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Effect of Acacia Gum Powder on the Rheological and Thixotropic Properties of Drilling Fluids

Onur Eser Kok[1]*

[1]Department of Petroleum and Natural Gas Engineering, Iskenderun Technical University, 31200, Hatay, Turkey

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Contact
*Onur Enes Kok
oeser.kok@iste.edu.tr

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Abstract
Drilling operations are an important component of energy production. For a successful drilling operation, highly efficient drilling fluid must be used. The efficiency of drilling fluid is provided by different organic and inorganic additives. In this study, the effect of acacia gum powder on the rheological and thixotropic properties of drilling fluids is investigated. The results are compared with Xanthan Gum, which is widely used in industrial applications. The experiments added acacia gum powder and xanthan gum to the spud-type drilling fluids prepared at different ratios (between 0.05-1.0 wt.%). Firstly, rheogram curves of the additive drilling muds were created and the flow profile was determined. Then, rheological properties were analyzed by apparent viscosity, plastic viscosity, and yield point analysis. Also, thixotropic properties were determined by shear thinning index and thixotropy index calculations. As a result of the analysis, it is determined that acacia gum powder can be used as an alternative additive material to xanthan gum as a rheology and thixotropy enhancer in spud-type drilling fluids.

Keywords
Acacia gum powder, drilling fluid, rheology, thixotropy, drilling

1. Introduction

Drilling operations are an important component of detecting and producing subsurface resources. Many factors contribute to a successful drilling operation, and they interact with each other. Factors such as location selection, drilling mud, formation structure, materials, and equipment affect the drilling operation's success. The accordance of these parameters is very important for successful and cost-effective drilling (Kim and Dornfeld, 2001).

Drilling fluid is a general concept; it has many sub-components. An efficient drilling fluid system must be available for an efficient drilling operation. These fluid systems vary according to reservoir type, formation structure, and drilling method (Guan et al., 2021). However, in general, it should fulfill the main tasks (carrying the cuttings to the surface, balancing the formation pressure by creating downhole hydrostatic pressure, cooling and lubricating the drill bit, suspending the cuttings in an unsuspended environment, providing torque force to the drill string, preventing corrosion, etc.). To fulfill these tasks, different types of drilling fluid systems and additives are available, and their flow properties can be regulated (Caenn and Chillingar, 1996).

Drilling fluid additives refer to organic and inorganic materials used to achieve a highly efficient drilling mud system. In general, additives are used to regulate viscosity and filtration, increase cuttings carrying capacity, and prevent leaks and bacteria. Many additives are available in industrial applications to provide these properties. However, new and high-performance additives are being investigated both industrially and experimentally for a highly efficient, stable flow characteristic, low-cost, and environmentally friendly drilling fluid system (Oseh et al., 2023; Agwu et al., 2021).
Viscosity is one of the important parameters of drilling fluid and should be checked regularly during the drilling. However, and an efficient viscosity value is aimed rather than a high viscosity value. This reduces the energy and cost of the

circulation system (Menezes et al., 2010; Villada et al., 2017). Organic additives such as polyanionic cellulose (PAC), carboxymethyl cellulose (CMC), hydroxyethyl cellulose (HEC), xanthan gum (XCD), and guar gum (GG) are widely preferred in industrial applications for viscosity regulation in drilling fluids (Khan et al., 2024).

This study aims to advance this field by proposing a novel organic viscosity enhancer, acacia gum powder (ACP) for drilling fluids. In the experiments, ACP is compared with XCD for performance testing. Different additive ratios are investigated, and the optimum rate is determined. The findings gained in this research pave the way for using ACP as a viscosifier in the drilling industry.

2. Material and Method

2.1. Acacia Gum Powder (ACP)

Acacia gum, also known as Arabic gum, is obtained from exudates of *Acacia* trees and has complex chemical forms. It is a complex polysaccharide with low acidity. It has a pale to orange-brown solid physical form and is soluble in water. It is utilized as an emulsifying, stabilizing, thickening, and suspending ingredient in dilute oil-in-water emulsion systems and is regarded as the best gum available (Akpan, 2024). Acacia gum was used as powder form in the experiments, and it was taken from Blue Chemical Co. as food grade. The chemical structure (O Kimya Limited, 2025) and physical form of ACP are given in Fig. 1.

