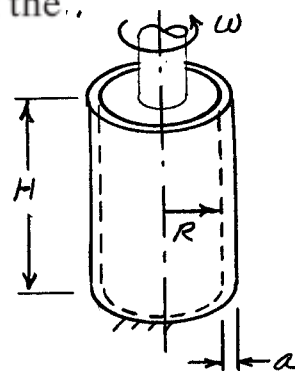



[Difficulty: 5]

Solution: Apply definition of Newtonian fluid



Assumptions:

- (1) Steady
- (2) Newtonian liquid
- (3) Narrow gap, so "unroll" it
- (4) Linear velocity profile in gap
- (5) Neglect end effects

Flow model:  $u = V \frac{y}{a} = WR \frac{y}{a}$; $\frac{du}{dy} = \frac{WR}{a}$

Thus $\tau = \mu \frac{du}{dy} = \mu \frac{\omega R}{a}$ and torque on rotor is $T = R\tau A$, where $A = 2\pi R H$

Consequently $T = R \mu \frac{\omega R}{a} 2\pi R H = \frac{2\pi \mu \omega R^3 H}{a}$, or

$$\mu = \frac{T_a}{2\pi \omega R^3 H}$$

From this equation the uncertainty in μ is (see Appendix F),

$$u_{\mu} = \pm [u_T^2 + u_a^2 + u_w^2 + (3u_R)^2 + u_H^2]^{\frac{1}{2}} = \pm [13 u^2]^{\frac{1}{2}} = \pm 3.61 u$$

if the uncertainty of each parameter equals u . Thus

$$u = \pm \frac{4\mu}{3.61} = \pm \frac{1 \text{ percent}}{3.61} = \pm 0.277 \text{ percent}$$

Typical dimensions for a bench-top unit might be

$H = 200 \text{ mm}$, $R = 75 \text{ mm}$, $a = 0.02 \text{ mm}$, and $\omega = 10.5 \text{ rad/s}$ (100 rpm)

From Appendix A, Table A.8, water has $\mu = 1.00 \times 10^{-3} \text{ N}\cdot\text{s}/\text{m}^2$ at $T = 20^\circ\text{C}$.

The corresponding torque would be

$$T = 2\pi \times 1,00 \times 10^{-3} \frac{\text{N} \cdot \text{s}}{\text{m}^2} \times \frac{10,5}{\text{s}} \times (0,025)^3 \text{m}^3 \times 0,2 \text{m} \times \frac{1}{0,0002 \text{m}} = 0,278 \text{ N} \cdot \text{m}$$

It should be possible to measure this torque quite accurately.

{ Many details would need to be considered (e.g. bearings, temperature rise, etc.) to produce a workable device. }