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OPTIMIZING WELLBORE INTEGRITY: XANTHAN GUM CONTRIBUTION TO CEMENT SLURRY PERFORMANCE

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ABSTRACT

Oil well cementing is considered one of most important operations to improve the wellbore integrity in term of blowouts, well failures and environmental disasters. Various additives have been used to improve the API properties of cement slurry to enhance the effectiveness and success of cementing operations. The aim of the study is to use Xanthan gum as a viscosifying agent in cement slurry to improve the properties of cement slurry. This work demonstrated laboratory experiment, in which rheology, thinking time and compressive strength of cement specimen were determined using Xanthan gum with other additives. The improvement in plastic viscosity, yield point and gel strength using different concentrations reveals that Xanthan gum acts as a rheology enhancer in cement slurry. Furthermore, the addition of Xanthan gum with other additives increases the thickening time of slurry and makes it pumpable at surface conditions. The compressive strength of cement specimen was 724 Psi after one day of curing. The compressive strength of the xanthan-gum based cement specimen further increased to 856 psi after 3 days of curing and to 1032psi after 7 days of curing. In is concluded that xanthan gum improves the API properties of cement slurry in terms of rheology and thickening time while provide sufficient strength that could reduce the risk of cementing operation failure.

Keywords: Xanthan, Cement Slurry, Rheology, Compressive Strength, Additives.

I. INTRODUCTION

The petroleum industry continues to explore innovative applications of polymers to improve various processes. Among various polymers, polysaccharides and their derivatives have received widespread attention in various fields of the petroleum industry due to their versatility and practicality[1]. These natural polymers, including xanthan gum, guar gum, and cellulose ethers, play key roles as film formers, thickeners, and viscosifiers in petroleum applications[2]. Xanthan gum is a water-soluble polysaccharide with several properties that make it ideal for a variety of industrial applications. It can be used as a thickener, film former, water retaining agent, suspension aid, surfactant, and gel strength agent, making it invaluable in the petroleum industry[3,4]. Its stability at high temperatures and its ability to increase viscosity at gelling temperatures make it particularly effective for cementing operations. Additionally, xanthan gum's multifunctional properties make it widely used in various industries including food, pharmaceuticals, and construction[5]. This multifunctional substance has a basic chemical structure consisting of glucose, mannose, and glucuronic acid units that are linked together in a complex manner to form a linear backbone[6,7]. Furthermore, selected glucose units in this structure were modified, leading to the formation of characteristic side chains.

One of the key applications of xanthan gum in the petroleum sector is its incorporation into oil well cementing processes[8,9]. Cement plays a central role in drilling operations, providing zone isolation, protection, and support for the casing string, and providing structural strength to the wellhead unit. In the production of well cement, cement is mixed with water and a variety of additives, including dispersants, accelerators, retarders, defoaming agents, fluid loss agents, and leak-stopping agents[10]. Each of these additives gives the grout specific properties and makes it suitable for the intended application. This paper focuses on the application of xanthan gum in cement slurries and evaluates its impact on cement slurry properties according to the American Petroleum Institute (API). Xanthan gum acts as an important rheology modifier in cement slurries [4]. Not only does xanthan gum improve rheology, but other additives can be added to increase stability, thickening time, and provide mechanical strength.

II. METHODOLOGY

Class G oil well cement was used as base material with a specific gravity of 3.14. SiO_2, AL_2O_3, Fe_2O_3, TiO_2, K_2O, P_2O_5, CaO, MgO and SO_3 were the major components of class G cement. Defoamers, dispersants, accelerator, silica fume and Xanthan Gum were used in this study. API recommended practice 10-B2 was used to prepare the cement slurry. Cement slurries were prepared by mixing Class G cement, xanthan, and. High speed mixing equipment was utilized to prepare the mixture of cement slurry. Measured quantity of water was added in mixture, the additives and cement were pound in the mixture. Initially, the speed of mixture kept low and after 20 seconds the speed rose to 12000rmp to homogenize the materials and prepare cement slurry The formulation of designed cement slurries is provided in Table 1.

Table 1: Formulation of Cement Slurries

Slurry No	Defoamer Gps	Dispersant gps	Accelerator gps	Xanthan gps	Silica Flour gps
01	0.02	0.20	0.04	-	0.15
02	0.02	0.20	0.04	0.20	0.15
03	0.02	0.20	0.04	0.40	0.15
04	0.02	0.20	0.04	0.60	0.15
05	0.02	0.20	0.04	0.80	0.15
06	0.02	-	0.04	01	0.15

The rheology of cement slurries was determined using Fann rotational viscometer. The rheology cement slurry was evaluated by changing the dial reading of viscometer. The dial reading values were used to determine plastic viscosity, yield point and gel strength at 10 seconds and 10 minutes. The thickening time of cement slurry was determined using consistometer. The aim to determine is to evaluate the slurry performance as how much time it will remain in liquid state and pumpable.

