E-5 A NOTE ON THE ENVIRONMENTAL STRESS-CRACKING OF POLYETHYLENE : EFFECT OF TEMPERATURE ON THE TIME TO CRACK

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If polyethylene is subjected to multiaxial stresses in the presence of certain environments, the material will suffer brittle fracture by cracking which does not occur in the absence of these environments.

The authors previously (1, 2) studied the effects of stress, environment and temperature on the environmental stress-cracking of a high-density polyethylene, with a tubular specimen under uniaxial or biaxial stress conditions. Test results were represented as a generalized master design curve expressed by the functions of stress, work of adhesion and temperature (Fig, 1).

In this short note, the relationship between temperature and time to crack is discussed, paying special attention to the change in structure of a material during the test.

Fig. 2 shows the temperature dependence of the time to crack. An increase in temperature tends to decrease the time to crack more remarkably than expected from the rate-process theory. This suggests that, at higher temperatures, the structure of a material changes appreciably during the test period. In fact, this consideration was proved to be valid by the aid of electron micrographs. Photo. 1 indicates the microstructure of a material before testing, while Photos. 2 - 6 are after testing. Photos. 5 and 6 provide direct evidences of the change in microstructure caused by the temperature effect under loading. It was also recognized that the change in microstructure was clearly seen at a temperature higher than 40°C (Photo. 3), and it becomes more remarkable both with increasing temperature and with decreasing stress. However, in a higher stress region, the change was not so clear even at 50°C, because it was extremely localized (Photo. 4).

Consequently, the following modified rate-process theory should be applied to the phenomenon in question, namely:

$$r = S(T,t,\sigma)\exp(-Q(\sigma)/RT)$$

where r is the rate of process and $S(T,t,\sigma)$ a structure parameter depending on temperature T, time t and stress σ.

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References

1. Suezawa, Y., Hōjō, H. and Ikeda, T., Materials Research and Standards, Vol. 3, No. 7, 550, 1963.

2. Suezawa, Y., Hōjō, H., Ikeda, T. and Okamura, Y., Materials Research and Standards, Vol. 5, No. 2, 55, 1965.

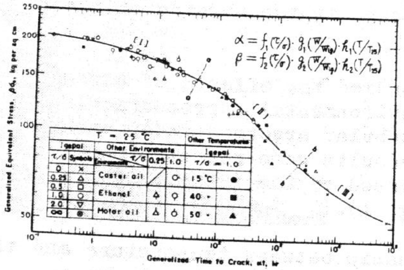

Fig. 1. Generalized master design curve for environmental stress-cracking of high-density polyethylene at an arbitrary test condition.

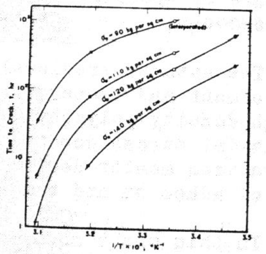

Fig. 2. Relationships between time to crack and the reciprocal of temperature for various stresses.

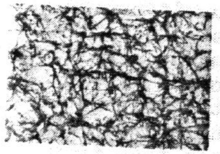

Photo. 1. Microstructure of polyethylene before testing. 4800X

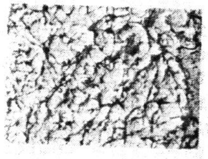

Photo. 2. Microstructure of polyethylene after testing (T=25°C, σ_0=80 kg/cm², t= 2165 hr) 4800X.

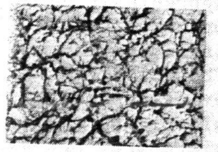

Photo. 3. Microstructure of polyethylene after testing (T=40°C, σ_0=65 kg/cm², t= 1744 hr) 4800X.

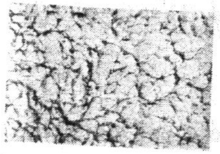

Photo. 4. Microstructure of polyethylene after testing (T=50°C, σ_0=120 kg/cm², t= 1.17 hr) 4800X.

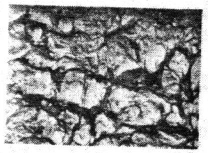

Photo. 5. Microstructure of polyethylene after testing (T=50°C, σ_0=80 kg/cm², t= 66.5 hr) 4800X.

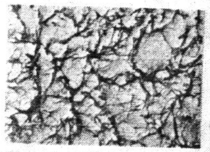

Photo. 6. Microstructure of polyethylene after testing (T=50°C, σ_0=55 kg/cm², t= 174 hr) 4800X.