

*The Stress Dependence of Creep of Polyethylenes*

High polymers are nonlinear in their behavior in that doubling the load in a creep test always more than doubles the creep after a given length of time. In some cases, at least, the stress dependence of the creep follows approximately a hyperbolic sine function:<sup>1-6</sup>

$$\epsilon(t) = K(t) \sinh (\sigma/\sigma_0) \quad (1)$$

where  $\epsilon(t)$  is the creep elongation at any time  $t$ ,  $K(t)$  is a function defining the time dependence of the creep,  $\sigma$  is the applied stress, and  $\sigma_0$  is a material constant. The creep is fairly linear up to stresses equal to  $\sigma_0$ ; at higher stresses the creep becomes very nonlinear.

Several hundred creep tests have been made on polyethylenes of two densities (0.950 and 0.955) both filled and unfilled over the time range of 0.1 to  $10^4$  min. The fillers were kaolin at a volume fraction concentration of 0.20 and wollastonite at volume concentrations of 0.2, 0.3, and 0.4. Tests were made at 22, 50, and 60°C at loads of 300, 500, 750, and 1000 psi. Complete details and other aspects of the creep behavior will be published separately;<sup>7</sup> just the stress dependence and the variation in  $\sigma_0$  will be discussed here.

Because of the nature of creep tests and probably the difficulty in producing identical specimens, there was considerable scatter in the data on stress dependence and, therefore, relatively large variations and errors in the values of  $\sigma_0$ . However, since a very large number of tests were made, it is believed that significant averages could be obtained from which several conclusions can be drawn. Equation 1 is not completely adequate to describe the stress dependence, but little effort was made to find an expression better than the hyperbolic sine function. The inaccuracy of this function shows up as a general variation in  $\sigma_0$  with load;  $\sigma_0$  tended to increase with load rather than being a true constant.

The presence of filler particles had little if any effect on  $\sigma_0$ . This is to be expected if the filler does not change the inherent properties of the polyethylene matrix. Even though the fillers greatly increase the elastic modulus and thus bring about a decrease in  $K(t)$ , the hyperbolic sine function remains nearly unchanged by the filler.

As shown in Table I,  $\sigma_0$  gradually decreases with temperature, especially with the lower density polymer. At 60°C the value of  $\sigma_0$  is considerably smaller for the polymer with the 0.950 density. Although the standard deviations of  $\sigma_0$  are large, the consistent trends in the data indicate that the above conclusions are probably valid. Turner<sup>6</sup> found a similar trend with density although the values he reported are somewhat larger than those given in Table I. For instance, Turner's value of  $\sigma_0$  for a polyethylene density of 0.950 at 20°C is 850 psi for unfilled polymer.

TABLE I

Polymer density	Temperature, °C	$\sigma_0$ , psi	Standard deviation, psi
0.950	22	622	145
0.950	50	453	57
0.950	60	390	86
0.955	22	565	141
0.955	60	507	129

**References**

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