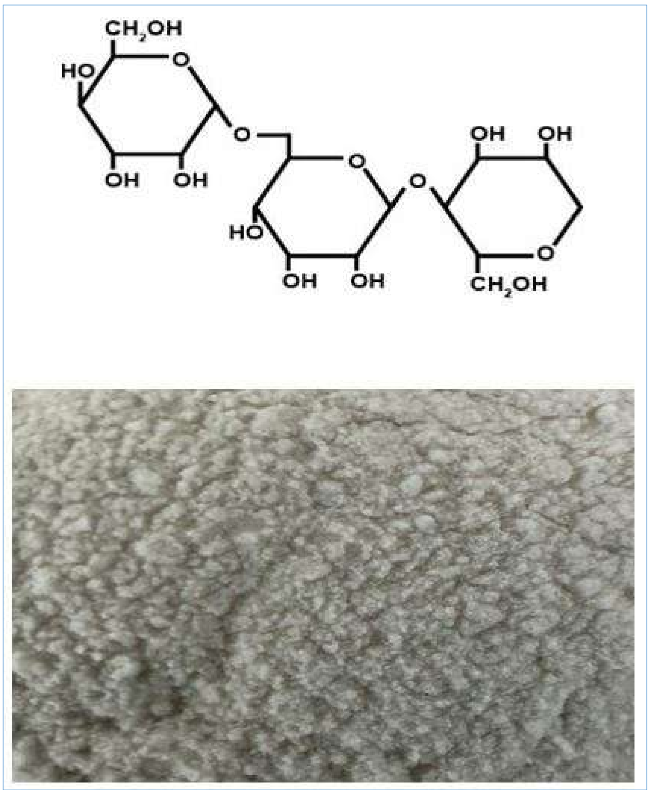

Fig. 1. Chemical structure and physical form of ACP

2.2. Drilling Fluid Preparation

The materials used in the drilling fluids prepared for the experiments were collected from different companies. Bentonite was taken from CANBENSAN Co. in Turkey as suitable for drilling (Sodium type and lower than 75 µm particle size) and used as viscosity enhancer and filtration reducer material. Barite was taken from BARIT MADEN TURK Co. in Turkey as micronized size and as weighting and fluid loss control material. Sodium hydroxide (NaOH) and sodium carbonate (Na_2CO_3) were taken from TEKKIM as technical products and used as alkalinity control materials. Drilling fluid samples were prepared with different material concentrations using a spindle mixer equipped with a high-speed sine wave impeller. The samples were 400 ml and aged 16 hours in a closed container cup. Concentrations and sample codes are given in Table 1.

Table 1. Properties of the drilling fluids

Materials and concentrations (pound per barrel, ppb)	ACP amounts (wt.%) and sample codes	XCD amounts (wt.%) and sample codes
Bentonite – 22.5 ppb Barite – 3.0 ppb NaOH – 0.2 ppb Na_2CO_3 – 0.25 ppb	0.05 – ACP1 0.15 – ACP2 0.25 – ACP3 0.35 – ACP4 0.45 – ACP5 0.75 – ACP6 1.00 – ACP7	0.05 – XCD1 0.15 – XCD2 0.25 – XCD3 0.35 – XCD4 0.45 – XCD5 0.75 – XCD6 1.00 – XCD7

2.3. Rheological Measurements

Rheological measurements were conducted with apparent viscosity (AV), plastic viscosity (PV) and yield point (YP) analysis. These were calculated from 300 and 600 rpm (ϑ_{300} and ϑ_{600}) dial readings according to *Equations 1-3* by using an OFITE Model 800 viscometer equipped with R1-B1 rotor-bob system (rotor diameter: 1.8415 cm, bob diameter: 1.7245 cm, bob length: 3.8 cm). All measurements were conducted under atmospheric pressure and room temperature.

$$AV\,(cP) = \vartheta_{600} \,/\, 2 \tag{1}$$

$$PV\,(cP) = \vartheta_{600} - \vartheta_{300} \tag{2}$$

$$YP\,(lb/100ft^2) = \vartheta_{300} - PV \tag{3}$$

2.4. Thixotropy Calculations

The thixotropic evaluation was conducted with two main indicators: the shear thinning index (STI) and the thixotropy index (TI). STI and TI were calculated from ϑ_3, ϑ_{300}, ϑ_{600min} and ϑ_{600max} dial readings using the viscometer used in rheological measurements.

