A Microfluidic Technique for Measuring the Wax Appearance Temperature (WAT) of Crude Oils

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We present a novel technique for rapid measurement of the wax appearance temperature (WAT) of crude oil using a microfluidic device. The device comprises of a long (1 m) capillary with a cross-section of 50 μm x 50 μm, etched on to a silicon substrate. The technique is based on accurate pressure measurements across the device to detect changes in cross-sectional area of capillary due to wax deposition. The Poiseuille law dictates that when a fluid travels through a capillary at low Reynolds numbers, the flow rate correlates strongly with the capillary radius: $Q \sim R^4$. Therefore, small changes in radius due to deposition of wax can be accurately detected by monitoring the changes in flow rate or the pressure across the capillary. Due to the small thermal mass of the device, the temperature of the system can be changed quickly. By monitoring the differential pressure, a rapid pressure increase was observed as sample temperature was systematically decreased to wax appearance temperature. The relationship between the rate of pressure changes and the sample temperature was used as the working principle in the proposed WAT measurement technique.

This technique was validated systematically by measuring the solid-liquid phase boundaries for single-component and multi-component synthetic samples, as well as crude oils. The measurements agreed well with literature data and cross-polar microscopy measurements. The crude oils used in this study were stock-tank samples with wax content ranging from 2.5-11 wt. %. The microfluidic device offers a simple and rapid measurement technique that is suitable for field applications. The technique can be extended to study rheology of live waxy oil and also to simulate flow assurance issues such as restart pressure.