Polymer Processing Lab 4

Plasticating, Single-Screw Extruder.

Objectives: To become familiar with a simple lab-scale, single-screw extruder. The purpose of this lab is to observe several features of melt flow in an extruder, shark skin, melt fracture, die swell, as a function of extruder temperature (barrel and die) and screw rate as well as to determine the residence time for the extruder under several conditions.

Background: Middleman Chapter 6: Extruder (See Web).
Middleman Chapter 12: Short section on Extruder P. 323-327.
Middleman Chapter 14: Elastic Phenomena (Die Swell, Melt Fracture).

Tadmor and Gogos: Chapter 10 Section 10.3 pp. 347-60, Chapter 11 pp. 452-461, Chapter 12 pp. 467-518, Chapter 13 pp. 521-551. Many other parts of Tadmor deal with the extrusion process as it is the main work-horse for polymer processing.

The extruder that will be use is similar in design to that shown in TG Figure 12.7 on pp. 468. The dies are single hole dies of 1/16, 1/8 and 1/4 inch diameter, the die length is about 1 cm. The extruder is about 1 foot in length. The screw can run at two speeds, slow and fast and the temperature in the barrel and die can be controlled independently.

A) Die Swell:

Measure the die swell ratio (TG pp. 533 M section 14-1) for three die temperatures and two screw rates using a ruler for the two larger dies (6 runs). Measure the torque on the screw using the ruler approach used in the mixing lab. Cut 10-second samples to estimate Q for these situations (weigh in 513). Assume that the viscosity is inversely proportional to the weight (and proportional to the torque) of the 10-second samples and attempt to construct a plot similar to TG Figure 13.12 and M Figure 14-12 but with temperature as the x-axis.

B) Melt Fracture and Shark Skin:

We will attempt to produce helical distortions of the melt flow and shark skin behavior which is discussed on TG pp. 539 to 542 M section 14-2. This will be done using the largest die (1/4 inch diameter) and variation of the die temperature for PS or PMMA resin.

Wind the melt on a mandrel and see what the effect of drawing the melt from the die has on this effect (TG pp. 542, M section 14-2).

Once the conditions for melt fracture have been met for the large die, the die will be swapped with the smallest die to demonstrate that smaller D_0/L decreases the severity of this entrance effect (TG pp. 540 middle of the page M p. 475).

C) Residence Time: (M section 12-4)

Measure the shortest and longest residence time for the blue color concentrate and for the black color concentrate using HDPE resin.

The shortest residence time, t_0, can be calculated using TG equation 11.10-13 on pp. 456

$$t_0 = \frac{3z}{2 V_{bz}\left(1 + {Q_p}/{Q_d}\right)}$$

$$Q_d = {V_{bz} W H}/{2}$$

$$1 + Q_p/Q_d = Q/Q_d$$

in terms of the helical distance, Z, the velocity down the barrel, V_{bz}, and the ratio of pressure to drag flow, Q_P/Q_d, figure 10.14 pp. 355.

Measure the shortest residence time for the three dies at the two speeds (fast and slow) under the same conditions and assume that Q_P/Q_d is -1 for the smallest die at the highest rate of screw rotation. Convert the two screw rates by assuming that $V_{bz\ slow} = (\Omega_{slow}/\Omega_{fast})V_{bz\ fast}$. You will need to measure the rotational velocity of the screw, Ω, for the two speeds.

Plot Q_P/Q_d, obtained from equation 11.10-13, versus D_0/L for these dies. Estimate the mean residence time for the three dies at the two speeds and compare this with $t_0 + (t_\infty - t_0)/2$. Estimate the total flow rates out of the extruder by taking 10-second samples and weighing. Plot this 10-second flow rate versus $(1 + Q_P/Q_d)$ to demonstrate the validity of equation 11.10-13.

Figure 11.34 shows that mean strain decreases with increasing Q_P/Q_d. We also know that the cumulative strain is related to how well a sample is mixed. Is there any evidence for better mixing in samples taken with lower Q_P/Q_d? (i.e. the smallest die?)

