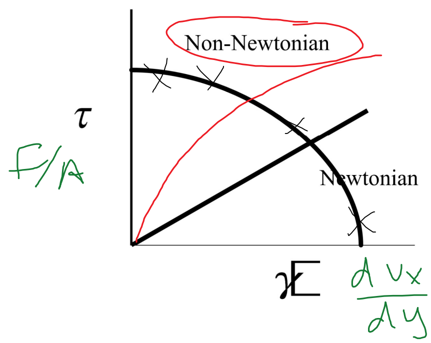
NON-NEWTONIAN FLUIDS

- Non-Newtonian Fluids are those for which **shear stress is not proportional to shear rate.**

force - shear stress



1

— not linear τ vs γ

NON-NEWTONIAN FLUIDS

i.e. cornstarch solution, Ketchup, quicksand

Non-Newtonian Fluids can be further divided into:

- **Time Independent Fluids**: The fluid behavior does not depend on the past shear history of the fluid. Examples are most of the foods such as mayonnaise,tomato ketchup, yogurt etc.
- **Time Dependent Fluids**: The fluid behavior depends on the past shear history of the fluid. Examples are whipping cream, bentonite suspensions etc.

apparent viscosity instead of viscosity

2

Ketchup - more force = low viscosity

cornstarch/quicksand - more force = high viscosity

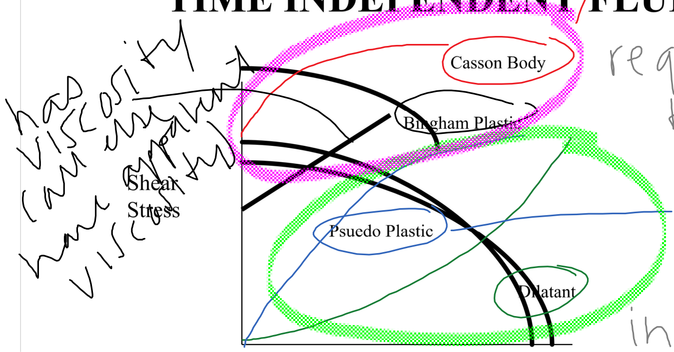
i.e chocolate

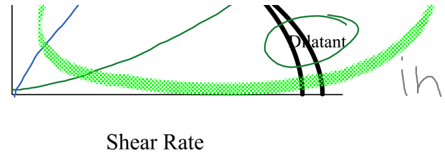
TIME INDEPENDENT FLUIDS

requires yield stress to cause movement
intercept ≠ 0

i.e. Ketchup

intercept = 0





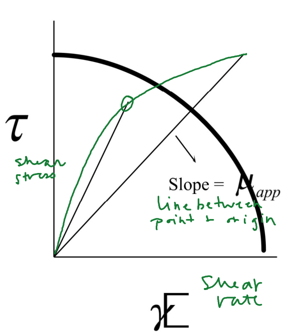
intercept = 0

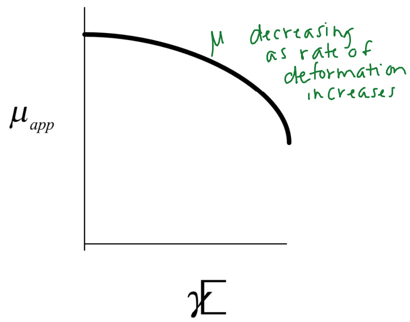
behaves like solid until critical force causes flow (i.e toothpaste)

3

PSUEDO PLASTIC FLUID

Shear Thinning: Apparent Viscosity Decreases with Shear Rate

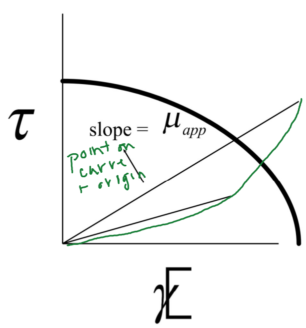


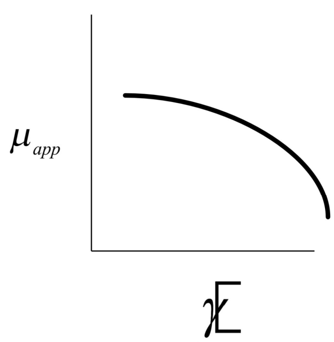


4

DILATANT FLUID

Shear Thickening: Apparent Viscosity Increases with Shear Rate





5

no yield stress.