$$STI = \vartheta_3 \,/\, \vartheta_{300} \tag{3}$$

$$TI = \vartheta_{600min} \,/\, \vartheta_{600max} \tag{3}$$

3. Results and Discussion

3.1. Evaluation of Rheology Results

The rheogram curves of the drilling fluids show that the shear stresses of ACP and XCD-added drilling fluids increase with increasing shear rate (Fig. 2). However, this increase is not linear, and non-linear curves represent non-newton type fluids. According to the slopes of the rheogram curves, it is seen from the graph that the slope of the shear stress decreases with increasing shear rate. This situation is defined as shear thinning behaviour and refers to the flow of clay-polymer suspensions. In addition, it was determined that these drilling fluids, which show plastic flow properties from the initial shear rate, show yield-pseudoplastic flow. This flow type shows the typical properties of drilling fluids. Thus, it was determined from the rheogram curves that the prepared drilling fluids are compatible with the general properties of drilling fluids in terms of flow properties. In addition, according to the measurement results given in the graph, the highest shear stress values (at 600 rpm shear rate) were obtained from ACP-7 and XCD-7 coded samples (1 wt.%) as 81 cP and 109 cP, respectively. This shows that the additives have a shear stress-increasing effect and improve the flow rheology.

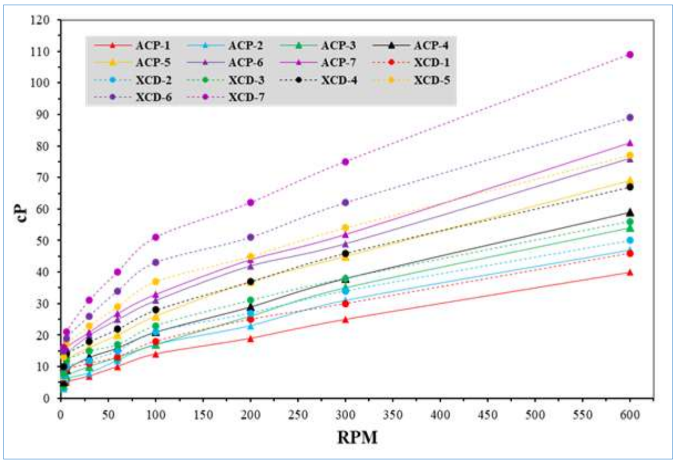

Fig. 2. Rheogram curves of the drilling fluids

Rheological results consisting of AV, PV, and YP analysis are given in Figure 3. According to the AV results, it is seen that ACP and XCD increase the AV depending on the addition rate. The highest AV values were obtained from ACP-7 and XCD-7 at 40.5 cP and 54.5 cP, respectively. Also, average AV values for all samples were calculated as 30.4 cP and 35.3 cP for ACP and XCD, respectively. Results showed that ACP improved the viscosity of drilling fluids, but XCD has more yield than ACP.

The PV results showed that XCD had a more positive effect on the PV of the drilling fluids. The highest PV values were obtained from 1 wt.% added ratios samples as 29 Cp (ACP-7) and 34 cP (XCD-7). Also, the average PV is 21.6 cP and 22.1 cP for ACP and XCD-added drilling fluids, respectively. Results showed that ACP and XCD improved the inert material (colloids or polymers, etc.) effect on the drilling fluids, but the effects are close to each other.

According to the YP results, it is seen that high YP values were obtained from the high added of ACP and XCD. The highest AV values were obtained from ACP-7 and XCD-7 as 23 lb/100ft^2 and 41 lb/100ft^2, respectively. Also, average YP values were calculated as 17.7 lb/100ft^2 and 26.3 lb/100ft^2 for ACP and XCD, respectively. Results shown that XCD has a higher effect than ACP (nearly 1.5 times) on the cutting transport and hole cleaning performance of drilling fluids.

