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Impact of Natural Polymer (Xanthan Gum) and Bentonite Clay on the Development of Oil-In-Water (O/W) Emulsion Drilling Fluids

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Abstract*: Drilling fluid plays the same role in oil and gas well drilling as the blood in human body. A new type of oil-in-water (o/w) emulsion drilling fluid has been developed using diesel oil as dispersed phase, brine water as continuous phase, xanthan gum as viscosity modifier and clay as emulsion stabilizer and filtration controlling agent. Initially, standard recommended techniques were opted to detect the rheological properties of the emulsions. The fluids have also shown stable properties upto 70°C after aging for 24 h. As drilling fluids encounter a lot of variation in temperature and pressure as drilling depth increases, hence the stability of such fluids becomes an imperative parameter. Furthermore, emulsion itself is a heterogeneous fragile system so the stability was investigated using shear stress-shear rate rheology measurements. Emulsions have shown strong shear-thinning (pseudoplastic) behaviour which is considered an advantageous property for the drilling fluids. Experiments conducted to determine the dynamic rheology of the emulsions have shown the elastic behaviour towards emulsion breakdown processes. The fluids have also shown physical stability after 30 days at ambient conditions. Inter-facial variables such as zaeta potential, inter-racial tension (IFT) and contact angle measurements were conducted to examine their role in stability characterization.

***Keywords*: drilling fluid, clay, shear-thinning, zeta potential**

I. INTRODUCTION

The drilling of oil and gas wells is the primordial step in successful exploration of oil and gas fields and is the most expensive expenditure in oil and gas industries. Drilling fluid, a composite and multifunctional system provides a suitable environment for effective and efficient drilling operations and improves the productivity of oil and gas wells [1-3]. The selection of the drilling fluids and variation in their rheological and filtration control properties are the major concerns for drilling engineers and operators.

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Plane water is the principal constituent of the majority of drilling fluids and is considered to be the first drilling fluid used with the purpose of removal of cuttings from the borehole in Egypt in third millennium [4]. But down the time, variations in the composition of drilling fluids have been done in the oil and gas industries for different purposes and conditions.

In rotary drilling, drilling fluids play several functions simultaneously. The mud engineer or well site personnel can alter the properties of the fluid as per requirement to obtain a speedy, safe and satisfactory completion of the well.

Emulsion drilling fluids or emulsion muds have surfaced as an important category of drilling fluid which has gained prime position in modern drilling operations. The stability of the emulsion is achieved by using suitable surface active components (commonly known as 'surfactants') and polymers. The polymers and different additives are used to control the rheology and filtration properties of the drilling fluids. The development of emulsion drilling fluids has balanced out some of the unwanted characteristics of water-based drilling fluids. These unwanted characteristics are primarily due to the unique properties of water especially its capability to dissolve salts present in the reservoir, interfere with the flowing oil and gas, promote the risk of swelling of clay and corrode the heavy metal tools used in the drilling. Experiments conducted for the suitability of these types of water-based muds in high temperature and pressure conditions has shown that drilling fluids containing emulsions provide greater scope of well bore stability as compared to water-based drilling muds [5, 6]. On the other side, oil-based drilling muds containing around 95 % oil, have many well known disadvantages like more damaging effects on the environment as they contain higher percentage of aromatics. They also enhance thickening of the fluids when they are mixed with water present in the reservoir and large amount of hydrophilic solids, thickening is also observed with the loss of disperse medium during filtration. Moreover, the viscosity of such fluids is dependent of on reservoir temperature. Also the higher soap content in such fluids can have unwanted impacts on the formation fluid characteristics and above all the cost of oil-based drilling muds is much higher than that of emulsion drilling fluids. Emulsion drilling fluids have many advantages like lighter rheology flow profile, better lubrication characteristics of drilling tools are achieved and most importantly ecology faces lesser detrimental load than the conventional oil-based drilling muds.

Emulsion drilling fluids can also be effective at varying temperature and pressure conditions. Such fluids are electrically conductive so normal electric logs can be obtained with conventional equipments.