POWER LAW FLUID

pseudoplastic or dilatant

homework: fit τ vs. $\dot{\gamma}$ to power law to find k & n

$$\tau = k\left(\frac{dv}{dy}\right)^n = k\dot{\gamma}^n$$

shear stress

k is the consistency index, N s^n m^{-2} Pa.s^n

n is the flow behavior index, dimensionless

n = 1 for Newtonian Fluid

n < 1 for Pseudo Plastic Fluid

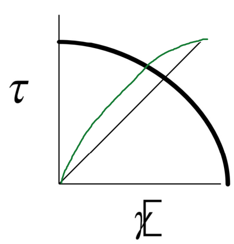
n > 1 for Dilatant

6

POWER LAW FLUID

$$\mu_{app} = \frac{\tau}{\dot{\gamma}}$$

same as Newtonian but different @ different pts



For Power Law Fluid

$$\mu_{app} = k\dot{\gamma}^{(n-1)}$$

pseudoplastic If n < 1, μ_{app} decreases with an increase in $\dot{\gamma}$

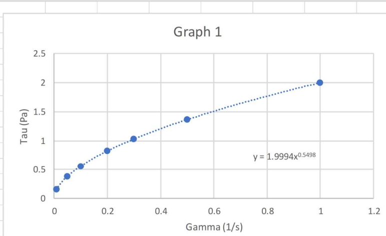
dilatant : If n > 1, μ_{app} increases with an increase in $\dot{\gamma}$

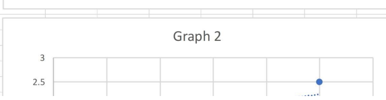
Newtonian If n = 1, μ_{app} is independent of $\dot{\gamma}$ $\mu_{app} = k$

example.

Lecture 1 Non-Newtonian Fluids 18 - 1 - Spreadsheet

gamma (1	tau (Pa)	Tau with yield stress
0.01	0.159	0.659
0.05	0.385	0.885
0.1	0.564	1.064
0.2	0.825	1.325
0.3	1.031	1.531
0.5	1.366	1.866
1	2	2.5

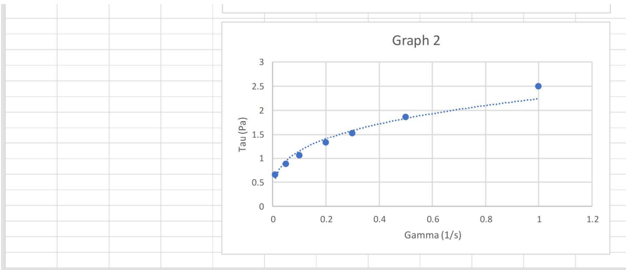




Observations of Graph 1:

- Curved
- N < 1
- Pseudoplastic
- Assume it goes through origin
  - Equation: y = 1.9994x^(0.5498)
  - K = 1.9994
  - N = 0.5498

If there is a yield stress (graph 2)
Find yield stress (tau0)
Shift y axis by tau0, do same equation as Graph 1 + tau0
Equation: y = 1.9994x^(0.5498) + 0.5
Valid only when tau > tau0
Velocity gradient is nonzero when tau > tau0



If there is a yield stress (graph 2)
Find yield stress (tau0)
Shift y axis by tau0, do same equation as Graph 1 + tau0

- Equation: y = 1.9994x^(0.5498) + 0.5
  - Valid only when tau > tau0
  - Velocity gradient is nonzero when tau > tau0
  - Gamma is 0 is tau < tau0
  - (tau - tau0) = k*gamma^n
  - Plot tau-tau0 vs gamma to fit to power equation
  - Find tau0 with the y intercept (extrapolate)
  - Ln(tau-tau0) = ln(k) + nln(gamma)
  - Plot ln(tau-tau0) vs ln(gamma) to get a straight line. Slope is n, intercept is ln(k)