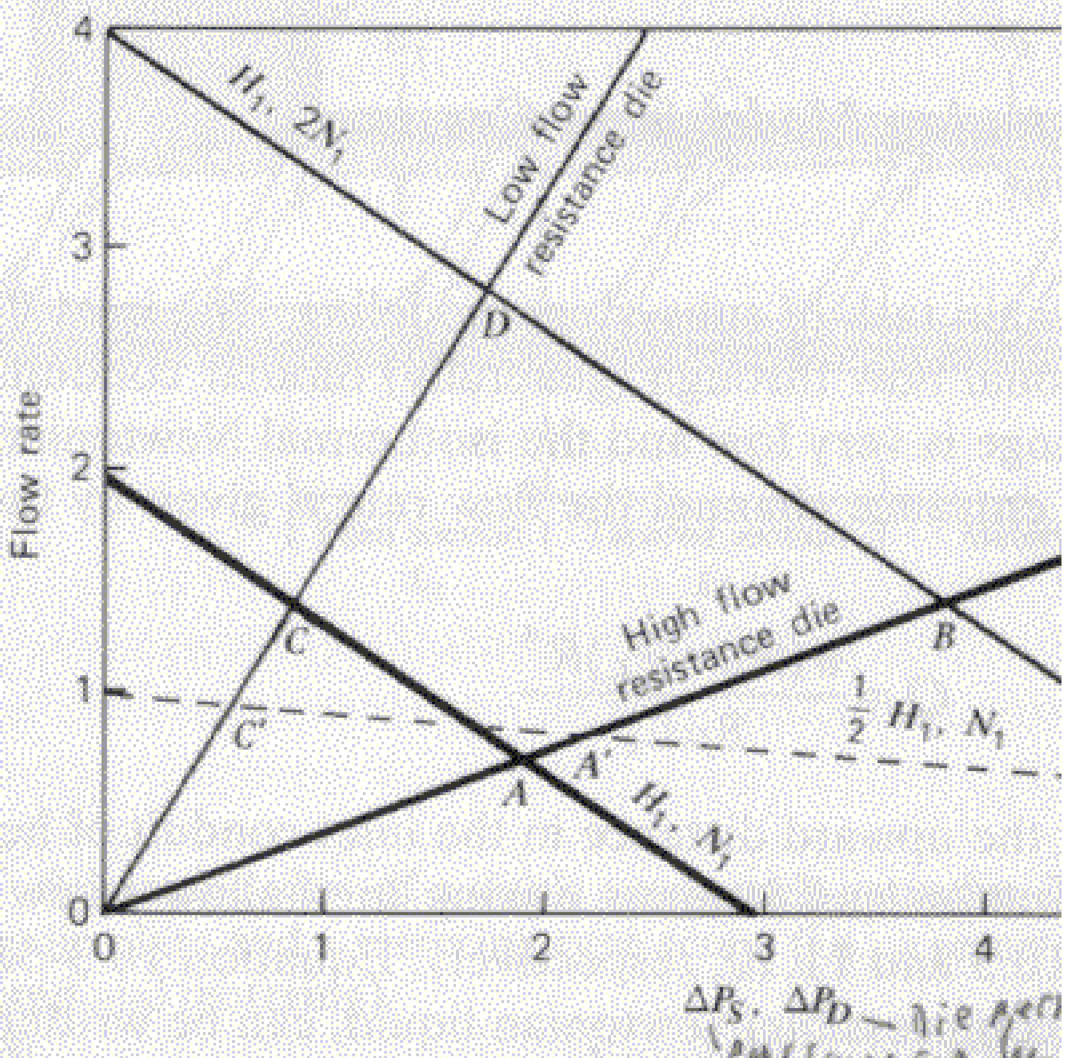
Required Analysis (Summarized from above).

1. Construct a figure similar to TG figure 13.12 from your data (M section 12-4, M 14.15 p. 470).
2. Discussion of shark skin and melt failure with processing conditions (M chapter 14).
3. Calculate t_0.
4. Plot Q_p/Q_d (11.10-13) versus D_0/L
5. Estimate mean residence time from your measurements and compare with calculation (Use above equation and M Equation 12.90).
6. Plot measured flow rate versus $(1+Q_p/Q_d)$
7. Discuss mixing in the extruder with respect to processing conditions as mentioned above.

Questions:

1. The important parameters for an extruder are the channel depth, channel width, unwound channel length, flow resistance of the die, rotational velocity of the screw, flight angle, and melt viscosity. For a given set of parameters, **is it possible** to say that an increase in channel depth will lead to an increase in flow rate from an extruder? Why? (See TG figure 12.3). Explain Answer.

its level and slope.



2.

3.
4.
5.
6.
7.

Fig. 12.3 Schematic view of screw and die characteristics
isothermal flow. The points where screw and die characteristi
points. The effect of screw speed and channel depth on the lo
demonstrated.

PART B. With this extruder it is difficult to get shark skin and melt fracture with HDPE or PMMA. It is pretty easy to get it with PS. The black color concentrate is in a PS base and will melt fracture easily. This should be run last as it makes everything black for a few days.

The extruder should be rinsed with HDPE before shutting down.