Particle Size Analysis for Drilling in Petroleum Industry

Nicolas Marchet, PhD - Industrial Instrumentation, Application Engineer, CILAS
8, avenue Buffon, B.P. 6319, Z.I. La Source, 45063 Orleans, France. Tel: + 33 (0) 2 38 64 15 55 Fax +33 (0) 2 38 64 59 07

In order to drill a successful oil well, most drilling operators will use a good drilling fluid or mud. Mud cools and lubricates the drilling tool, helps to attack the rock by injection under pressure, and cleans out the hole, carrying away the pieces of crushed rock [1]. These mud systems are usually WBM (Water-Based Mud), OBM (Oil-Based Mud) or SOBM (Synthetic Oil-Based Mud). One of the major problems with these systems, particularly when reused on different wells, is the build-up of very fine micron solids (less than 5 microns) known as Low Gravity Solids (LGS).

The generation of LGS in the mud creates, slower penetration rates, high pump pressures and increased solids surface area or plastic viscosity. The main risk is the mud becomes stuck and to loose the hole drilled.

Particle shape determination permits also to quantify the shape anisotropy of particles or to provide information relating to surface area regularity.

In this article we show the importance of morphological analysis and show the benefits of combining laser diffraction size measurements with simultaneous shape analysis using the same sample.

The use of Particle Size Analysis (PSA) for Drilling in the Petroleum Industry

Particle Size Analysis (PSA) based on laser diffraction is an easy-to-use technique to measure liquids and dry products. All mud systems with their different carry liquids can be tested, from WBM and OBM to SOBM.

In the *figure 1*, we can observe that the particle size distribution decreases during drilling process from 35 µm to 2.6 µm.

This analysis makes it possible to detect the presence of 5-µm particles in drilling fluids in order to avoid the cementing process in the well.

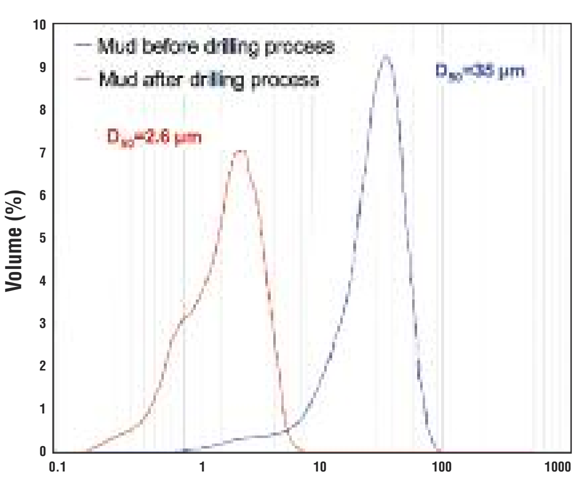

Figure 1: Particle size distributions of drilling fluids

Along with drilling mud, the particle size measurement of LCM (Lost Circulation Material), such as calcium carbonate ($CaCO_3$) and barite ($BaSO_4$) (*figure 2*), is significant.

The latter are used as a weighting material to increase the apparent density of the mud and can be measured with adapted dispersion protocols.

By adjusting the viscosity of the carrying liquid, the stabilisation of weighting materials makes it possible to take the particle size measurement without sedimentation.

Dispersing agents are usually added to provide steric stabilisation. This mechanism is usually based on

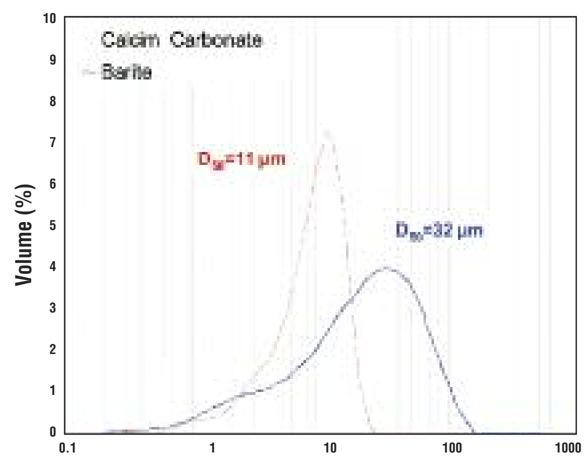

Figure 2: Size distributions of materials used in drilling fluids

adsorption of polymers onto particle surfaces to reduce the Van der Waals attractive forces.

