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EFFECT OF MICRO-SIZED FLY ASH ON THE RHEOLOGICAL AND FILTRATION PROPERTIES OF WATER-BASED MUDS

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Abstract

The aim of this study is to examine the effect of the micro-size fly ash on the rheological and filtration properties of the water-based drilling mud such as; viscosities, gel strength, and filtration rate. The fly ash has been added in different concentration to the drilling fluid; 1 wt. %, 2 wt. %, 3 wt. %, 4 wt. %, 5 wt. %, 6 wt. % of the total drilling fluid weight. As a result, it was concluded that the rheological parameters showed an optimum ratio which is 4 wt. % of micro-sized fly ash. The apparent viscosity and the yield point increased by 20% and 43%, respectively, with the adding 4 wt. % fly ash. And, the filtration rate is generally enhanced with the increase of the concentration of fly ash.

Keywords: *Micro-sized fly ash; Water-based mud; Rheology; filtration.*

1. Introduction

During drilling operation, the most important component that helps to transport the cuttings from the bit up to annulus to the surface is the drilling fluid. Drilling mud exerts the required hydrostatic pressure in order to maintain the wellbore stability, to lubricate and cool the system equipment, and to prevent formation fluids to flow from the rock to borehole. Thus, it is of prime importance to select the suitable mud parameters that make the operation easier, safer and economical [1].

Drilling fluid is classified into three groups; water-based mud, oil-based mud and gas-based mud. However, the water-based mud is the most used in drilling operations. Due to the increase of the exploration activities in oil industry, the use of the bentonite water-based mud has also been increased noticeably [2]. This type of drilling fluid contains bentonite as a main viscosifier agent, as well as different other agents, which help to obtain the desired rheology properties. For instance, xanthan gum, carboxy methyl cellulose among other polymers. In addition, fineness particles have been introduced as additives in the mud to enhance its properties [3].

Fly ash is a "silico-aluminate rich pozzolanic material" obtained usually after the combustion of coal. In petroleum industry, fly ash is mainly used to prevent groundwater from contamination. Moreover, it is used in foamable-drilling-fluid for deep-water-drilling as an additive [4].

Fly ash is generally somber in color, mostly alkaline, and abrasive. The "pozzolanic" characteristic of the fly ash makes it beneficial for the fabrication of cement, concrete, and building materials [5]. The reason of the fly ash has been selected among other products is its bridging properties and as it is an environment-friendly byproduct.

In the present study, the possibility of introducing fly ash has been investigated to improve the mud for well drilling. The goal of the study is to examine the rheological and filtration properties of water-based bentonite mud with fly ash.

2. Experimental

2.1. Laboratory mud preparation

As the most common drilling mud types used in drilling operations; the water-based mud has been selected among the other types. Firstly, based on the API standards, bentonite was added to distilled water and mixed. Then, the xanthan gum, a high-molecular weight biopolymer, was added to bentonite-distilled water suspension as viscosifier. The carboxy methyl cellulose (CMC), a cellulose derivative obtained by chemically modificating the natural cellulose, was also added to suspension to control filtration. After mixing, the mud was left to age for 16 hours in order to assure the exact hydration of the bentonite [6]. On the other hand, the fly ash particle, its size ranges between 30 μm and 63 μm, was mixed with the bentonite water-based mud in various concentrations from 1 wt. % to 6 wt. %.

2.2. The characteristics of fly ash

Raw fly ash used in the different experiments was obtained from 900 MW power plant situated in Tiszaújváros-Hungary. The raw fly ash, which is brown colored coal, had been dried at 105°C in an oven for 8 hours in order to eliminate moisture. Eventually, the moisture fly ash content was found as 24.8 %.