Xanthan gum is a natural polymer that has enormous industrial applications. The rheology of fluid solutions containing this gum remain intact over a good range of salt concentration. It has ability to stabilize emulsions and decrease dispersion. It also has stability towards high temperature and has potential of cross linking. Solutions containing the gum exhibit shear thinning (pseudoplastic) features which make it an effective component for drilling fluids. In emulsion drilling fluids, it manly acts as viscosity promoter and emulsifier. Its properties remain constant upto the temperature of about 120°C [2,7,8].

Clay (bentonite) is the cheapest material for the formulation of drilling fluids. It contains *montmorillonite* and when added to fresh water, the hole cleaning properties are increased. It reduces filtrate loss into permeable reservoir formation by forming a thin filtercake on the wall if the well bore. It also overcomes the loss of circulation and promote hole stability in defective cemented formations. But clay concentration in the drilling fluids should be maintained to the minimal level to minimize the sticking tendency and reduce drag and torque. As clay concentration is kept low, so it is unable to provide desired rheology and filtration at low concentration hence polymers are added to achieve the results for maximum performance in drilling operations [1-3].

Long-term physical stability of colloidal emulsions can be quantified using rheology measurements. It is observed that emulsions show viscoelastic properties. The inception of the elasticity is due to the inter-facial energy within the emulsion droplets. It has been concluded in the past research that the trimming of the continuous film separating the two dispersed emulsion droplets is controlled if the film has viscoelastic properties which is due to the result of adsorption of particle network at the oil and water interface. Viscoelastic properties of complex drilling muds are important to examine their parameters such as gel strength and solid suspension. In case of emulsion drilling fluids, stability is the most important parameter which is required to be controlled to achieve effective performance during drilling operations [9].

The aim to this research work was to examine the properties of o/w emulsions for it suitability as drilling fluids. Emulsion muds were prepared using varying concentrations of oil, xanthan gum and clay. It was observed that all these components were found suitable for the formulation of an emulsion system that can be used as a drilling fluid. Xanthan gum being a polymer stabilized and controlled the rheological properties along with oil. Clay controlled the filtrate loss to a satisfactory extent. Moreover, fluids have shown stable properties at high temperature conditions and exhibited shear thinning behaviour which is supposed to be an obligatory parameter for drilling muds. The stability of emulsions muds was characterized using shear stress-shear rate and oscillatory (dynamic) rheology measurement techniques which were subsequently used to demonstrate the physical stability of emulsions.

Other objectives of this research were to study the effects of these additives on the inter-facial properties such as zeta potential, inter-facial tension (IFT), and contact angle of emulsions. These properties play important role in the supervising phenomena like adsorption at the solid-liquid and liquid-liquid interfaces and wettability.

II. MATERIALS AND METHOD

For this investigation oil (diesel) was purchased from the regional distributor of Indian Oil Corporation, Dhanbad, Jharkhand area. Polymer (xanthan gum) was procured from Otto Kemi, Mumbai and clay was taken from Kutch region of Gujrat area, India. The different compositions of emulsions have been tabulated in Table 1 with varying concentration of oil, polymer and clay.

Drilling personnel, monitor the fluid consistency, rheology and filtration parameters of a drilling fluid on a constant basis because the properties may change with increasing drilling depth. Conventionally, rheological properties are measured using a ‘March Funnel Viscometer’. It is the simplest device to measure the viscosity of the fluid by observing the time taken by the fluid to flow through a narrow tube. It mainly gives the apparent viscosity of the fluid. Apparent viscosity is the viscosity observed a given shear rate at a particular temperature. Other rheological parameters along with apparent viscosity are plastic viscosity, yield point and gel strength are measured using Fann V-G viscometer (Model 35 SA) at ambient temperature conditions. V-G viscometer (direct-indicating viscometer) is a rotational cylinder and bob instrument that is used for rheology estimation at lab scale. The properties are calculated from 300 rpm and 600 rpm dial readings by using empirical mathematical relationships according to the methods recommended by API (American Petroleum Institute) [3]:

Apparent Viscosity (μ_a) = $\Theta600/2$ (1)

Plastic viscosity (μ_p) = $\Theta600 - \Theta300$ (2)

Yield point (y_p) = $\Theta300 - \mu_p$ (3)

Where,

$\Theta300$ = Dial reading obtained at 300 rpm and

$\Theta600$ = Dial reading obtained at 600 rpm

The unit for apparent viscosity and plastic viscosity is cP and yield point is $lb/100ft^2$. 10 seconds and 10 minutes gel strength are measured by rotating the cylinder at 3 rpm speed. The gel strengths are measured by observing maximum deflection of dial at 3 rpm speed before the gel breaks [5].

