Viscosity Flow Curve Tells All

flow behavior

Characterizing any material for flow behavior involves testing it over a range of shear rates relevant to how it is processed in manufacturing or how it is used by the consumer. Ointments, for example, are used to coat human body parts like skin, lips, finger/toe nails, hair, eyeballs, etc. The coating action is such that the medicinal mixture, once applied to the surface of the object, spreads as it is rubbed into place. Therefore, a relevant viscosity test would employ shear rates that mimic this type of spreading action.

Squeezing the ointment out of the tube is another type of flow behavior that should be tested for acceptable performance. The situation that we are all familiar with is not being able to get the ointment out of the tube, no matter how hard we squeeze. This type of flow behavior measurement is known as "yield stress" and it quantifies the force needed to initiate flow of material out of the tube.

It's worth noting that pharmaceutical marketing departments have increased their focus on product packaging to make sure that the customer experience is acceptable in all respects. This includes providing user friendly tubes which open easily and expel controlled amounts of the ointment according to the recommendation of the physician.

Figure 1 displays a cone/plate rheometer which is typically used to characterize flow behavior of ointments. Test material is placed on the flat metal plate and the cone spindle is brought down into contact with the ointment, causing a spreading action. Sample material will flow out to the circumference of the cone spindle and perhaps beyond if there is too much sample volume. The excess material is removed and the instrument is ready to run tests.

Cone spindles look like they have a flat bottom, but there is a slight angle of perhaps 1° or greater relative to horizontal. Because the geometry is precisely defined and there is a known "gap" between the plate and the rotating surface of the spindle, shear rate and shear stress are calculated using the equations in Figure 2.

Measuring yield stress can be accomplished by one of two methods. The first is to gradually increase the torque applied to the spindle until rotational movement is detected. The torque value at which rotation commences is called the "yield stress". The second is to run a shear rate ramp from a low rotational speed to a high speed, then use a math model to find a best fit line through the shear stress vs. shear rate data. Point of intersection for the best fit line with zero shear rate is by definition the yield stress because there is no flow movement at this shear rate value. The values for yield stress measured in these tests correlate with the squeezing action on the tube .

Figure 3 shows graphical data for a yield stress test using the second method. The math model used to evaluate the data is called "Ostwald". The yield stress value for this ointment appears to be around 350 Pascals.

Figure 1: Brookfield RS Rheometer with Cone and Plate Geometry

Figure 2: Equations for Shear Stress and Shear Rate

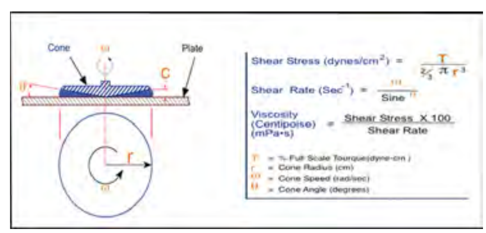
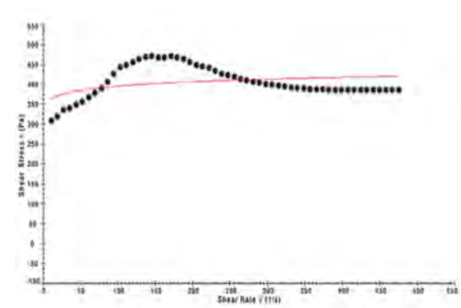


Figure 3: Graph of Data from Yield Stress Test Using Ostwald Math Model



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Viscosity "flow curves" are generated by testing the ointment over a range of shear rates, using the shear rate ramp mentioned above. Typical flow behavior for ointments exhibits very high viscosity values at low shear rates and decreasing viscosity values as the shear rate increases. "Pseudoplastic" is the term used to describe this phenomenon. Figure 4 shows a viscosity flow curve for a commercially available ointment.

Reversing the shear rate ramp gives additional information on the time sensitivity of the ointment to the shearing action. The spatial separation of the viscosity data from the two shear rate ramps can be quantified by calculating the area between the two curves. This numerical value is referred to as the "thixotropy" of the ointment. Figure 5 shows this property.

Controlled stress rheometers, like the instrument shown in Figure 1, provide an advantage when performing these tests because they operate in both controlled shear stress (torque) mode as well as controlled shear rate (rotational speed) mode. The stress mode is especially advantageous when measuring highly viscous materials because the torque applied to the spindle is increased gradually until movement commences. This is a preferred method for testing flow behavior to simulate the startup torque conditions on a pump motor when processing the ointment. Should you have the opportunity to consider this type of instrument for your laboratory, you will be impressed with not only the data, but also the speed and efficiency with which the controlled stress instrument completes the testing.

Figure 4: Graph of Viscosity Data from Shear Rate Ramp

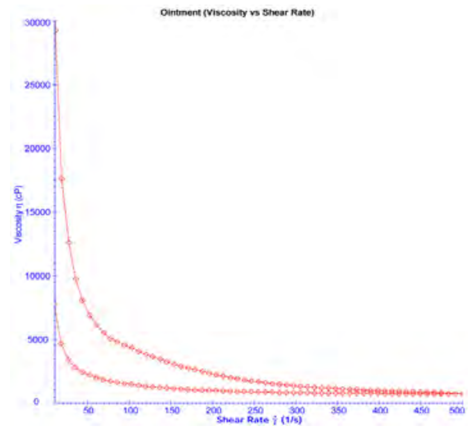
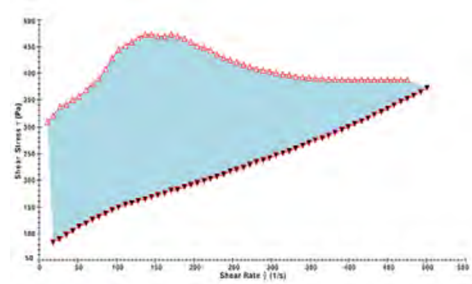


Figure 5: Graph of Data Used to Calculate Thixotropy of the Ointment



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