Report Name: App Note 005-OLR

Measurement of greases using the OnLine Rheometer

The rheological properties of three extreme pressure greases were measured using the Rheology Solutions OnLine Rheometer (OLR).

A genuine process monitoring and control rheometer which can be operated in-line or on-line and measure the viscoelastic properties in a flow environment and in real-time has the potential to improve product quality and reduce processing costs.

Greases are viscoelastic fluids and knowledge of their rheological behaviour is essential to optimise the processing and quality control and dictate the flow properties of the final product.

ONLINE RHEOMETER

To date, the control of the properties of process flows has been attempted by the use of capillary viscometers, vibrating probe viscometers, and slit rheometers. In-line process viscometers by their very nature yield only viscosity data, and hence provide an incomplete analysis of viscoelastic fluids. All of the instruments mentioned above operate only at a single shear rate (or frequency), thereby potentially limiting the usefulness of the data.

If more detailed knowledge of the viscoelastic properties of the fluid is required to control the properties, quality, and reproducibility of the product, test volumes must be removed from the process stream and measured using an off-line laboratory rheometer. However, this is a time consuming procedure that may require the process line to be shut down until the results are available to confirm, or otherwise, the quality of the product. Alternatively, the process flow may continue with the potential loss of product. In some cases, the volume of lost fluid could be large and this could be particularly problematic when processing high-value materials (such as pharmaceuticals), products that cannot be reprocessed or products that incur a disposal cost (for example, an environmental levy).

Thus a genuine process monitoring and control rheometer which can be operated in an in-line or on-line configuration and measure the viscoelastic properties of a process fluid in a flow environment, and in real time, has the potential to improve product quality and reduce processing costs.

An online rheometer (OLR) has been designed which is capable of being used in industrial process flows as a process monitoring and control tool. The OLR uses a patented multi-frequency squeeze flow technique that allows the viscoelastic flow properties of a material to be measured over a wide frequency range in a very short time. The body of the rheometer is made from stainless steel and constructed such that no dead spaces exist that could potentially trap process fluid and lead to fouling or contamination of subsequent materials. The operation of the instrument is fully computerised. The measured rheological parameters can be used with (or without) a factory PLC as inputs for process control in a feedback system for monitoring and control the of the final product.

The modified Cox-Merz rule was applied to the rheological data as measured by the OLR and a controlled strain rheometer resulting in a very good correlation between the two sets of data.

LUBRICATING GREASE MEASUREMENTS

Lubricating greases are rheologically complex materials as they are required to provide a protective barrier under extreme operating conditions. Various materials are added to improve the operational behaviour of the grease. For example molybdenum disulphide is added in a fine powder form to the grease base to improve the load carrying and shock loading protection.

The National Lubricating Grease Institute (NLGI) has developed a grading system to quantify the consistency or hardness of greases. The greases investigated in this study are graded as NLGI No. 2 which corresponds to a worked penetration depth of 26.5 – 29.5 mm at 25ºC.

The penetration is measured using a conical penetrometer which is a standard procedure for quantifying the structure of a particular grease. This technique and others including the Lincoln Ventmeter pumpability test are single point measurements that can be indirectly related to the viscosity of the grease. These tests are however unable to fully characterise the rheological behaviour and hence the performance of the grease. Alternatively the OLR can measure the viscoelastic flow properties of a material over a range of frequencies in a very short time.

The rheological parameters of the three extreme pressure greases as measured using the OLR are shown in the following graphs. Figure 1 shows the elastic component or storage modulus G' as a function of frequency, Figure 2 shows the viscous component or storage modulus as a function of frequency and Figure 3 shows the complex viscosity as a function of frequency for three extreme pressure greases as measured by the OLR. The decreasing viscosity with increasing frequency (or shear rate) is known as "shear thinning". This behaviour is an essential characteristic of greases in order to facilitate lubrication at high frequencies during the movement of the lubricated surface. When the surfaces are at rest the viscosity of the grease increases providing a protective barrier.

One of the rheological parameters sensitive to changes within the process fluid (such as the storage modulus or the loss modulus in this case) can be used as a control factor in the feedback system to control the process and consequently determine the quality of the final product.

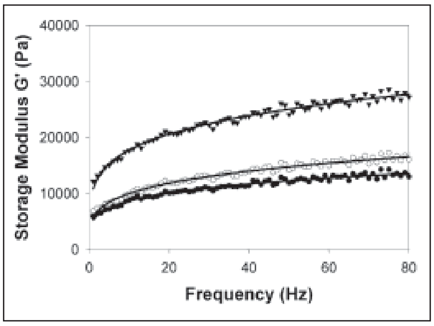

Figure 1: Storage modulus as a function of frequency for three grease samples.

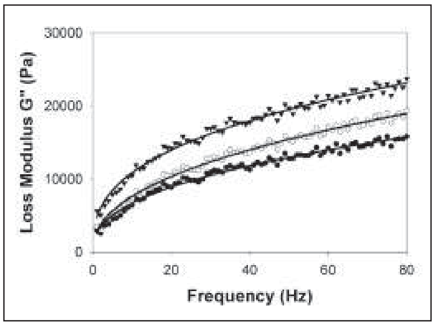

Figure 2: Loss modulus as a function of frequency for three grease samples.

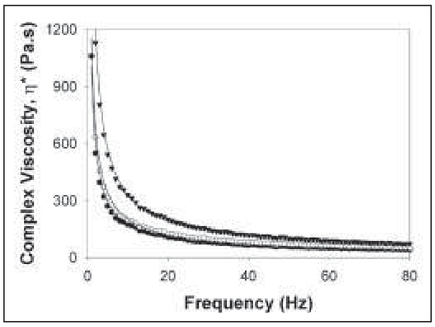

Figure 3: Complex viscosities as a function of frequency for three grease samples.