I recently realized that, in 10 years of writing “Coatings Clinics,” I had never written one on leveling. So, here it is.

When paint is applied, it rarely is smooth. It usually has a non-uniform thickness with irregularities such as brushmarks, orange peel, roughness, or patterns. The term leveling refers to the flowout of these often ugly surface characteristics. It is a process that receives little notice when it works well, but the effect is very apparent when it does not. The driving force for leveling is surface tension, which acts to reduce the surface area to a minimum, thereby promoting a smooth, even surface. Viscosity, viscoelasticity, and yield behavior act to resist this flow, and their influence increases as the coating loses volatiles and begins to dry and/or cure.

One way to look at leveling is in terms of leveling time, a simplified expression for which is:

\[ t = \frac{\eta G}{\sigma T^3} \]

where \( \eta \) is the viscosity, \( G \) characterizes the changing geometry of the brushmark or other irregularity, \( \sigma \) is the surface tension, and \( T \) is the film thickness. The leveling time must be minimized in order to have leveling occur before loss of solvent and building of structure stops or greatly reduces flow. Based on the equation, more rapid leveling may be achieved by lowering viscosity, increasing surface tension, or applying a thicker film. Unfortunately, raising surface tension may affect wetting of the substrate and a thicker film may not be desirable, so reducing viscosity often is the only practical choice among the three.

However, if the film can be kept open longer, then it is likely that both the rates of increase of viscosity and decrease in film thickness will be lower. The time over which leveling occurs can be stretched through the use of slower solvents, less or a weaker thickener, and with baked coatings, the use of less crosslinker or a weaker catalyst.

It is possible to predict the leveling tendencies of a formulation by characterizing its viscosity behavior using a step-shear method similar to that used to follow thixotropic recovery. The idea is to begin with a shearing action comparable to application, followed by immediate application of low shear stress, low shear rate motion, and measurement of the resultant viscosity behavior of the paint over a period of several minutes. A controlled stress rheometer with a wide shear stress range and the ability to quickly drop the applied shear stress to a low level probably would be the best choice. Such measurements can follow the increase in viscosity with time regardless of whether it is caused by the building of structure or simply by the increase in solvents through loss of solvent.

A useful technique is to compare the smoothness of films after application and drying/curing using a profilometer. This has been coupled with a rolling ball technique that can follow viscosity changes over time at low shear stress after paint has been applied [A. Quach and C.M. Hansen, *J. Paint Technol.*, 46 (592), 40 (1974)]. Latex paint was applied with a spiral-wound drawdown bar and, after drying, the surface waviness profile was measured with a contact profilometer. The viscosity measurements involved rolling small stainless steel balls down a wet coating film on an inclined surface a number of times while the coating dried. The viscosity is inversely proportional to the velocity of the ball. The beauty of this method is that it is carried out under the actual conditions of leveling and drying. The evaporation of volatiles is taken into account inherently, and the shear stresses exerted by the rolling sphere should be comparable to those that exist at the beginning of the leveling process. Quach and Hansen found that the paints that leveled better showed slower increases in viscosity following application.

I have used rolling ball viscosity measurements more for evaluating sag and crater resistance than leveling [C.K. Schoff, *JCT CoatingsTech*, 4 (8), 72–77 (2007)], but Figure 1 shows results for a series of high solids industrial coatings that exhibited differences both in leveling and sag. Coatings B and D leveled well, but sagged, coating C had both adequate leveling and sag resistance, and coating A had excellent sag resistance, but did not level.