30 min filtration loss was monitored with API recommended apparatus (Fann filter press, Series 300) at the pressure of 100 psi at ambient conditions. Emulsions were filtered through filter paper (Whatman no. 50). Filter cake thickness is important in the effectiveness of a drilling fluid so it was measured to the nearest of 1 mm after washing off the excess drilling fluid in stream of tap water [10].

Model : Rheo Lab QC; Anton Paar rheometer was used to determine the shear stress- shear rheology. In this process, the emulsion was put in a measuring cup and it was fixed to EC motor drive with CC27 measuring system.

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The temperature was maintained by the hot water bath externally connected to the motor. The shear rate was maintained in the range of 1 s^{-1} to 1000 s^{-1} for the duration of 120 seconds.

Dynamic (oscillatory) rheology measurement was conducted using Bohlin-Gemini II Rheometer (Malvern Instruments Ltd., UK). The temperature for the measurement was maintained at 40°C. It performs the tests such as creep, viscometry, controlled stress (CS), controlled rate (CR), and controlled deformation (CD), CD oscillation, CS oscillation, stress relaxation and time temperature superposition with advanced data processing. It can operate in the temperature range of 40°C to 300°C. It has measuring geometry like parallel plates, cone and plate, cup and bob. Parallel plates geometry was used for the determination of oscillatory rheology.

TABLE-I: Composition of emulsion muds.

Emulsion Mud Systems	Oil (vol. %)	Xanthan Gum (wt. %)	Clay (wt.%)
1	5	0.5	2
2	10	0.5	2
3	20	0.5	2
4	40	0.5	2
5	20	0.3	2
6	20	0.4	2
7	20	0.6	2
8	20	0.5	3
9	20	0.5	4
10	20	0.5	5

Zeta Meter 4.0 was used to calculate zeta potential of the emulsions to study the charge properties at ambient condition (30°C). in this study the samples were prepared by diluting the emulsions by mixing 1 ml of fluid in 100 ml of distilled water. Zeta Meter uses a high-quality stereoscopic microscope and contains 20X (magnification) wide field eyepieces in addition with a 4.0X paired objective lenses with magnification of 80X (overall). The diluted fluid sample is loaded into the electrophoresis cell to view under the microscope. The electrophoresis cell is made of Teflon and quartz consisting of 2 electrode chambers which are connected by an polished electrophoresis tube of 10 cm length and 4 mm diameter. Electrode chambers are locked by teflon electrode stoppers and are placed on the mirrored cell holder. The cell is illuminated and transport of droplets is observed under CCD camera when electricity is applied. The resultant value of zeta potential is taken as the average of 5 analogous readings.

IFT and contact angle measurements were conducted using (Drop Size Analyzer) DSA 25, KRUSS (GmbH) at 30°C temperature. This DSA consists a basic configuration for accurately measuring IFT and contact angle of the fluid to be tested, using a 656 X 492 pixel camera for enhanced monitoring of the judgement of the colloidal droplets. In this process, a droplet of the prepared emulsion is placed on the sample stage using a syringe which is fixed at the dosing unit above the sample stage. The drop is illuminated from one side and a camera on the other side records the image of the emulsion drop. The image is transported to the computer and shown on the monitor. DSA software contains tools for analyzing the image of the fluid droplet with the help of which it is possible to calculate IFT and contact angle.