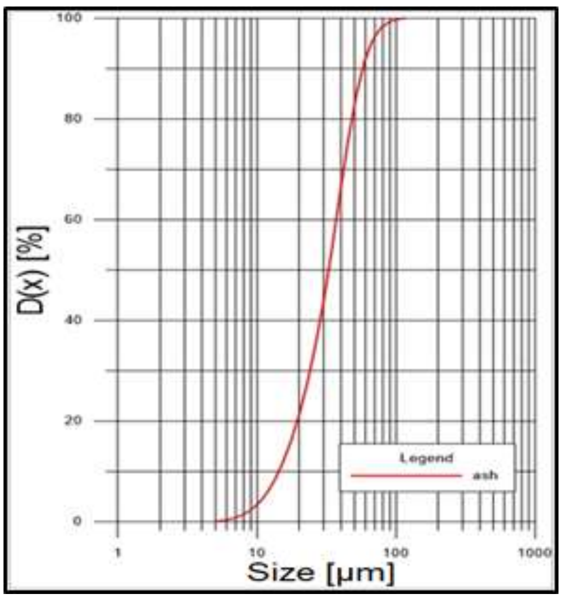

Figure 1. Particle size distribution of fly ash samples

To obtain the desired micro-particle size of the fly ash (smaller than 63 μm), firstly it has been sieved using 100 μm mesh sieve then mechanically grinded by the mean of the planetary ball mill machine to reduce further the fly ash particle size and after that sieved for a second time using a 63 μm mesh sieve.

The determination of the fly ash particle size distribution has been calculated using a laser diffraction analyzer model "Horiba LA-950 V2" in distilled water [7]. Fig.1 displays the particle size distribution of the micro-sized fly ash. The distribution of the micro-particles range from 20 μm to 50 μm represented by the D20 and D80, respectively. The chemical composition of the fly ash (as oxides) was carried out by Rigaku Supermini 200 type X-ray fluorescence spectrometer (XRF) with 200W palladium (Pd) target (50KV and 4.0mA). The evaluation was done by ZSX driving program in quantitative mode on each components

Table 1. Chemical composition of fly ash

Components	Content (%)	Components	Content (%)
SiO_2	59.3	K_2O	1.52
Al_2O_3	25.8	Fe_2O3	5.25
MgO	1.13	MnO	0.030
CaO	1.69	TiO_2	0.627
Na_2O	0.84	P_2O_5	0.049

2.3. Experimental procedures

The calculation of the apparent viscosity, plastic viscosity, and yield point, as well as 10 seconds and 10 minutes gel strength, which are the main rheological parameters of the drilling fluid, were determined and calculated using the "Fann viscometer model 35A" manufactured by Fann Instrument Company, Huston, Texas. The Fann viscometer is available in six speeds, which are 3 rmp, 6 rpm, 100 rpm, 200rpm, 300 rpm and 600 rpm. The equipment is configured to calculate the viscosities in centipoise using the dial readings at speed of 600 rpm and 300 rpm;

The apparent viscosity (cP) was determined using the formula below.

$$AV = \frac{\Theta_{600}}{2} \qquad (1)$$

The plastic viscosity (cP) was recorded by counting the difference between the readings measured at the two speeds of 600 rpm and 300 rpm.

$$PV = \Theta_{600} - \Theta_{300} \qquad (2)$$

So as to calculate the yield point which is expressed in lb/100ft², the following equation was applied in function of the plastic viscosity.

$$YP = \Theta_{300} - PV \qquad (3)$$

The gel strength was measured using the viscometer. The viscometer speed was set at 3 rpm, two dial readings for gel strengths, at 10 seconds and at 10 minutes. The mud must be static preceding each measurement test, and the highest peak was recorded on the dial reading is considered.

The filtration loss test was conducted by using the low pressure-low temperature API filter press at 100 psi for 30 minutes. The filtrate volume, which is measured in ml/30min of time, was collected in the graduated cylinder and read to the nearest one tenth of milliliter.

3. Result and discussion

The diversity of the different viscosities in function of the various concentration is given in the Fig. 2 below. It has been noticed that apparent viscosity, and yield point decrease at 1 wt. % fly ash then start to rise with the increase of the fly ash ratio up to 4 wt. %. Then, they tend to drop. The result of experiments reveal that the apparent viscosity increased to 27 cP and the plastic viscosity is more or less constant (i.e. varies between 10 and 12 cP). This means that adding fly ash until 4 wt. % to the mud might improve the flowability, provide effective hole cleaning and also could reduce some drilling problems such as mechanical pipe sticking, high rotary torque, excessive overpull on trips. Likewise, yield point shows the similar pattern as the apparent viscosity. It increases from 21 lb/100ft² to 30 lb/100ft² at fly ash concentration of 4 wt. %. After that, it decreases.

