Creep in Crosslinked Polymers

Creep is defined as the time-dependent strain $\gamma(t)$ developed by a sample when a stress σ is applied. The amount of creep depends on the *compliance* of the sample, *J*(*t*), which relates the stress to the strain as:

$$\gamma(t) = \sigma J(t)$$

For a perfectly elastic material, the compliance is the inverse of the modulus (i.e. a less stiff material is more compliant). For most samples, however, the different time dependencies of these functions results in more complex relationships.

Creep is an issue in orthopedic devices containing a polymeric component, such as the ultrahigh molecular weight polyethylene acetabular liner in a total hip replacement. These components are machined to tight tolerances, and long-term stability of the implant depends on maintaining these tolerances dimensions in the body. If the liner undergoes creep, or room-temperature flow, upon application of a stress such as body weight, the leg can shorten or dislocations can occur. Minimization of creep is thus desired.

It is virtually impossible to completely eliminate creep. The very nature of polymeric components allows chain motion, and subsequently some flow, when enough energy is introduced into the polymeric system. Application of stress is one such example of energy introduction. Methods exist for minimizing creep, however. Given enough energy, polymer molecules will move until they encounter an obstruction, which pins them, preventing further movement. Examples of obstructions include crystals, external additives, entanglements from other molecules, or covalent bonds.

In the latter case, crosslinking will minimize bulk chain motion that can lead to creep, effectively reducing the compliance over time. A crosslinked system will creep initially as the polymer molecules attempt to flow under the influence of an applied load, effectively rearranging the entangled nest of molecules. Once they are stretched taut against the crosslinks, however, no further flow is possible, and creep stops. Effectively, the compliance has shifted from that of an uncrosslinked system to a steady state *plateau compliance*. This phenomenon is routinely observed in crosslinked polymeric implants, where initial creep is observed in the first year of *in vivo* service, often termed a "bedding-in" period, but no further creep is observed after this point. Wear, however, may continue, and often manifests itself as creep. Creep results in no volume change, and is merely a rearrangement of the polymeric material. Wear does result in volume loss, however.

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