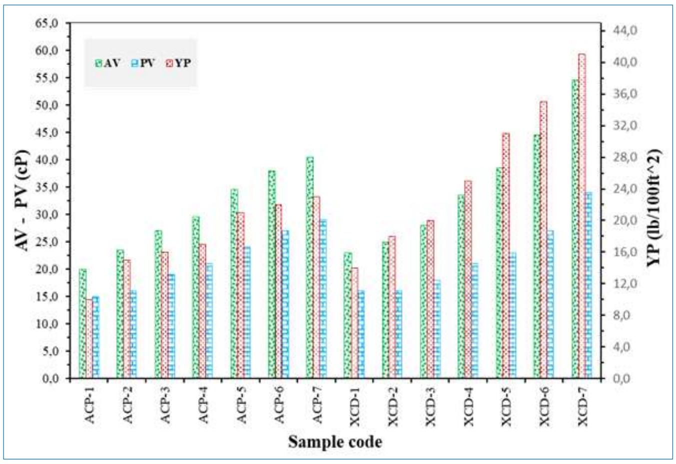

Fig. 3. Rheological results of the drilling fluids

3.2. Evaluation of Thixotropy Results

Thixotropy results, consisting of STI and TI values are given in Fig. 4. According to the results, it is shown that lower addition amounts (0.05-0.15 wt.%) have no determined positive effect on the shear thinning of the drilling fluids. STI was calculated as 0.12 and 0.097 from ACP-1 and ACP-2, respectively. In addition, 0.233 and 0.206 values were calculated from XCD-1 and XCD-2 coded samples.

However, in the other amounts (higher 0.25 wt.%), an increase is determined in STI, an increase is determined in STI, and it expresses the improvement of shear thinning of the drilling fluids.An increase in STI is associated with improving shear thinning behavior on drilling fluids in flow conditions. Thus, according to the calculations after the 0.25 wt.% addition rate, STI begun to increase, and thixotropy was improved. The highest STI values were calculated from ACP-7 and XCD-6 coded samples as 0.192 and 0.242, respectively. Also, a decrease is determined from the XCD-7 coded sample. Thus, the optimum addition rate is determined as 0.75 wt.% for XCD.

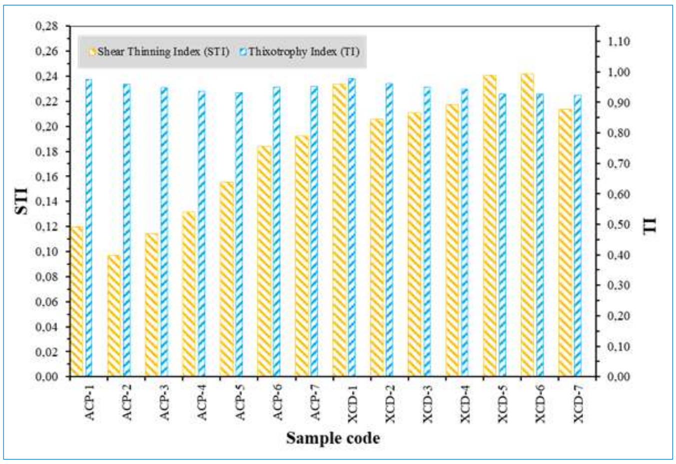

Fig. 4. Thixotropy results of the drilling fluids

TI is associated with the thixotropy properties of drilling fluids in non-circulated conditions. Decreasing in TI is expressed as improving the thixotropy of drilling fluids and the occurrence of stronger bond forces between particles. According to the results, TI values of the ACP-added samples decrease to 0.45 wt.% addition rate (ACP-5). According to the TI calculations, an increase began after the ACP-6 and ACP-7 coded samples, and this showed that a high additive amount of 0.75 wt.% has a negative effect on the thixotropy properties of ACP-added drilling fluids in non-circulated conditions. Also, it is determined that regular decrease in TI of the XCD-added samples. The lowest TI value was calculated as 0.924 from XCD-7.

In general, it is determined that ACP and XCD have a positive effect on the thixotropy of the drilling fluids, but XCD has a more frequently and high impact than ACP.

4. Conclusion

This study presents the positive effect of ACP on the rheological and thixotropic properties of drilling fluids. In this study, ACP was added to the prepared drilling fluids at different ratios, and the amounts' effects were experimentally investigated. In addition, the results obtained were compared with XCD, which is widely used in industrial applications, and a performance evaluation was performed. It is determined that the flow profile of the ACP-added samples was suitable for drilling fluids, with higher viscosity, better hole cleaning performance, and thixotropy. This demonstrates that ACP can be used in drilling fluids up to 1.0 wt.% in general on laboratory tests. In the performance comparison with XCD, it is seen that ACP has a lower positive effect to compared to than XCD. Thus, it is more suitable for surface drilling and non-complex drilling fluids. As a result of the results obtained, it is determined that ACP can be an alternative to XCD, but it has lower efficiency.

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