**ABE 307**

**Rotational Viscometers**

Viscometers are instruments used for measurement of viscosity in different processing industries. We have seen the use of capillary viscometers. A capillary viscometer uses various measurements of pressure differences and mass flow rates to estimate viscosity of a fluid (recall the problem based on the Hagen-Poiuessile equation).

Another instrument that is used by industries is the rotational viscometer.

Concept of Rotational Viscometer: The resistance to rotational motion of fluid is measured by torque generated which is related to the geometry of the viscometer and the fluid properties used to calculate viscosity.

Categories of Rotational Viscometers: Two major types of viscometers.

1. Stormer type: instrument measures shear rate against constant torque. (stirrer)
2. Searle and Couette type: instrument measures torque with defined shear rate. (container moved)

Couette viscometer generally consists of two concentric cylinders. Outer cylinder rotates with an angular velocity Ω and the inner cylinder is stationary. The angular momentum gets transferred to the stationary cylinder producing a torque which is measured by a sensing device. From force balances, the torque applied by momentum transfer is equal to the torque measured by the devices. This theory is used to develop relationship between measured and other parameters of the device that is finally used to estimate viscosity μ.

Use the above information and general equations (Equation of Continuity and Equation of Motion for constant ρ and μ to get the equation for measuring viscosity using Couette viscometer).

Set up and Geometry of the viscometer: Book pg 90



Objective: to obtain an expression that relates the torque to fluid properties and geometry of the instrument.

Flow condition: steady state, incompressible fluid, μ = constant, no radial flow, no flow in z-direction, laminar flow

Approach: use the equation of continuity and motion to come up with relationship for velocity, 𝜏 (torque), and geometry

Assumptions:

ρ and μ = constant

vz = 0

vr = 0

v𝛳 = v𝛳(r)

P = P(z,r)

Equation of Continuity

Because of steady state, vr = 0, v𝛳 ≠ f(r), this is a trivial equation. Everything cancels to 0.

Equation of Motion

R-component: -ρv𝛳2/r = -dp/dr

Pressure variation in r-component

𝛳-component: 0 = μ(d/dr(1/r d/dr(rv𝛳))

Z-component: 0 = -dp/dz + ρgz

Pressure relation with z-direction

Velocity Profile:

0 = μ(d/dr(1/r d/dr(rv𝛳))

1/r \* d/dr \* (rv𝛳) = C0

d/dr (rv𝛳) = C0r

rv𝛳 = C0r2/2 + C1

v𝛳 = C0r2/2 + C1/r

Use boundary conditions:

At r = R, v𝛳 = Ω0R

At r = kR, v𝛳 = 0

Ω0R =

𝜏r𝛳 = -μr \* d/dr \* ( v𝛳/r) = -2μΩ0 \* (R/r)2 \* (k2/1-k2)

T = -𝜏r𝛳|r=kR(kR)(2πkRL)

T = 4πμΩ0R2L \* (k2/1-k2)

T’ = kt𝛳b

This is what the instrument measures

**Equating the two expressions**

μ = (ktፀb)/4πΩ0R2L(k2/1-k2)

Re = Ω0R2ρ/μ