MULTIPLE FRACTURE OF POLYMERS

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Plastic flow of polymers is analyzed for the extrusion in solid state. The conditions are determined to obtain samples without defects and with the increased values of strength and stiffness. The types of defects and the reasons of their formation are studied. It is determined that the loss of stability if plastic flow takes place under certain conditions. The criterion of the formation of unstability is suggested. It is shown that the formation of defects for the temperatures depends on the processes of melting and crystallization. The multiple fracture of material and the formation of powder proceeds when the material is crystallized during the plastic flow. The mechanism of multiple fracture is suggested.

INTRODUCTION

The application of the theory of volume pressure of metals is difficult due to the change of mechanical properties of polymers during the extrusion in solid state.

We suggested the model of plastic flow which takes into account the orientation of a polymer during the extrusion in solid state (1). In this case we obtain defectless transparent samples with smooth surface and high σ_f (Fig.1). When the rate of the movement of the piston V_p increases over a certain value σ_f decreases sharply. This fall of σ_f is caused by the formation of defects. The defects of two main types are seemed to be formed. The first type of defects is due to sharp opaqueness along the axis of the extrudate.

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The second type of defects is caused by the distortion of a cylinder form and the formation of spiral cracks on the surface of the extrudate. The appearance of the defects of the first type is similar to the beginning of turbulence and the formation of the defects of the second type signifies the transition to a certain periodic regime.

During the plastic flow of polymers the two processes compete:1) storage of reversible elastic deformation and 2)irreversible viscous flow. However, a polymer is able to accumulate the reversible elastic deformation only within certain limits and after reaching this limit the stability of the plastic flow is lost. There is the critical value of D when the loss of stability takes place

$$\mathcal{D} = \dot{\varepsilon}\,\tau \qquad (1)$$

If we assume that τ is described by Arrhenius law we obtain

$$\frac{u}{RT_e} + \ln c = \text{const} \qquad (2)$$

Thus we have the explanation of alignment the curve of defects formation in Fig.2.

The transfer to irregular regime takes place according to Feigenbaum mechanism, that is by the series of consequitive doubling-of-period bifurctions.

When extrusion takes place in isothermical regime of $T_e \lesssim T_m$ the spiral defects of the second type are formed. When When during the extrusion T_e increases from 75^o to $T_e \gtrsim T_m$ only spiral defects are formed. When T_e decreases from $T_e \gtrsim T_m$ to 75^o we obtain another pattern of fracture of extrudates: at the beginning the recooled melt of polymer gets out of the die and then the bar is swarmed by the flocks of polymer powder. When T_e decreases further the diameter of the bar decreases and the layer of the flocks increases. Then the flocks fall off easily and we obtain the powder. Thus, crystallization of a polymer is the main factor of multiple fracture of polymers and of the formation of powder during extrusion. The polymer can essentially accumulate ε_e during crystallization and when $\varepsilon_e \sim \varepsilon_f$ the polymer is destroyed. The boundaries of crystallites are the embroys of polymer fracture.

SYMBOLS USED

σ_f = tensile strength (MPa)
D = Deborah number
τ = effective relaxation time
$\dot{\varepsilon}$ = effective strain rate
c = critical rate of extrusion
U = energy of activation
R = gas constant
T_e = temperature of extrusion
T_m = temperature of melting
V_p = rate of piston movement (mm/min)

REFERENCES

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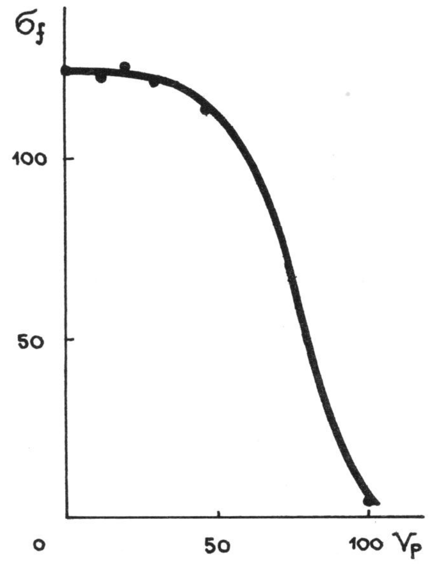

Fig.1. Influence of V_p on σ_f. $T_e = 85^o$

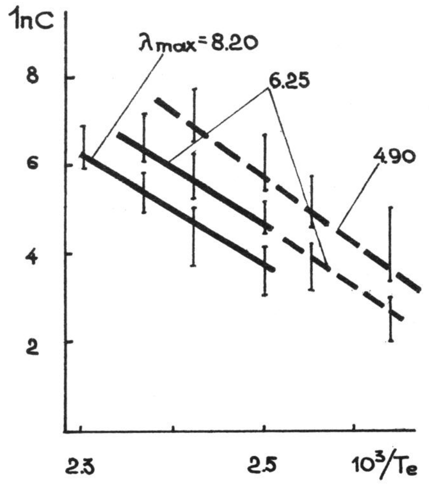

Fig.2. Influence of T_e on C.