

Corrections to flow data in polymer melts

Narongrit Sombatsompop Polymer PROcessing and Flow (P-PROF) Materials Technology, School of Energy & Materials King Mongkut's University of Technology Thonburi (KMUTT)



 Bagley's corrections or entrance corrections for shear stress data

Rabinowitsch corrections for shear rate data

Corrections due to head effect

## **Origins of entrance corrections**

- When the rheological properties of two fluids, one Newtonian and the other polymer melt with quite similar viscosity, were determined using the common shear stress and shear rate equations, the results of experimental viscosities from both were different.
- Rheological properties of a fluid varied with different rheometer designs (barrel/piston/die sizes).

a) The melt accelerates, as it enters the die, and the velocity profiles in the barrel are rearranged to other forms. These require the application of a force.
b) The number of molecular entanglements and the shape of the molecules may change as a result of the shearing stress or flow.
c) Elastic deformation of the molecules recovers

### **Drives to entrance corrections**

- a) The melt accelerates, as it enters the die, and the velocity profiles in the barrel are rearranged to other forms. These require the application of a force.
- b) The number of molecular entanglements and the shape of the molecules may change as a result of the shearing stress or flow.
- c) Elastic deformation of the molecules recovers

#### **Pressure drop along the barrel and capillary die** Pressure









For a capillary die:

$$\frac{RP}{2(L NR)}$$

 $\frac{R(P P_o)}{2L}$ 

true

true

or

For a slit die:

true 
$$\frac{HP}{2(L NH)}$$

or

$$\frac{H(P P_o)}{2L}$$

# Limitations of entrance corrections

Entrance corrections are necessary for practical important, but not quite for comparative results of materials over an existing material with known flow properties due to the following limitations:

 a) N and Po vary with shear rate, a number of experimental work being required and thus resulting in time consuming.

**b)** The relationship between pressure drop and L/R is not always linear, this giving rise to errors of extrapolation.

**c**) Negative value of N have been found, this being practical impossibility.

d) Entrance corrections are only experimentally determine (not theoretically), thus it is difficult to reserve the process for calculation.

Origin of exit corrections The shear stress obtained from the Bagley method is always greater than that from the direct measurement. This is because such corrections are made without consideration of non-zero exit pressure.

$$\frac{R(P \quad P_{exit})}{2(L \quad NR)}$$

$$\frac{RP}{2(L \ RN \ RN_{exit})}$$

# Significance of exit correction

However, it should be noted that, at large L/D ratio of a die and high  $D_{barrel}/D_{die}$  ratio of the rheometer used the value of entrance pressure drop is relatively much greater than the exit pressure. As a result of this the exit corrections are often negligible.



Since a polymer melt is pseudoplastic non-Newtonian fluid the velocity profile in the die capillary is frequently assumed to be pluglike. However, in practice, such velocity profiles vary, this being related to the shear rate being measured. The velocity profile or shear rate profile is suggested to be related to the power-law index, n. Therefore, it is necessary to obtain the true shear rate, normally by finding the power-law index as the flow properties of the melt is being determined.

#### n values and velocity profiles





The correction for shear rate is carried out by plotting log [wall shear stress] against log [wall shear rate] as shown below. By fitting an orthogonal polynomial curve, the slope of each curve is obtained, the value being the power-law index.

$$n \quad \frac{d \log[RP/2L]}{d \log[4Q/R^3]}$$



true 
$$\left[\frac{3n-1}{4n}\right]\left[\frac{4Q}{R^3}\right]$$

true 
$$\left[\frac{2n-1}{3n}\right]\left[\frac{6Q}{WH^2}\right]$$

# Head effect

In the case of viscometers which are *not* equipped with a pressure transducer inserted into the side of the reservoir just above the capillary, the pressure is measured at the top of the reservoir ( $\Delta P$ ). The relationship of pressure drops in the reservoir and capillary die for a power-law fluid is. [Ideally, R<sub>R</sub> is much greater than R<sub>C</sub> the head effects are usually negligible]

$$\frac{P_R}{P_C} \quad \frac{L_R}{L_C} \quad \frac{R_C}{R_R} \quad \overset{3n-1}{}$$