III. RESULTS AND DISCUSSION

The rheology and filtration properties of emulsion muds formulated using xanthan gum and clay as stabilizer have been tabulated in Table 2. It is observed that apparent viscosity increased with the increase in the concentration of oil but the major change is observed in yield point/plastic viscosity ratio. This ratio increased from 1 at 5 vol. % oil concentration to 6.5 at 40 vol. % oil concentration. The higher value of yield point/ plastic viscosity ratio is an indication of shear thinning (pseudoplastic) behaviour of emulsion drilling fluids and is considered to be an advantageous property for better bore hole cleaning capacity as it forms gel when circulation is stopped during trip and trip out of drilling tools so the drilled cuttings which are generated due to drilling are suspended and do not settle down at the bottom. Secondly, it breaks up quickly to a flowing thin fluid when circulation is resumed [11,12]. Likewise, increase in the concentration of xanthan gum also increased the rheological properties of emulsion systems. Increasing the amount of clay also enhanced the rheology of emulsions. Muds containing bentonite clay exhibit thixotropic behaviour. As most shear thinning fluids are thixotropic in nature so the same behaviour was observed in this case also. Thixotrophy is considered a desired property during the drilling process as when drilling fluid is at rest, it is required to act as a suspending solid as moving drilling fluid is required to behave as a viscous fluid capable of transporting the drilled cuttings. In industrial applications, thixotropy means a reversible change from a higher viscous gel state at rest to a lower viscous sol state activated by stress. During this process, the micro-structure of the fluid material is destroyed reversibly that means the micro-structure is regained at rest though at a much slower rate [13,14]. The fact behind the increased rheology with clay concentration is the swelling and flocculation of clay due to the penetration of water into the spaces between the layers of its molecular structure [15,16]. Increasing the concentration of diesel oil decreased the 30 min filtration loss from 16 ml/30min at 5 vol. % to 4 ml/30 min at 40 vol. %. Increasing the concentration of clay also decreased the filtrate loss significantly as can be seen in Table 2 as clay acts as a bridging agent in almost kinds of drilling fluid systems.

The properties of desirable emulsion muds after 24 hours aging at 70°C were also found stable and there was negligible changes in them. It shows that xanthan gum along with clay can be a perfect stabilizer for emulsion systems. The aging studies were also done above 70°C but properties were not stable above this temperature.

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Emulsions are broadly classified in two broad categories. First is the dilute emulsion where the concentration of dispersed phase is low and exhibits almost pure Newtonian behaviour and the second belongs to highly concentrated emulsion where the concentration of dispersed phase is higher and exhibits non-Newtonian viscous characteristic [17,18]. The fluid exhibiting Newtonian behaviour is characterized by the viscosity that is independent on the rate of shear applied on the fluid. Besides, fluid that exhibits non-Newtonian behaviour shows viscous characteristic that depends on the rate of shear applied on the fluid. The non-Newtonian rheology of polymeric emulsions has demonstrated shear thinning (pseudoplastic) behaviour in which the viscosity of the emulsions decreases with increase in applied rate of shear. Such property is readily explained by 'Power Law equation' [19]:

$$\eta = k\,\dot{y}^{n-1} \qquad (4)$$

Where, 'η' is apparent viscosity in Pa.s; 'ẏ' is shear rate in 1/s; 'k' is the flow consistency (viscosity of the fluid at unity shear rate). The value 'k' is a parameter to examine the thickness of the emulsion. At increased value of shear rates, the value of 'k' indicates more amount of solids in the fluid and overall bore hole cleaning effectiveness ; 'n' is the Power Law index. The value of 'n' gives the idea about the degree of deviation from Newtonian behaviour of a fluid. On the basis of value of 'n' a fluid can be classified in three types as explained below:

When n = 1, fluids exhibit an ideal Newtonian behaviour.

When n > 1, fluids exhibit shear thickening (Dilatant) behaviour.

When n < 1, fluids exhibit shear thinning (Pseudoplastic) behaviour.

In the case of emulsions, lower the value of 'n', more shear-thinning the fluid system will be. Emulsions that are weakly flocculated or have thickeners added to them are usually shear-thinning [12,19]. In the drilling fluids that follow 'Power Law model', the value of 'n' and 'k' can be predicted by using of following mathematical relationships [1]:

TABLE-II: Rheological and filtration properties of emulsion muds.

