatibility problem.

The rheological values fall between the values for the cement and spacer respectively at the 113 °F temperature.

However, (Figure-3) is test result for spacer /mud mixtures at 190 °F. Though there was no separation and undesirable reaction observed, the rheological values at 90%spacer/10%mud and 90%mud/10%spacer ratios respectively fall outside the values of the uncontaminated mud and spacer values.

From (Figure 4), test results indicated a high level of incompatibility. Rheological values at 50%mud/50% cement, 75% cement/25% mud and 90%cement/10%mud respectively exhibited higher values and sharp deviations outside the uncontaminated mud and cement values.

This underscores the need to ensure that spacers are used between the muds and cement interface to avoid this undesirable reactions and incompatibility problem.

The spike in rheological values in the mud/cement mixture (Figure 4) was not evident in the results obtained for cement/spacer mixture (Figure 5). (Figure-6) indicated results with spacer tested at 150°F with the various mixtures as indicated. Abnormal spikes of rheological values at 25% spacer/75%mud and 50%mud//50% spacer was evident. This was also noticed with results of cement/mud mixtures (Figure 7). This tendency will create mud displacement problem and make for poor cement bond. (Figure 8) results with cement/spacer mixtures had no incompatibility problems, though there were little differences in some of the rheological values with some of the mixture ratios. The results obtained have shown that temperature affect the behaviour of the rheological properties in spacer/mud, spacer/cement and cement/mud slurries.

CONCLUSSION

The mixtures are said to be compatible if there is no undesirable reaction and the rheological values of the mixtures fall between the rheological values of uncontaminated mud, spacer and cement values respectively.

In all the tests where we had mud/cement interface, incompatibility phenomenon was evident as indicated by higher rheological value of the mixtures. However, where we had, spacer/mud, spacer/cement mixtures, the incompatibility was less pronounced.

The results obtained from the evaluation have shown that understanding the total wellbore fluid rheologies not only helps improve the standard cement job, but can also be applied to efficiently recover expensive drilling fluid or a combination of both.

Therefore, for efficient mud removal and better cement bond, the choice of spacer formulation as well as ensuring that spacers are pumped ahead of cement is imperative.

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