It is also possible to measure the particle size distribution in dry mode by selecting the air pressure to disperse agglomerates. The desagglomeration is obtained by airflow turbulence combined with particle-particle and particle-wall collisions. The resulting two phases flow is then directed to the laser path through a succession of venturi sections and a special nozzle.

The Influence of Shape Factor in Drilling Efficiency

In addition to particle size distribution, shape parameters provide much information on the drilling fluid's properties. In the *figure 3 a)*, we have reported the influence of particle's morphology on the two main shape parameters. The aspect ratio defined as the ratio of Feret diameters corresponding to the length represented in *figure 3 b)* and the circularity ratio, proportional to the ratio of the area of the particle to its perimeter squared.

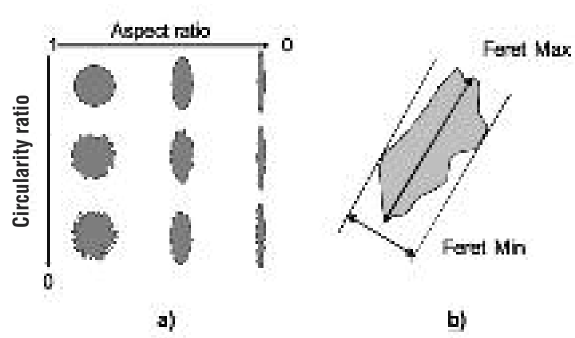

Figure 3: a) Some shape parameters and b) Definition of Feret diameters

The morphology of particles plays a role in the thixotropic behaviour of drilling fluids. Thixotropy is the property of some fluids to show a time-dependent change in viscosity.

For example, the intrinsic viscosity [η] of particles with the same volume is directly related to their aspect ratio (*figure 4*) [1-2].

Furthermore, the rheological properties of some materials used in petroleum industry are of great importance in structural and geotechnical engineering.

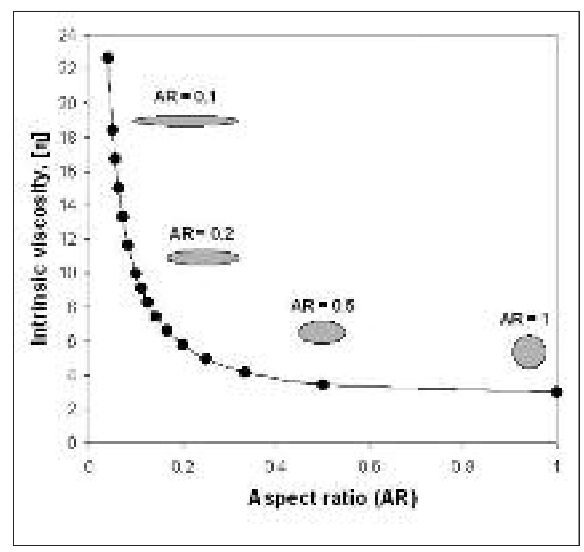

Figure 4: Variation of intrinsic viscosity as a function of the aspect ratio

The flow rate of particle suspensions may be of importance in transfer steps. The importance of particle morphology may be demonstrated, for example, by the intrinsic viscosity value for the solution, since this has an effect on the thixotropic behaviour of viscous solutions.

Figure 4 shows the change in this variable as a function of the aspect ratio for particles at constant volume and concentration. This graph therefore shows a rapid increase in intrinsic viscosity when particles exhibit a high degree of shape anisotropy. This property may have important consequences when transferring solutions [2-4] or during the use of drilling muds in the oil industry.

Technical Benefits of Combined Particle Size and Shape Analysis

Shape analysis coupled with laser diffraction provides quantitative information not only gives a more precise characterisation of the sample's dispersion but also provides information on the presence of impurities or of synthesis by-products or to identify the differences in morphology as a function of their size.

The state of dispersion of particles is a step which has a direct effect on laser diffraction size measurements. The use of an appropriate dispersion protocol may involve optimising the conditions, the power and duration of ultrasound or the addition of chemical dispersants.

Figure 5 shows an improvement in the state of dispersion due to optimisation of the period of ultrasound treatment. The modification of the state of dispersion can also be seen through the change in the particle size distribution.