The prepared cement slurry was poured into molds measuring 2x2x2 inches, and they were allowed to rest at room temperature for a duration of 24 hours for cement specimen preparation. The cement specimen was placed and cured in a water bath for a period of 1,3 and 7days. After curing of specified time, the samples removed and tested for compressive strength measurement.

III. RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of xanthan on properties of cement slurry. The density of all cement slurries lies in between 12.5 ppg to 13.5 ppg. The API properties of all 6 cement slurries were determined by changing the concentration of xanthan from 0.2 gps to 1gps with increment of 0.2 in each slurry. the quantity of other additives remains same to observe the effect of only xanthan gum. The determined API properties of xanthan gum-based cement slurries are shown in Table 2.

Table 2: API properties of cement slurries

Slurry No	Plastic viscosity cP	Yield Point (YP) Ib/100 ft^2	Gel Strength 10 Sec Ib/100 ft^2	Gel Strength 10 min Ib/100 ft^2	Thickening Time hh:mm
01	48	20	18	21	1:15
02	58	24	22	24	1:35
03	71	28	24	26	1:57
04	78	31	27	29	2:10
05	85	35	30	32	2:24
06	98	41	32	35	2:40

Effect of Xanthan concentration on API Properties of Cement slurry: The rheological properties of cement slurries were evaluated using a Fann viscometer with readings ranging from 3 rpm to 600 rpm. Using rotational viscometer readings, the rheology of the slurry is translated into two important parameters: plastic viscosity and yield point. These rheological properties are important because they directly affect pressure drop and promote the generation of turbulence, which is critical for mud cake removal. The initial slurry, Slurry-01, without xanthan gum, had a plastic viscosity of 48 cP and a yield point of 20 lb/100 ft^2. The gel strength of slurries was also increased due to the increase in viscosity of slurry. Subsequent addition of xanthan gum results in a gradual increase in the viscosity and yield point of the plastic. Higher concentrations of xanthan gum further reinforce this trend. It is noteworthy that, slurry No. 6 reaches the peak of plastic viscosity, yield point and gel strength as shown in Figure 1 and Figure 2.The improvement in rheological properties can be attributed to the elongation of the long-chain polymer structure that occurs with increasing xanthan gum concentration[11]. This elongation leads to an increase in viscosity within the cement slurry, which promotes water untake within the cellulose groups and contributes to the observed rheological changes.

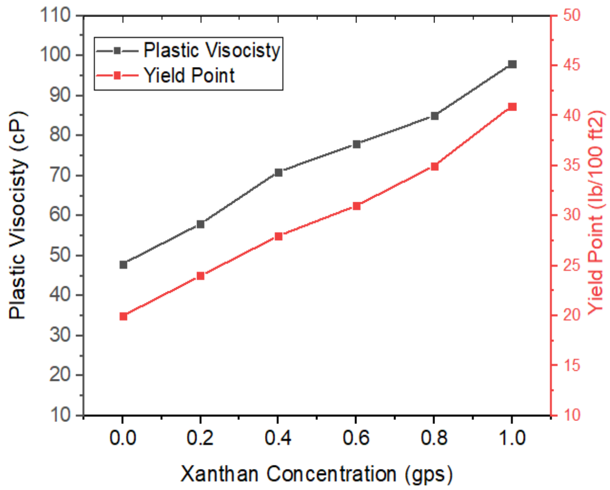

Figure 1: Plastic viscosity and yield of cement slurries

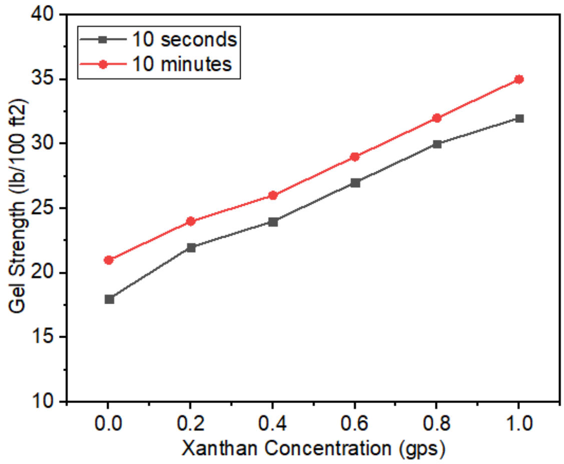

Figure 2: Gel strength (10 second and 10 minute) of cement slurries

The thickening time of cement slurries is considered a critical parameter associated with pumpability. Ensuring that thickening time is prolonged is crucial to prevent solidification of slurries during the displacement process. The API RP-10B-2 guidelines outline thickening time as the length of time required to reach 100 BC (Bearden Units). The slurry-1 without Xanthan has a thickening time of 1 hour and 15 minutes signifying the point at which it achieved 100 BC. On the other hand, Slurry-02, enriched with a 0.20 gps concentration of Xanthan, exhibited a longer thickening time of 1 hour and 35 minutes as results provided in Table 2. A comparison of Slurry-03 to Slurry-06 reveals the significant impact of xanthan polymer's retarding additive properties. The maximum thickening time of slurry was 2 hours and 24 minutes achieved by using 01gps concentration of xanthan in cement slurry. The increasing trend of thickening time is shown in Figure 3.These properties make it a valuable component in cement slurries, extending the thickening time to meet the specific requirements of well cementing operations in high-temperature and deep drilling environments.

