MultiScan MS 20

Stability Analysis of Temperature-Sensitive Cutting Fluids

dataphysics
Understanding Interfaces

Cutting fluids are essential in most metalworking processes (Fig. 1), as it should on one hand reduce the friction between the cutting tool and the surface as well as cooling it down. These two criteria can ideally be met by oil-water emulsions. However, these emulsions often have a critical temperature over which they collapse limiting their effectiveness tremendously. Due to the various applications in metalworking, stability in a broad temperature range or designed for a specific operation temperature is beneficial for a superior product. Temperature dependent stability analysis is thus an important tool to assist in the development of new cutting fluids with the desired capabilities and temperature range.

Fig. 1. Cutting fluid in metalworking processes.

Keywords: MultiScan 20 (MS 20) ▪ Cutting Fluids ▪ Temperature Dependent Stability Analysis

Technique and Method

A fast and reliable stability analysis of emulsions can be performed with the MultiScan MS 20 and its software MSC developed by DataPhysics Instruments.

For stability analysis, the MultiScan MS 20 measures in its Scan Towers time-, position- and temperature-dependently the transmission and backscattering of the sample. The instrument works with six independent Scan Towers (Fig. 2). Each tower comprises an internal heating device and respective temperature controllers. Hence, the MS 20 is optimally suited to study the temperature-dependent stability of systems like cutting fluids.

Fig. 2. DataPhysics Instruments stability analysis system MultiScan MS 20 with six independent Scan Towers.

In this application note we present a detailed temperature stability study of a commercially available cutting fluid.

Experiment

The sample was filled in a glass vial that was subsequently placed in a Scan Tower. Scans of the transmitted and backscattered light were performed in constant time intervals while a predefined temperature profile was executed. In the first experiment, the temperature was increased from 30 °C to 80 °C with increments of 10 °C. The heating rate was 60 °C/h while the dwelling time for each increment was 10 min (Fig. 3, top). In the second experiment, the sample was heated from 30 °C to 50 °C with increments of 5 °C and subsequently cooled to 30 °C. The heating rate was 2.5 °C/h with a dwelling time of 60 min per increment, while the cooling rate was 5 °C/h (Fig. 3, bottom).

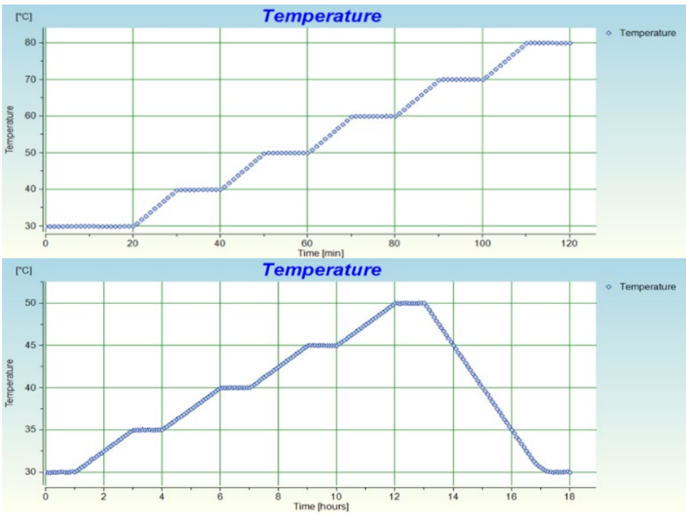

Fig. 3. Graphical representation of temperature profiles for the two experiments

Results

The obtained transmission and backscattering intensities are represented in intensity-position diagrams. Changes in the detected measuring signals provide information on the stability properties of the sample.

Figure 4 shows the transmission intensity of the cutting fluid over the scanning position for the first experiment. Each curve represents one single scan; the colors of the curves indicate the scanning time (from red, i.e. first scan, to purple, i.e. last scan, as shown in the colored legend bar on the right). The transmission intensity of the cutting fluid decreases over time. With the MSC software this decrease can be quantified using the Values evaluation method and plotting the mean transmission per scan over the time (see Fig. 5).

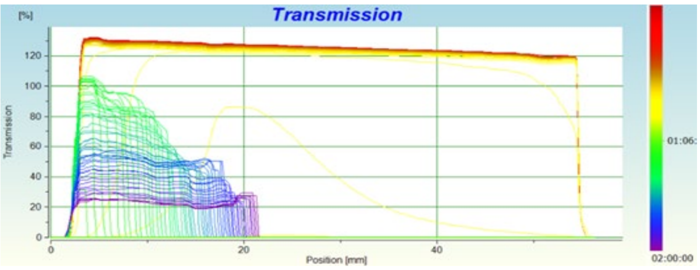

Fig. 4. Transmission intensity vs. position for the measurement of the cutting fluid.

Fig. 5 shows high transmission intensities in the beginning of the experiment which indicates that the cutting fluid is transparent emulsion at low temperatures. After 50 min, when a temperature of 50 °C is reached, the transmission signal immediately drops to 0%. It is concluded that the emulsion collapsed at this temperature. Upon further heating, at temperatures of 60 °C, the transmission increases again. Here, a phase separation is observed (Fig. 4): In the bottom of the vial a transparent phase accumulates under a still nontransparent upper layer.