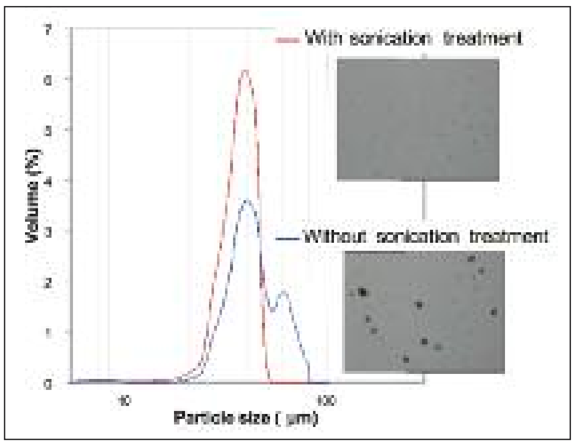

Figure 5: Effect of ultrasound treatment on the dispersion of oxide particles.

Particle size Distribution and Observations using Optical Microscopy

A second benefit lies in the quantification of the state of agglomeration, for example through the circularity or degree of sphericity of particles or of agglomerates of particles.

The photographs in *figure* 6 show that the production sequence for the glass beads has either produced particles with a high degree of shape anisotropy (a), adhering particles of very variable sizes (b), or that contaminants have been introduced into the production batch (c). In this last case, the difference in morphology and the transparency of the material provide information about its chemistry.

This specific design makes it possible to perform a shape analysis with the same sample analysed by laser diffraction and to compare these two techniques.

Laser diffraction measurement of particle sizes can be carried out both via a dry process and via a wet process. After optimisation of the sample dispersion conditions, the results obtained can be correlated with those obtained by optical microscopy (*figure 7*). For the three modes of measurement, the particle size distributions are similar and median diameters of 50 µm are obtained.

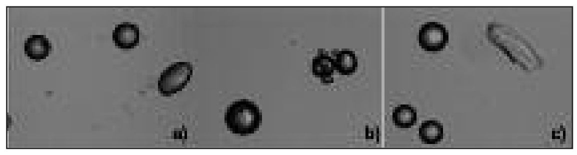

Figure 6: Examples of pictures indicating a) shape anisotropy, b) agglomerated by-product and c) presence of impurities (Magnification x10)

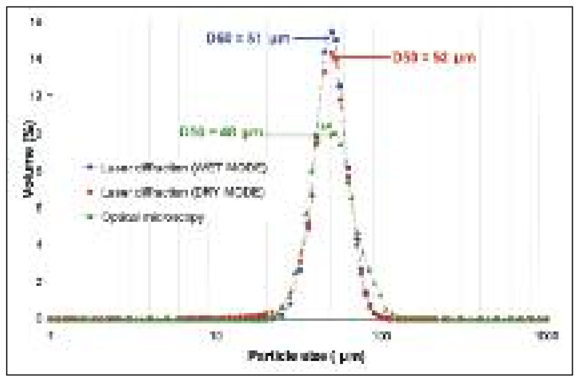

Figure 7: Correlation between particle size distributions obtained by laser diffraction using a dry process, using a wet (liquid) process, and by optical microscopy

Conclusions

The measurement of particle size is a key point for drilling fluid formulation, which itself plays an important role in the efficiency of drilling wells. CILAS Particle Size Analysers are easy to use, fast, accurate and very reliable with liquid and dry formulations.

With their robust design, they enable testing and analysis to be performed in the field without being affected by dust or vibration, and provide reliable analysis even under adverse industrial conditions for routine analysis.

From this information, the condition of the drilling fluid can be quickly and accurately assessed. Shape analysis makes it possible to control the particle morphology to complete knowledge of the material's properties.

Decisions can be made based on this accurate data to correct the problem in the most efficient way before a serious incident occurs.

By employing robust analytical methodologies, formulators can use this tool to generate reproducible particle size data rapidly, which in turn facilitates the development of formulations suitable for drilling in diverse geologies.

References

[1] Alteration of permeability by drilling fluid invasion and flow reversal

Journal of Petroleum Science and Engineering

Volume 58, Number 1–2, p. 227–244, (2007)

[2] Rheology modification in mixed shape colloidal dispersions.

Part I: Pure components

Soft Matter

Volume 3, p. 1145–1162, (2007)

[3] Rheology modification in mixed shape colloidal dispersions.

Part II: Mixtures

Soft Matter

Volume 4, p. 337–348, (2008)

[4] Intrinsic viscosity and the polarisability of particles having a wide range of shapes

Advances in Chemical Physics, Volume XCI, (1995)