

Problem 2.53

[Difficulty: 2]

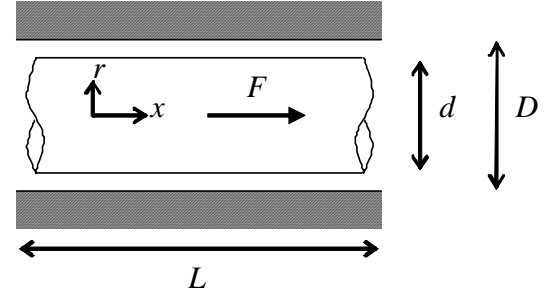
2.53 Magnet wire is to be coated with varnish for insulation by drawing it through a circular die of 1.0 mm diameter. The wire diameter is 0.9 mm and it is centered in the die. The varnish ($\mu = 20$ centipoise) completely fills the space between the wire and the die for a length of 50 mm. The wire is drawn through the die at a speed of 50 m/s. Determine the force required to pull the wire.

Given: Varnish-coated wire drawn through die

Find: Force required to pull wire

Solution:

Governing equations: $\tau_{yx} = \mu \cdot \frac{du}{dy}$ $\Sigma F_x = M \cdot a_x$



Assumptions: Laminar flow; linear velocity profile in varnish layer

The given data is $D = 1 \cdot \text{mm}$ $d = 0.9 \cdot \text{mm}$ $L = 50 \cdot \text{mm}$ $V = 50 \cdot \frac{\text{m}}{\text{s}}$ $\mu = 20 \times 10^{-2} \text{poise}$

Equation of motion $\Sigma F_x = M \cdot a_x$ so $F - F_v = 0$ for steady speed

The friction force is $F_v = \tau_{yx} \cdot A = \mu \cdot \frac{du}{dr} \cdot A = \mu \cdot \frac{V}{\left(\frac{D-d}{2}\right)} \cdot \pi \cdot d \cdot L$

Hence $F - F_v = 0$

so $F = \frac{2 \cdot \pi \cdot \mu \cdot V \cdot d \cdot L}{D - d}$

$$F = 2 \cdot \pi \times 20 \times 10^{-2} \text{poise} \times \frac{0.1 \cdot \text{kg}}{\text{m} \cdot \text{s} \cdot \text{poise}} \times 50 \cdot \frac{\text{m}}{\text{s}} \times 0.9 \cdot \text{mm} \times 50 \cdot \text{mm} \times \frac{1}{(1 - 0.9) \cdot \text{mm}} \times \frac{\text{m}}{1000 \cdot \text{mm}}$$

$$F = 2.83 \text{ N}$$