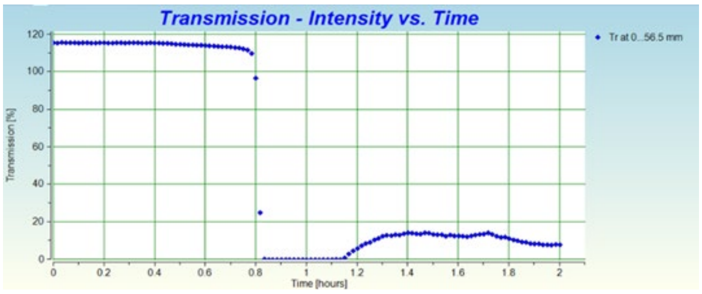

Fig. 5. Mean transmission intensity over time of the cutting fluid during the first experiment.

The MSC software can also calculate a stability index (SI) as a simple and comparable number that represents the stability of a system at a certain time. A low SI indicates a stable system. As shown in Fig.6, the system is stable during the first 50 min.

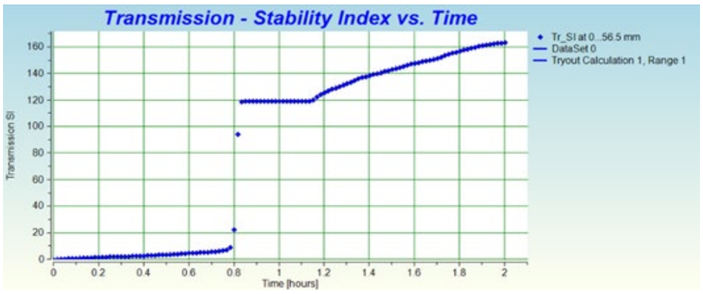

Fig. 6. Stability index (SI) plot of cutting fluid during the first experiment

Afterwards, the index increased, which supports the previous observation. The phase separation taking place after 70 min is a migration process (creaming of the oil droplets in water) for which the migration rate can be calculated with the respective function of the MSC software. For this purpose, the migration front position is plotted over time (see Fig. 7). From this plot an average migration rate of 0.27 mm/min was determined in the time span from 80 min to 120 min.

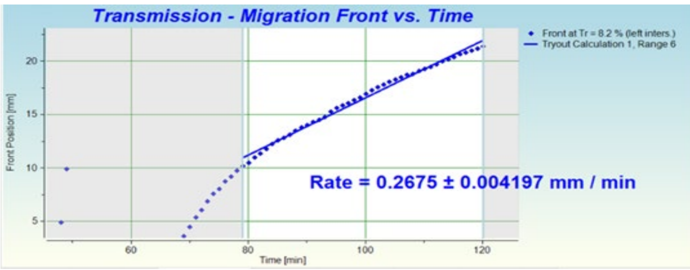

Fig. 7. Migration front analysis (between 79 min and 120 min) of the phase separation taking place during the first experiment.

To further investigate the temperature-induced collapse and its potential reversibility, the second experiment was performed. In this case the temperature was increased to 50 °C, where the emulsion collapsed previously. Afterwards, the temperature was decreased to 30 °C.

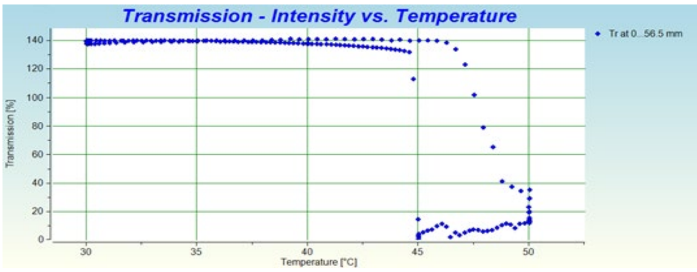

Fig. 8. Mean transmission intensity over temperature during the second experiment.

The reversibility of the temperature-induced transmission collapse of the cutting fluid is shown in Figure 8. Here the transmission intensity over the temperature is depicted. In this case the transmission drop occurred after 9 h and thus at a temperature of 45 °C. It was possible to identify the studied cutting fluid as an optically clear emulsion below temperatures of 45 °C. Above 45 °C a reversible phase separation of the system was observed. Hence, the lower heating rate provided a more precise result. When the cutting fluid was subsequently cooled, this led to a fast increase of the transmission intensity to the initial value which indicates the recovery of the initial emulsion.

Summary

MultiScan MS 20 stability analysis system provides a simple and reliable method to observe temperature-dependent changes in cutting fluid emulsions and analyze its thermal stability. Notably, the technique has internal heating device and respective temperature controllers, so that it can be used to develop and optimize the product at specific temperatures.

Literature

[1] Byers, J.P. (2006). Metalworking Fluids. CRC Press

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