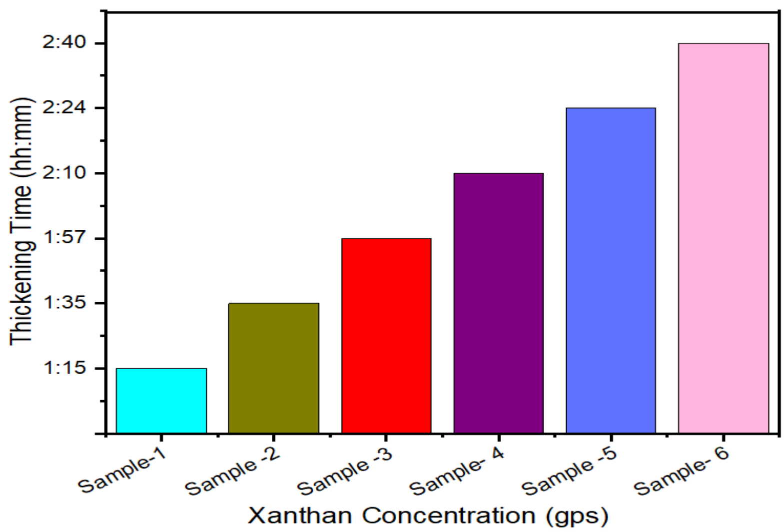

Figure 3: Thickening time profile of cement slurries

Compressive strength of cement slurries:

Compressive strength was determined to evaluate the integrity of hard cement after socking time. The compressive strength determined of three samples to observe the effect of xanthan in slurries. The compressive strength with different curing time is provided in Table 3.

Table 3: Compressive strength of cement slurries

Sample-	Xanthan Concentration (gps)	Compressive strength (psi)		
		1 day curing	3 days curing	7 days curing
1	0	815	925	1124
2	0.2	724	856	1032
3	0.50	701	815	987
4	1	654	705	837

The compressive strength of cement slurry without xanthan was 815psi after one day of curing. Subsequently, the compressive strength exhibited a progressive increase, reaching 925psi after three days of curing. The maximum compressive strength recorded for cement sample-1 was 1124spi achieved after seven days of curing. This trend underscores the positive impact of curing duration on compressive strength. Similarly, sample-2 initial compressive strength of was 724. With the passage of time and extended curing, this value increased to 856psi and 1032 with increasing curing time. It was observed that the increasing concentration of xanthan in cement decreases the compressive strength as shown in Figure 4. The decrease in compressive strength was due to the delay thickening, high water demand and increase in viscosity by addition of xanthan in cement.

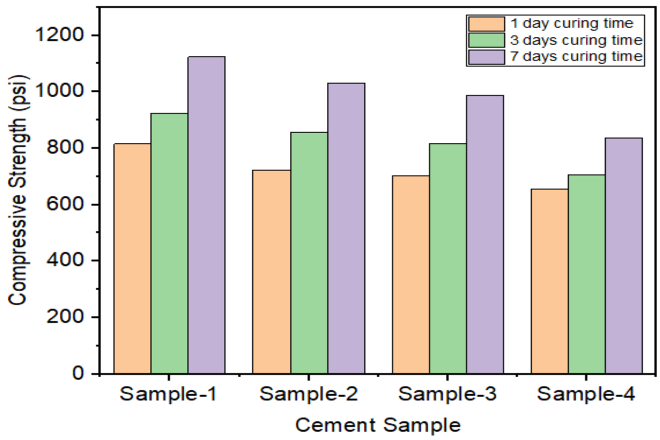

Figure 4: Compressive strength of cement samples

IV. CONCLUSION

Based on the experimental results, it is concluded that xanthan gum significantly enhances the API properties of cement slurry. Xanthan gum acts as viscosifying agent in cement slurry, thereby increasing its rheology in term of plastic viscosity, yield point and gel strength. Furthermore, the increased thickening time revealed that xanthan gum also has capability to retard the cement slurry and delays the thickening time. Additionally. It is noteworthy that the compressive strength of xanthan-based slurry exceeded 500psi, which is critical threshold for providing structural integrity to the casing. In summary, xanthan gum serves as multifunctional polymer that improves the API properties and integrity of cement slurry. Further, it is recommended to increase the concentration of silica fumes in mixture to utilize the xanthan gum in cement slurry for high temperature and high-pressure conditions.

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