Cast Film Quiz

Solutions

1.) Film thickness decreases exponentially, localized film velocity increases exponentially, and film temperature decreases linearly as the film moves away from the die

2) $\rho Q C_p \frac{\partial T}{\partial z}$ = heat removed in the gap $= -2wU(T-T_{air}) - 2\varepsilon\lambda w(T^4 - T_{room}^4)$

if the amount of heat to be removed and the volumetric flow are to be held constant and we assume that at the given conditions $\frac{\partial C_p}{\partial T} \approx 0$, we have:

$$\frac{\partial T}{\partial z} \propto \frac{-\text{constant}}{\rho}$$

This means that the cooling rate in the gap between the die and the chill roll is slower for the higher density polymer, which makes sense if you consider the higher density polymer would have a higher ΔH, meaning that more energy would have to be removed on a mass basis to induce crystallization and lowering of the film temperature below its T_c. From a commercial process perspective, the chill roll temperature would have to be lowered to remove the additional heat.

3.) $$\sigma_{11} wh = -2Q\eta_0(\pi)\left(\frac{1}{w}\cdot\frac{\partial w}{\partial z} + \frac{2}{h}\cdot\frac{\partial h}{\partial z}\right)$$

so: $\sigma_{11} \propto \eta_0$

choosing a polymer with higher shear viscosity would increase the stress in the machine direction.

The increase in stress in the machine direction would be observed with an increase in the winder tension (F_L).

Cast Film Quiz - continued

Solutions

4.) The heat balance around the film extrudate is given by:

$$\rho Q C_p \frac{\partial T}{\partial z} = -2wU(T-T_{air}) - 2\varepsilon\lambda w(T^4 - T_{room}^4)$$

Assuming ρ, Q, C_p, λ and the convective part of the heat transfer, the geometry, and the temperature of the film at z and the air remains constant, we have:

$$\frac{\partial T}{\partial z} \propto -C_1 - C_2\varepsilon(T^4 - T_{room}^4) \quad \text{where } C_i \text{ is a constant}$$

The carbon black film will have a higher emissivity than the clear film since it emits more energy than the clear (closer to a "black body")

$$q_{CB} > q_{clear}$$

$$\varepsilon_i = \frac{q_i}{q_{black}} \quad \text{so:} \quad \varepsilon_{CB} > \varepsilon_{clear}$$

So the magnitude of the left hand side becomes large, resulting in a greater rate of heat transferred rate from the film to the surrounding air.

5.) A faster quench rate would result in a lower percent crystallinity in the film, as shown by the Avrami equation:

$$\ln(1-X_c) = kt^n$$

A lower percent crystalline film will have better clarity since there would be fewer crystals to diffract the light passing through the film. Increasing the quench rate in a commercial process can be achieved by running faster line speeds, shortening the gap between the die and the chill roll, decreasing the chill roll temperature, or by using an air knife with refrigerated air to pin the molten curtain to the chill roll