EMRP Call 2013 – Energy and Environment

Selected Research Topic number: **SRT-g08**
Version: 1.0

Title: Sensor development and calibration method for inline detection of viscosity and solids content of non-Newtonian fluids

Abstract

Measurement of the viscosity of non-Newtonian fluids is relevant for many industries, such as the oil and gas (drilling) industry, food, paint, pharmaceutical and the chemical industry. However, the absence of a measurement standard for non-Newtonian fluids currently leads to an inability to assess and validate measurement devices for viscosity. Therefore, measurement standards for non-Newtonian fluids for the inline measurement of viscosity and solids content are required. Furthermore, the development of an inline viscosity sensor that measures viscosity and solids content autonomously and continuously in non-Newtonian fluids, should lead to an increase in the capability of process automation.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Energy and Environment on pages 8 and 23.

Keywords

Rheology, viscosity, process control, non-Newtonian fluids, inline measurement, solids content.

Background to the Metrological Challenges

Newtonian fluids have by definition a viscosity that does not depend on the amount of shear to which the fluid is exposed, and their viscosity can be determined at a convenient shear rate set point. However, many industrial fluids exhibit non-Newtonian behaviour as their apparent viscosity varies strongly as a function of the shear rate and therefore a Newtonian viscosity model cannot be used to predict their properties. The measurement of the viscosity as a function of the shear rate is important for the industries that deal with non-Newtonian fluids. The behaviour of the fluid has to be chosen such that applications in industry match the circulation flow rates that may occur. For example, well construction operations in the oil and gas industry use drilling fluids for transporting the drilled rock cuttings through the well to surface while keeping the surrounding formation fluids in place and preventing damage to the surrounding subsurface. Thus, better measurement and control of non-Newtonian fluids would support their use in such industries.

Typically the viscosity of fluids is measured on a batch basis using rotational viscometers. These rotational viscometers do not work as inline sensors even though many industrial applications require inline measurement. The accuracy of viscosity measurement is largely determined by the capability used to measure the resistance of a fluid while imposing a known rate of deformation (i.e. shear rate). However, a problem arises when trying to impose the rate of deformation in non-Newtonian fluids, as in a viscometer this is usually determined by an ideal flow assumption, such as a linear (Couette) velocity profile between two concentric rotating cylinders, and certain assumptions for the shear rate in the capillary are not applicable for non-Newtonian fluids. Furthermore, the presence of coarse solids in the fluid may severely hinder torque measurements when the typical diameter of the solids is close to the gap between the two concentric rotating cylinders in a viscometer.

Currently, in the oil and gas industry, there are no standards for calibrating viscosity measurement devices. Instead the viscosity of drilling fluids is measured several times a day, even though drilling automation requires measurements at least every 120 s, as per the Norwegian standard NORSOK D-001 [1]. According to the same standard, an accuracy of 2 % is recommended for automated control of drilling. However, for measuring the viscosity of drilling fluids, there is no standard for measuring accuracy and no method for assessing the quality of existing commercial products. For Newtonian viscosity measurement processes, devices are usually calibrated using Newtonian calibration fluids for which the viscosity is known, but for non-Newtonian properties such a calibration fluid is not yet available.

There are many commercial devices capable of measuring the particle size distribution of solids suspended in a fluid. However, many of these devices rely on laser scattering principles that require some degree of transparency of the specimen and none of them is capable of measuring the solids content present in a fluid as a percentage. The solids content of a fluid is particularly relevant for assessing the quality of drilling fluids, as solids are added to the drilling fluids to increase their weight. As a result, typical drilling fluids have solid fraction of up to 50 %, yielding an opaque fluid. Any laser scattering method would only be suitable when the specimen is heavily diluted, which is not an ideal solution for autonomous and continuous operation.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

The JRP shall focus on the traceable inline measurement of viscosity and solids content in non-Newtonian fluids.

The specific objectives are

1. To develop a traceable calibration method for viscosity measurement devices measuring non-Newtonian fluids at a range of temperatures and of rates of shear in their operational environment.
2. To investigate the applicability of current viscosity measurement standards on non-Newtonian fluids. This should include:
    - wall slip in rotational viscometry
    - the time dependent behaviour of fluids (thixotropy)
    - high gel strength fluids
    - the accuracy of viscosity measurements at very low and very high shear rates
    - viscosity measurements of particle-laden fluids
    - the influence of solids content and particle size distribution on viscosity
3. To develop sensors and calibration methods for the inline measurement of viscosity, density, particle size distribution and solids content in non-Newtonian fluids.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the R&D work, the involvement of the user community such as industry, and standardisation and regulatory bodies, as appropriate, is strongly recommended.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

EURAMET expects the average size of JRPs in this call to be between 3.0 to 3.5 M€, and has defined an upper limit of 5 M€ for any project. Any proposal received for this SRT is expected to be significantly below 3.0 M. The available budget for integral Research Excellence Grants is 30 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (e.g. letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies

- transfer knowledge to the energy and industrial sectors.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] NORSOK D-001 Drilling facilities