Emulsion Mud Systems	μ_a	μ_p	y_p	Gel_0	Gel_{10}	y_p/μ_p	30 min FL (ml)
1	21	14	14	10	14	1	16
2	27	14	26	12	20	1.86	8
3	31	12	38	15	24	3.17	7
4	42	10	65	20	36	6.5	4
5	20	12	16	10	15	1.34	8
6	25	12	38	12	18	3.17	8
7	36	13	46	18	30	3.53	7.5
8	31	15	33	13	20	2.2	8
9	35	16	38	15	20	2.38	5
10	37	17	40	16	23	2.35	3

$$n = 3.32 \log (\Theta600/ \Theta300) \qquad (5)$$

$$k = \Theta600/ (1022)^n \qquad (6)$$

The values of 'n' and 'k' calculated using above relationships of the most favourable emulsion mud (emulsion mud system-3) have been found to be 0.31 and 7.24 respectively. It is clear from the data that fluid has shown strong shear thinning (pseudoplastic) behaviour. Apparently, Figure 1 depicts the log-log plot between the apparent viscosity and shear rate of the developed emulsion. Here also it can be observed that the fluid system has shown strong shear thinning behaviour (pseudoplastic) because the viscosity is decreasing with increasing shear rate. As described earlier, shear thinning behaviour in drilling fluids is an imperative desirable property as it promotes better hole cleaning capacity during the drilling operation. Moreover, the quality of rheological model of emulsion muds can be assessed from the shear stress vs. shear rate curve and interpretation of consistency curve has shown that the developed emulsion muds follow Power-law model [12].

The shear stress-shear rate rheology measurement at steady state is a convenient technique to assess most common emulsion breakdown process, 'flocculation'. The emulsion which is weakly flocculated or structured to reduce creaming or sedimentation, exhibits strong shear thinning behaviour. It also exhibits thixotrophy and variation in thixotrophy with time indicate the strength of the weak flocculation. The emulsion was found physically stable and homogeneity was sustained even after 30 days of settling time (Picture 1).

An Emulsion may also show elastic properties. The elasticity is brought about the inter-facial energy of the emulsion droplets. It has been concluded that the diminishing of the continuous film separating the two dispersed emulsion droplets can substantially be impeded if the film has both viscous and elastic properties which is the result of adsorption of particles present in the emulsion at the oil-water interface. Therefore, development of elastic gel like properties at the oil-water interface controls drainage and prevents emulsion breakdown. Secondly, viscoelastic property of the drilling fluid is important to investigate the parameters such as gel strength and solid suspension capacity. In case of emulsion drilling fluids, stability is also an important parameter which is required to be controlled and can be assessed using viscoelastic measurements [9].

Dynamic oscillatory measurement is the tool to monitor viscoelastic property of a fluid. The basis of this measurement is the application of a sinusoidal strain of frequency 'ω' to the viscoelastic fluid and measure the corresponding stress. For viscoelastic fluids, stress and strain are out of the phase with one other. The phase angle shift 'δ' can be measured as the time shift (dt) between the amplitudes of the oscillatory stress (τ) and strain (y):

$$\delta = \omega.dt \qquad (7)$$

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From the phase angle shift and amplitudes, various viscoelastic properties are obtained. These include complex modulus; G*, elastic modulus; G´, loss modulus; G´´ and tanδ.The relationships between these variables are as follows:

$$G^* = \tau / y \quad (8)$$

$$G' = G^* \cos \delta \quad (9)$$

$$G'' = G^* \sin \delta \quad (10)$$

To obtain these variables, a series of measurements are conducted to fix the linear viscoelastic region. From this region, constant strain amplitude is selected for subsequent number of measurements in which the stress amplitude is observed as a function of changing oscillatory frequency. The data is subsequently used to examine the shear moduli (both elastic and loss) of the fluid. The existence of network like structure is observed by measurements which examines G´ > G´´ and both are independent of changing ω. According stability criteria, a dilute weak emulsion is characterized by loss modulus > elastic modulus and both parameters show a marked reliance upon the frequency of the measurement.

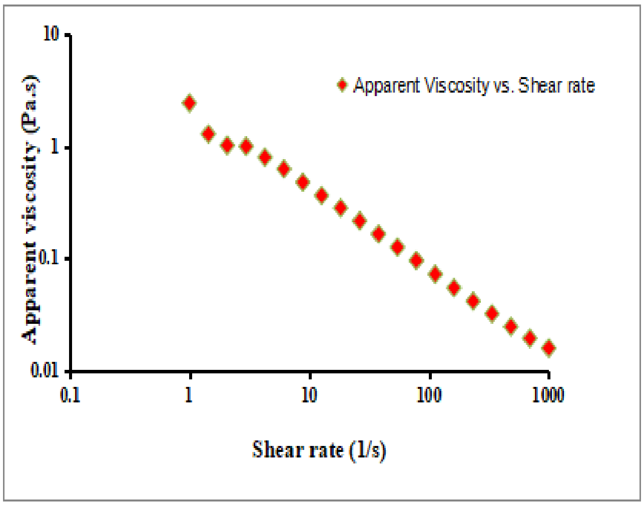


Fig. 1. Apparent viscosity-shear rate plot of emulsion mud system - 3 (Oil = 20 % + KCl = 5 % + Xanthan gum = 0.5 % + Clay = 2 %).