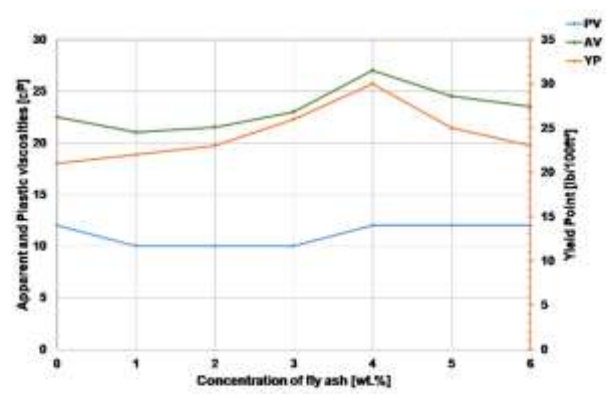

Figure 2. The rheological parameters of the micro-sized fly ash mud

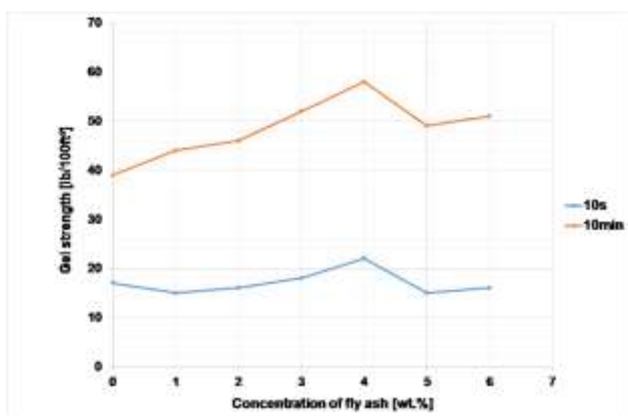

Figure 3. Initial and 10 minutes gel strength

The gel strength behavior is shown below in Fig. 3. It indicates the pressure required to move the mud after circulation has been stopped. The initial gel strength and 10 minutes gel

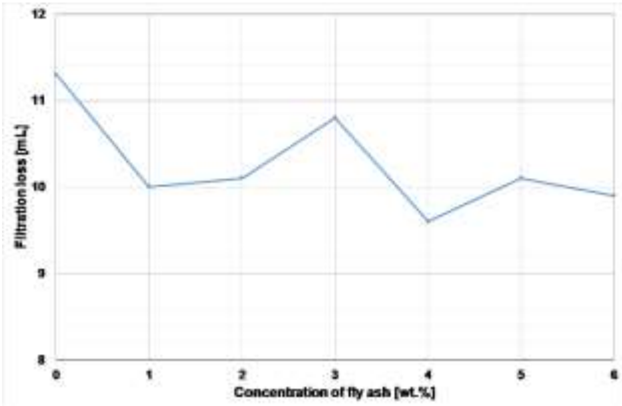

Figure 4. Filtration rate

strength have approximately the same trend as the viscosities. They increase to 22 lb/100ft² and 58 lb/100ft² up to 4 wt. % of fly ash concentration, after that the gel strength diminishes.The filtration loss in function of the fly ash concentration is represented in Fig. 4. The general shape of the filtration loss curve decreases comparing to the base mud. It decreases from 11.3 mL to 9.6 when the fly ash concentration reaches 4 wt. %. After this ratio, it rises slightly. It should be point out that when the fly ash ratio is at 3 wt. % the filtration loss suddenly increases from 10.1 mL at 2 wt. % to 10.8 mL at 3 wt. %. The filter cake from the other side decreases gradually from 2 mm to 1.6 mm. with the increase of the fly ash concentration.

4. Conclusion and recommendations

In the present study, the effect of micro-sized fly ash on the rheological and filtration properties of water-based mud was experimentally studied. Concerning the micro-sized fly ash, the rheological parameters showed that the optimum ratio which is 4 wt. % of micro fly ash. For instance, the apparent viscosity and the yield point are increased with adding 4 wt. % fly ash to the based mud. After that, they start to decrease. This enhancement could lead to a reduction of some wellbore problem. The filtration rate is generally enhanced with the increase of the fly ash concentration as well as a relatively thinner filter cake has been notified.

For further improvement, several recommendation might be taken into consideration. Firstly, the based mud composition could be different by adding other agents or using a free bentonite mud. In addition, smaller and more homogeneous particle size distribution may result in enhancement of the laboratory work. Finally, deeper study of the chemical interaction between the fly ash and the different agents of the drilling fluids may result on a better comprehension of the fly ash functioning.

Acknowledgments

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