Real-time rheology and density monitoring of drilling fluids at offshore installations

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ABSTRACT

A new device for automatic measurements of drilling fluids rheological properties and fluid density has been developed for offshore use. The Pipe rheometer sensor system is installed at several offshore drilling rigs operated by Equinor. The density and rheological properties including gels of drilling and completion fluids are monitored in real-time. During the operation, the autonomous sensor system has revealed some of its potential for supporting a safe and secure drilling operation. The Pipe rheometer is monitoring the active circulated drilling fluid volume, and the data is transferred in real-time to the fluid vendor and Equinor using the standard OPC UA interface. The installation is a part of a offshore pilot test period.

INTRODUCTION

The API[1] requirements used today are defining procedures for measuring density and rheology based on collecting a sample of the drilling fluid and manually analyse this drilling fluid sample in a drilling fluid laboratory room on the rig. The two most important drilling fluid properties are density and rheology. Density is measured using a manually operated Mud Balance, and the rheology is measured using a Couette type viscometer. Both these measurements instruments have been fairly unchanged the recent 50 years, are time consuming to operate and allows for errors when manually reading and recording the measurement.

A typical layout of a Couette type viscometer is presented in Figure 1.

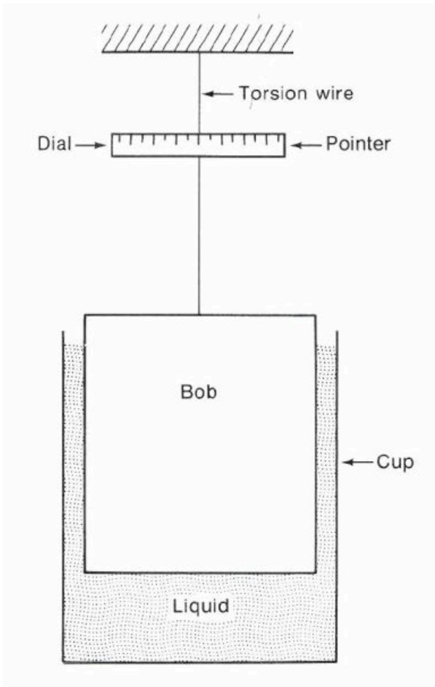

Figure 1 Typical layout of a Couette-type concentric rotary viscometers

The Pipe rheometer measurement principle is based on measuring the differential pressure on a horizontal segment and a vertical segment of a pipe. The horizontal segment measurement data will contain information of the drilling fluid frictional pressure drop. The vertical segment measurement data will contain information on both drilling fluid density and drilling fluid frictional pressure drop. By combining these two measurements together with information about the drilling fluid velocity, both the drilling fluid density and the drilling fluid rheology profile can be found.

A typical layout of a pipe rheometer is presented in Figure 2.

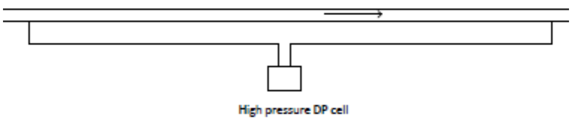

Figure 2. An example of a pipe rheometer using a differential pressure sensor.

The Couette type viscosimeter gives a direct reading at specified rpm's of 3, 6, 100, 200, 300 and 600 rpm. These are parameters monitored and tested for decades and gives information of viscosity at shear rates in the range from 5.1 to 1021 s^{-1}. In order to have an easy introduction of the automatic measurements from the pipe rheometer the measurements from the Pipe rheometer are calculated to give data in the same format. The Pipe rheometer is set up with a pump giving variable flow rates and two different pipe dimensions in order to be able to measure parameters at the desired shear rates.

The Pipe rheometer is monitoring the volume of drilling fluid in circulation during the drilling process, and the data is transferred in real-time to the fluid vendor and Equinor using the standard OPC UA interface. The installations is a part of a offshore pilot test period.

A picture of the Pipe rheometer installation is shown in Figure 3.

Figure 3. Offshore installation of the Pipe rheometer

Temperature influence - density

Due to thermal expansion effects, the density is dependent of the temperature in the wellbore. This temperature influence is typically adjusted by recoding the density at the current temperature. Alternatively, the density is measured at 50 °C. The Pipe rheometer measures the density at the actual temperature.

Temperature influence - viscosity

The viscosity of a fluid is typically dependent of the temperature, and the following relation has been given by Reynolds[2], giving

$$\mu(T) = \mu_0 e^{(-bT)}, \qquad (1)$$

where b is a temperature coefficient parameter. For the Couette type instruments, the sample of the drilling fluid is heated or cooled down to 50 °C. For the Pipe rheometer system, the rheology at the actual temperature is identified, and the online measurement of temperature is used to identify the b temperature coefficient.

Pressure influence - viscosity

The viscosity is typical less dependent of pressure, and the Couette viscosimeter measurement are typically measured at almost atmospheric conditions.

For the Pipe rheometer concept, the pressure is recorded and a relationship between pressure and rheology will be identified.

CONCLUSION

Real time drilling fluids viscosity and density have been measured automatically by Pipe rheometer with high accuracy and good reliability.

In drilling, there are occasionally situations where the cause for the situation is difficult to identify. Adding real-time information will assist in making faster diagnosis and actions. In combination with other data sets, a faster and better understanding of a drilling situation will be the result. The real-time monitoring of the drilling fluid density and rheology have saved rig time. This pilot is a cooperation with industrial partners, Equinor D&W and Equinor R&T.

REFERENCES

1. API, Recommended Practice 13D – *Rheology and hydraulics of oil-well drilling fluids*, 2009

2. Reynolds O. (1886). Phil Trans Royal Soc London, v. 177, p.157.