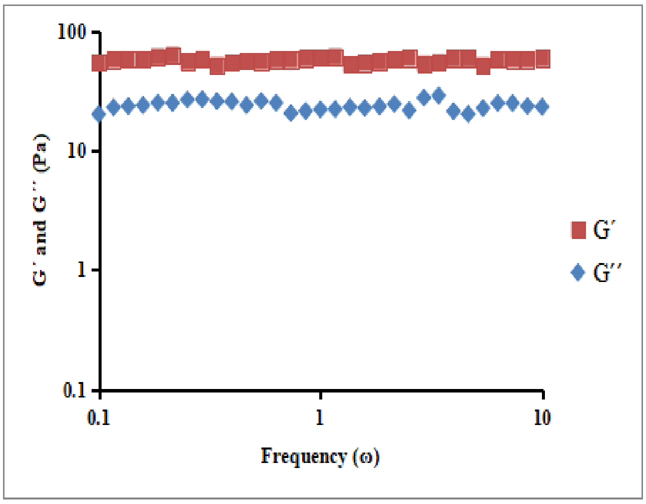


Fig. 2. Viscous and elastic moduli - frequency plot of emulsion mud system-3 (Oil = 20 % + KCl = 5 % + Xanthan gum = 0.5 % + Clay = 2 %).

Weak gels are characterized by elastic modulus > loss modulus and both variables show little dependence upon changing frequency. An emulsion is considered perfectly stable when elastic modulus > loss modulus both are independent of changing frequency. In that situation the emulsion demonstrate gel like property. This behaviour is demonstrated in Figure 2. As can be observed that both elastic and loss moduli are dependent of changing frequency and elastic modulus > loss modulus. This concludes that both the additives (xanthan gum + clay) played an important role in the stabilization of emulsion. The viscoelasticity brought upon by polymer is because of the entanglement of xanthan gum. In emulsion such behaviour arises due to an elastic network which is created among the droplets in the dispersed phase. Emulsion stabilizers such as colloidal particles get adhered to the dispersed phase droplets thus providing magnificent emulsion equilibrium [12, 20, 21].

Polymers and proteins stabilize emulsions by forming covalent binding or attractive electrostatic interaction. In electrostatic interaction, layers of conversely charged bio-polymers are formed around the oil droplets that create multi-layered membranes. These layers provide both thermal stability and resistance to external treatment to the emulsion.

Picture 1. Photograph of the emulsion mud taken after 30 days of settling time.

Figure 3 and Figure 4 show the effect on zeta potential of emulsion muds with increasing concentrations of xanthan gum and clay respectively. Study of zeta potential gives the idea about the steadiness of the colloidal systems. The greater value of zeta potential (either +ve or -ve) is the indication that colloidal droplets are far from each other and their chance of coming closer is less. So in a way zeta potential values indicate the distance between the droplets. This way emulsion droplets will not agglomerate and their breakdown chances are minimized. Both additives increased the -ve values of zeta potential which indicates that xanthan gum and clay both acted as stabilizers for developed o/w emulsions.

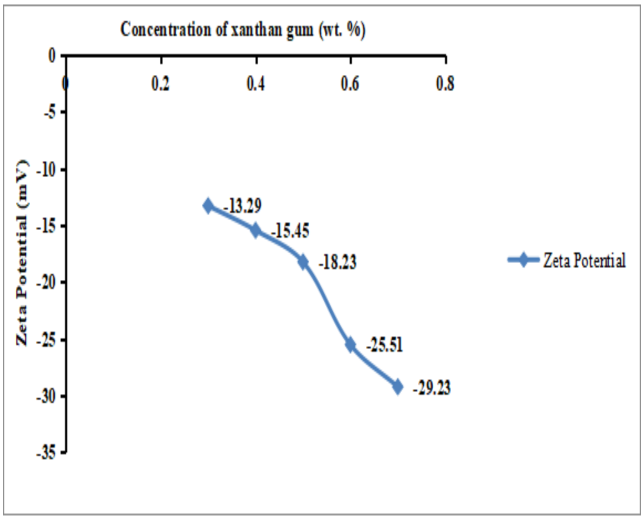


Fig. 3. Zeta potential of emulsion muds with increasing concentration of xanthan gum (Oil = 20% + KCl = 5 % + Clay = 2 %)

