Utilization of styrofoam waste as a lost circulation material in drilling mud

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Abstract. Lost circulation is a major problem that was often found in the well drilling process. This resulted in rock formations to become unstable, cause damage to wells, equipment, and workers. So to overcome this problem, drilling fluid will usually include lost circulation materials that act as connecting agents throughout the openings in rock formations, which physically close the formation of the opening by entering into the hole and prevent more fluid from coming out. The method used is laboratory research to test the rheology properties of sludge that has been treated with the addition of styrofoam (1 to 5 grams) under conditions of temperatures of 83 °F to 243 °F with intervals of temperature increase of 40 °F and testing using the Fann VG Meter. The measurement results are then compared with the standard. This test was carried out to see the effect of mass and temperature on the physical and rheological properties of drilling mud. The result of this research shows plastic viscosity, yield point, and gel strength of mud increases with increasing concentrations of styrofoam, and decreased when the temperature was increased. The combination of mud that best fits with the standard was addition with 1 gram of styrofoam.

1. Introduction
In oil and gas production, an efficient and safe drilling process is needed. One problem that is often experienced in the drilling system is the occurrence of lost circulation [1-3]. Loss of drilling fluids can occur in many areas of the formation and causes several damages, increased drilling time, loss of control and drilling time [4-7].

To solve this problem, a material that can prevent loss circulation is needed. Lost circulation material is a material that is added to good prevent lost circulation or to restore the state of circulation to its original state after circulation is lost [8-10]. Lost circulation material can be obtained in various sizes and shapes to be used in blockage of fissures and preventing loss of mud into the formation [11,12].

One type of material that can be used as lost circulation material is a fibrous type material, this fibrous material is in the form of wood fiber, plant fibers, as well as synthetic fibers, measuring 1/8 to ¾ inch [13,14]. This material is most effective for covering the cavities large because it contains crude fiber that can provide ability to wrap properly [15].

Styrofoam is a type of fibrous synthesis material [16]. Besides, this material is also a waste that is very difficult to degrade, causing environmental pollution problems. Styrofoam or polystyrene are polymers with styrene monomers that have hydrocarbon groups in their molecular chains [17,18]. The nature of the hard and rather rigid polymer results in the polymer being one of the main choices as lost circulation materials [19,20].
2. Materials and methodology

2.1. Materials and equipment
Fresh Water, Soda Ash, Bentonite, Caustic Soda, Ben-EX, CMC-HV, Styrofoam. Viscometer fann VG meter.

2.2. Methods
The type of sludge used in the experiment is mud with fresh water and mixed with bentonite. The addition of LCM material, which is 1 gram, 2 grams, 3 grams, and 5 grams, is heated with a hose of 40°F from 83°F to 243°F. The following ingredients composition below can be used:

| Material       | Unit | Composition | MIXING TIME (MIN) |
|----------------|------|-------------|-------------------|
| Fresh Water    | ML   | 343.3       | 0                 |
| Soda Ash       | MG   | 0.084       | 1                 |
| Bentonite      | MG   | 5.943       | 7                 |
| Caustic Soda   | MG   | 0.147       | 1                 |
| Ben-EX         | MG   | 0.049       | 5                 |
| CMC-HV         | MG   | 0.0462      | 5                 |
| LCM            | MG   | 0.714       | 1                 |

2.3. Plastic viscosity and yield point test
Measurement of plastic viscosity using viscometer with VG meter by filling the cup to the limit then run with a rotor rotation speed of 600 RPM and 300 RPM read the results on the clues and read the results.

Mathematically, the price of Plastic Viscosity can be written as follows:

\[ PV = \theta_{600} - \theta_{300} \]  

While in the Yield Point price determination experiment, a reading of 300 RPM was carried out. Mathematically, the price of Yield Point can be formulated as follows:

\[ YP = \theta_{300} - PV \]

2.4. Gel strength test
The sludge in the cup is rotated at a speed of 600 RPM for 10 seconds, then the gear is slowly set at 3 RPM rotation, stop the rotation for 10 seconds. Move the switch to a low position and read the maximum deflection (deviation), this price is called 10 seconds gel strength. Do the same steps as before and let stand for 10 minutes, the price that is read is 10 minutes’ gel strength in units of lb/100ft².

3. Result and discussion
In determining the rheological properties of this mud, the rotor rotation speed reading at 600 RPM and 300 RPM is very vital because the reading at both rotor speeds will determine the values of Plastic Viscosity (PV), Apparent Viscosity (AV), and Yield Point (YP). Besides, reading at a low rotor rotation speed will also determine the Gel Strength value from the mud.
Figure 1. Plastic viscosity vs. temperature relationship for each mud.

From the graph in figure 1, plastic viscosity increase with increasing the concentration of styrofoam and decreasing with increasing temperature and there is an orange highlight line that states that plastic viscosity matches the standard.

Figure 2. Yield point vs. temperature relationship for each mud.

From the graph in figure 2, yield point increase with increasing the concentration of styrofoam and decreasing with increasing temperature and there is an orange highlight line that states that yield point matches the standard.

Figure 3. Gel strength 10 sec vs. temperature relationship for each mud.
From the graph in figure 3, Gel Strength 10 Sec increase with increasing the concentration of styrofoam and decreasing with increasing temperature and there is an orange highlight line that states that gel strength matches the standard.

![Graph showing Gel Strength 10 Min vs. Temperature relationship for each mud.]

From the graph in figure 4, Gel Strenght 10 Min increase with increasing the concentration of styrofoam and decreasing with increasing temperature and there is an orange highlight line that states that gel strength matches the standard.

The value of plastic viscosity, first yield, 10 secs and 10 min gel strength showed the same results which increased with higher concentrations of styrofoam added, this was influenced by the ability of styrofoam to absorb the liquid that causes the increasing amount of styrofoam, the value of plastic viscosity and gel strength will increase. Whereas with the increase in temperature, the value of all rheological properties will decrease. It is known that plastic viscosity, yield point, and gel strength are influenced by the electrochemical force between liquid and liquid, solids with solids, solids with liquids so that with an increase in temperature the electrochemical force between liquids will decrease which results in decreasing value. Sajjadian et al, used CaCO$_3$ as lost circulation materials with variations of CaCO$_3$ concentrations of 10 to 30 ppb measured at 75 °F and showed results that with higher concentrations of CaCO$_3$, the higher the value of plastic viscosity, yield point and also gel strength \cite{15}.

4. Conclusions

Plastic viscosity (PV) initially increases with the increasing amount of styrofoam added to the mud, after the mud is heated to reach 243 °F, there is a decreased gradient of PV. The PV value according to the standard is added to 1 to 3 grams of styrofoam and heated to 243 °F. Yield point (YP) increases with the increasing amount of styrofoam added to the mud after the mud is heated to reach 243 °F, there is a decrease in a gradient from YP. YP values that conform to the standard are those added with 1 to 5 grams of styrofoam and heated to 243 °F. The ideal price of gel strength ranges from 10-16 lb/100ft², the price of 10 min gel strength and 10 secs has decreased due to rising temperatures but remains stable. This is due to the influence of the addition of Bentonite Extender which can control gel strength.

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