TA Instruments

Thermal Analysis & Rheology

RHEOLOGY SOLUTIONS

THE USE OF CREEP TO DETERMINE SEDIMENTATION VELOCITIES OF CONTACT LENS DYES

PROBLEM

Contact Lenses are usually transparent and colorless but recently there has been a demand for manufacturers to provide tinted contact lenses to either augment natural coloring or to change the color of the eye completely.

A well-known lens manufacturer used a printing process to apply a variety of colors to transparent lenses. While the printing process itself was relatively simple, with time the various pigments in the dyes tended to settle giving rise to inconsistent color distribution. This was not an acceptable situation. Therefore, a method that could predict which dye might cause a problem, and preferably how frequently a batch of dye should be stirred or replenished, was required.

SOLUTION

The major problem encountered by the manufacturer was that each color behaved differently. Some showed little sedimentation while others caused problems after a matter of minutes. From a rheological point of view sedimentation is a gravity driven process dependent upon a variety of factors including the size of the suspended particles and the density and viscosity of the suspending medium.

Using the creep technique it is possible to predict either relative or absolute sedimentation rates. To obtain an absolute value it is necessary to know the density, volume and radii of the particles (assumed to be spherical), and the density of the surrounding medium. The steps necessary to calculate the sedimentation velocity are:

1. Calculate the cross sectional area (A) of a single particle

$$A = \pi R^2$$

2. Calculate the stress (σ)

$$\sigma = F/A$$

$$F = M \bullet g$$

where M = Mass of a particle
g = Acceleration due to gravity

3. Use this stress to carry out a creep experiment and analyze the resultant data to reveal the Newtonian viscosity (η).

4. Calculate the settling velocity (v) using:

$$v = \frac{2(\rho_s - \rho_l)gR^2}{9\,\eta}$$

where ρ_s, ρ_l = density of solid and liquid phase respectively
g = acceleration due to gravity
R = radius of spherical particles

If the 'shelf life' (t) is required, it can be determined thus:

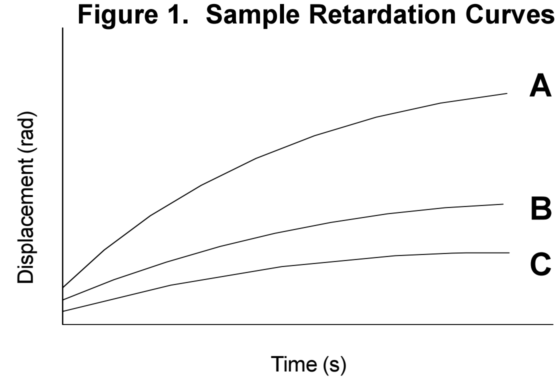
$t = d/v$ where d = acceptable settling distance.

If details regarding the particle mass, density and radius are not known it is still possible to determine a relative sedimentation rate by applying the minimum stress which forces the sample to just move. From the resulting creep curves of displacement against time it is possible to say which sample is likely to settle quickest. It was this technique which was used with the contact lens dyes.

Retardation curves for samples A, B and C (three different colors) are shown in Figure 1.

Sample A showed a more viscoelastic response (denoted by the amount of curvature). However, the fact that the attained displacement at any time was much greater than with either B or C indicated that the sedimentation velocity would be faster. On the other hand sample C would have the slowest sedimentation velocity.

Figure 1. Sample Retardation Curves



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