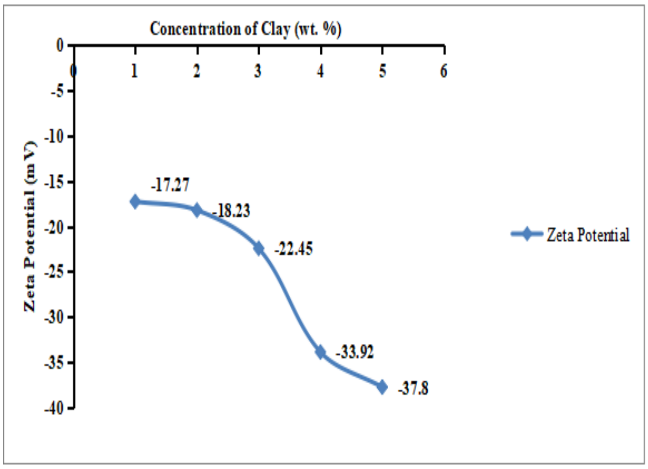


Fig. 4. Zeta potential of emulsion muds with increasing concentration of clay (Oil = 20% + KCl = 5% + xanthan gum = 0.5 %).

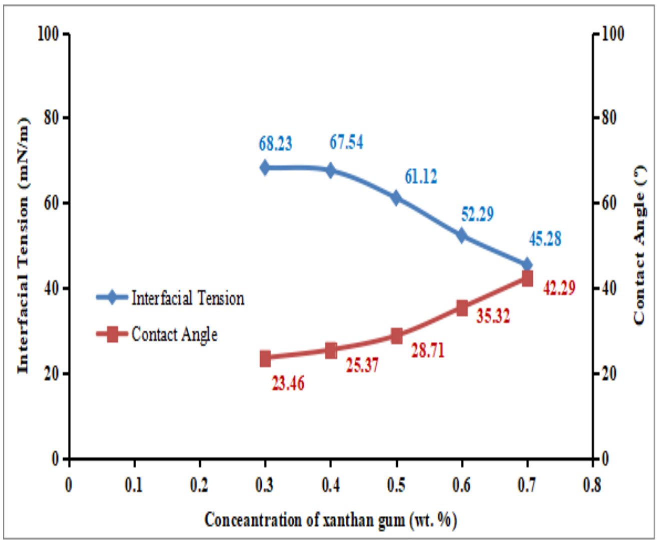


Fig. 5. IFT, contact angle of emulsion muds with increasing concentration of xanthan gum (Oil = 20%+ KCl = 5% + Clay = 2 %).

