Report Name: App Note 003-OLR

Measurement of flowing sunflower oil using the OnLine Rheometer

Rheology Solutions OnLine Rheometer (OLR) is an innovative technology for measuring the flow properties of fluids within a process pipe.

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.

Flowing sunflower oil was measured using the online rheometer (OLR) to demonstrate the ability of the instrument to capture and release discrete samples. An excellent level of reproducibility was achieved.

ONLINE RHEOMETER

The measurement of the rheological properties of commercial fluids and their use in a production environment by necessity involves their determination in a non-static system. The removal of a sample for off-line measurement is both time consuming and, unless the process is halted, will not be representative of the process fluid after the measurement is complete. At its worst this will lead to product wastage and at best to the necessity of re- processing the fluid at some future time together with a time penalty.

Process viscometers by their very nature yield only viscosity data, and hence provide an incomplete analysis of viscoelastic fluids. Additionally most process instruments operate only at a single shear rate (or frequency), thereby potentially limiting the usefulness of the data.

Rheology Solutions has developed an OnLine Rheometer (OLR) which is capable of being used in industrial process flows as a process 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 and the measured rheological parameters can be used as inputs for process control in a Factory PLC control system to monitor and control the process, and consequently the quality, of the final product.

SUNFLOWER OIL MEASUREMENTS

In order to evaluate the rheometer under flow conditions, it is first necessary to determine the characteristics of the instrument under ideal conditions i.e. under static non-flow conditions. To this end, the rheometer and a 20 L reservoir were filled with sunflower oil and the oil was pumped through the system. The measurements involved capturing the sunflower oil sample between the plates and taking ten consecutive sets of data. The plates were then separated and brought together again 20 min later and the measurements repeated. This was repeated a further eleven times to bring the duration of the test to four hours. Static measurements (no flow) were also undertaken. In all cases (static and flow) the storage modulus or

The measurement of the rheological properties of flowing sunflower shows than a discrete sample of process fluid is captured and released and that the instrument is stable over extended measurement periods.

elastic component was zero over the whole frequency range as expected for a purely viscous oil. The loss modulus (viscous component) and the complex viscosity of the flowing sunflower oil as a function of frequency are shown in Figure 1 and Figure 2 respectively. The rheological properties as determined in a flowing system are very similar to those determined in a static system (less than 4 % difference).

CAPTURE AND RELEASE OF SAMPLES

The average complex viscosity of the flowing sunflower as a function of time is shown in Figure 3. Calculating an average of the complex viscosity over the frequency range is quite valid given that the sunflower oil is a Newtonian fluid (viscosity constant at all frequencies). During flow measurements the temperature of the oil increases due to the heating effect of the pump, hence the viscosity decreases. In order to show the reproducibility of the rheological measurements over time, the average complex viscosity data was corrected for changes in temperature. The result was a complex viscosity independent of time indicating that the observed change was due to hotter oil being successfully captured and measured. An additional experiment was undertaken to verify that trapping occurs. The oil in the reservoir was heated to 60ºC leaving the oil within the rheometer and the pump at room temperature (21ºC). Measurements were made over a period of 5 min without opening the plates, allowing the hot oil to flow around the trapped sample. The values of the loss modulus and complex viscosity remained constant over the measurement time indicating that trapping of the sample between the plates is effective.

REPRODUCIBILITY

The percent standard deviation of each complex viscosity measurement was between 1% and 2% for the static measurements and around 2% for the flow measurements. The percent standard deviation of the average complex viscosity with time was 0.17% for the static measurements and 0.24% for the flow measurements showing an excellent level of reproducibility.

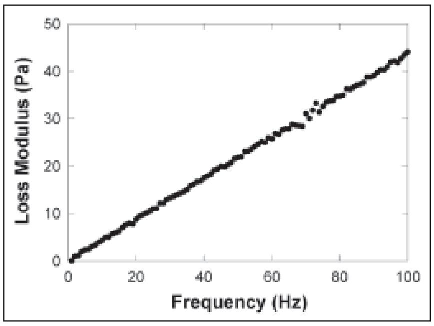

Figure 1 Loss modulus as a function of frequency for the sunflower oil under flow conditions.

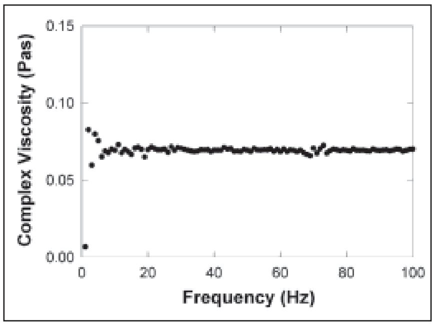

Figure 2 Complex viscosity as a function of frequency for the sunflower oil under flow conditions.

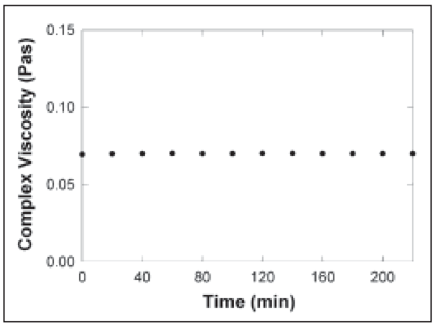

Figure 3 Complex viscosity as a function of time for the sunflower oil under flow conditions.

OLR_APPNOTE003