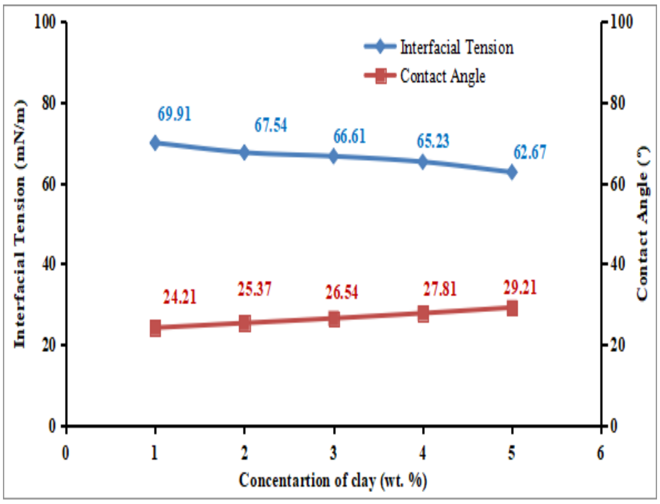
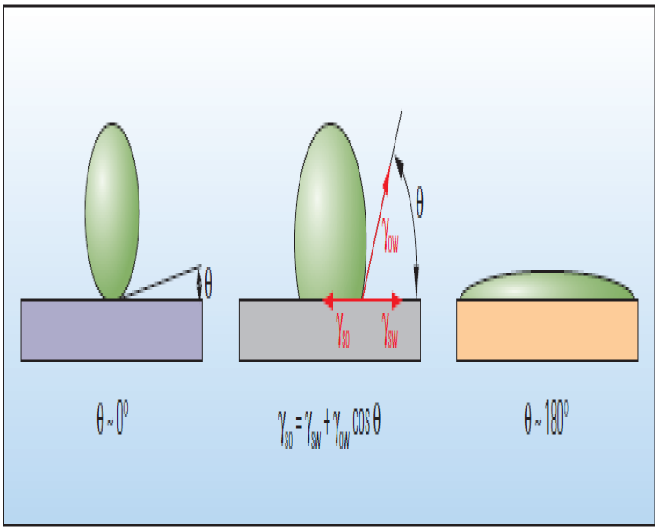


Fig. 6. IFT, contact angle of emulsion muds with increasing concentration of clay (Oil = 20 %; KCl = 5 %; Xanthan gum = 0.5 %).



Picture 2. An oil drop (green) placed on a water-wet (blue) solid surface forms a bead (left). The angle of contact (θ) is almost 0°; Oil spreads on an oil-wet surface making a contact angle approximately near to 180° (Right); On an intermediate-wet surface, the angle of contact is in the range of 0° to 180° due to balance of IFT which is described by Young's equation, $\gamma_{so} = \gamma_{sw} + \gamma_{ow}\cos\theta$, where γ_{so} = IFT between solid and oil; γ_{sw} = IFT between solid and water; γ_{ow} = IFT between oil and water.

IFT is measure of difference in energy between molecules at the interface when compared to their counterparts in the bulk phase. It is the extent of energy required to make a unit area at the interface between two immiscible fluids in N/m. The study of IFT is a concept of prime importance in colloidal chemistry that describes phenomena such as formation, shape and stability of liquid drops. Lower value of IFT indicates that tensile force per unit length at the interface of immiscible liquids is less and the system is stable.

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On the other side, contact angle is a common measure of wettability. Wettability describes the desire of a solid surface to be in contact with one fluid rather than another. A drop of a preferentially wetting fluid will remove another fluid and it will wet the solid surface. Contrarily, when a non-wetting fluid is dropped on a surface which is already covered by the wetting fluid, it will form a bead and its contact with the surface will be minimized. An intermediate condition is neither strongly water-wetting nor strongly oil-wetting. So, there is a balance of forces on solid, oil and water interface system that will result in the origin of angle of contact between the fluids and the solid surface as describe in Picture 2. It can be observed that IFT also decreased with increase in the concentrations of xanthan gum and clay as can be seen in Figure 5 and Figure 6 respectively. Reduction in IFT is an indicative that these additives helped in the stabilization of emulsion systems with their increase in concentrations. Contact angle increased with increase in the concentrations of xanthan gum and clay but major increase was observed in case of xanthan gum. This indicates that wetting characteristics of emulsions were found to be in water-wet region.

IV. CONCLUSION

This work has presented that physically stable diesel oil-in-water emulsion muds can be prepared using xanthan gum as viscosity modifier, stabilzer and clay as filtration control agent. All the emulsion systems have shown increased rheology with increasing concentrations of oil, gum and clay. Under compositional conditions the emulsions have shown shear thinning (pseudoplastic) properties with excellent long term stability towards emulsion breakdown processes. Dynamic oscillatory rheology have shown that emulsion systems exhibit viscoelastic properties which is an essential property for their stability. Studies conducted on the inter-facial properties of developed emulsion muds have shown that xanthan gum increases the negative values of zeta potential and reduces the IFT which finally helps in the emulsion consistency. It also promotes the water-wetting characteristics of emulsion muds. Furthermore, clay plays a major role in controlling the inter-facial properties of emulsion muds by increasing the negative values of zeta potential and reducing the IFT. It is concluded that developed emulsion can be used as drilling fluid for the better performance in oil and gas well drilling.

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