Non-Newtonian Flow Types(Time independent)		
Pseudo plastic flow(shear thinning flow)	Dilatant flow(shear thickening flow)	Plastic flow(Bingham flow)
The shear viscosity decreases with increasing of shear rate. Flow curve pass through the origin.	The shear viscosity increases with increasing of shear rate. Flow curve pass through the origin.	Flow curve Consists of non-linear and linear part and dose not pass through the origin.
Follow the power low fluids: $\tau = \mu \gamma^{\cdot n}$ n < 1	Follow the power low fluids $\tau = \mu \gamma^{\cdot n}$ n > 1	Newtonian at high shear rate: $U = \frac{\tau - \tau_\circ}{\gamma^{\cdot}}$ $\tau_\circ = yield\ shear\ stress,, U = Plastic\ viscosity$
The chains disentanglement, alignment, and ordered with shear rate increasing. The viscosity decreases associated with the chains disentanglement .	Particles or chains closely backed with less void space and high amount of vehicle when shear rate increase (breakage of aggregate)open backed high void volume insufficient vehicle and liquid .Then solids particles directly in contact and friction and viscosity increased.	Flocculated particles change into individuals particles due to the yield shear stress. After further stress increasing the substance flowing .
Most important phenomena in the non-Newtonian flow.	Exhibited in limited applications compared with the Pseudo plastic flow.	Regard as part of Pseudo plastic flow.
Useful in saving energy and produce easy manufacturing process.	Useful in impact applications	Useful in food , pharmacology And industry applications.
Pseudo plastic flow is exhibited by: Solutions of polymer solutions and polymer melts ,mucilage's and gums.	Dilatant flow exhibited by: Deflocculated suspension with high concentration of dispersion solids	Plastic flow is generally exhibited by: Concentrated solid suspensions.
Pseudo plastic flow: Natural and synthetic gums, polymer melts and solution, polymer MC and CMC, Sod. Alginate in water, Sodium CMC in water and Methyl cellulose in water .	Deflocculated suspension containing 50% solid contain, some pastes, concentrated titanium dioxide suspension, suspension starch 10-20% in water, aqueous glycerin or ethylene glycol containing 40-50% v/v starch, concentrated	Plastic flow is flocculated particles in concentrated suspensions 1-10%, suspension of ZnO in mineral oil, certain pastes, ointment, paints , gels, printing ink, lotion, cream, mayonnaise, yogurt, and milk.

	suspension of inorganic pigment(red iron oxide 12% v/v, zinc oxide 30% v/v, barium sulphate 30-% , titanium dioxide 30-50% v/v) i	
Zero shear stress no yield value is obtained. Gives response at low shear rate(Thixotropy). Thixotropy apply only on shear thinning behavior (plastic flow, and Pseudo plastic flow).When stress is remove the material show slow and recovery and reform. (Gel, Sol, Gel) Gel on standing (intermolecular forces, closely backed), sol, on shaking (particle arrange in align form), gel on standing(Brownian motion).	Reversible i.e. when the stress removed the original state of fluidity is regained (Rheopexy) clay suspension. Increase in volume when sheared. (Sol, Gel, Gel)	.The linear part extrapolated to intersect the shear stress at yield value. No response on low shear rate. The substance behave initially as elastic body .The plastic flow behave Newtonian above yield point at high shear rate.

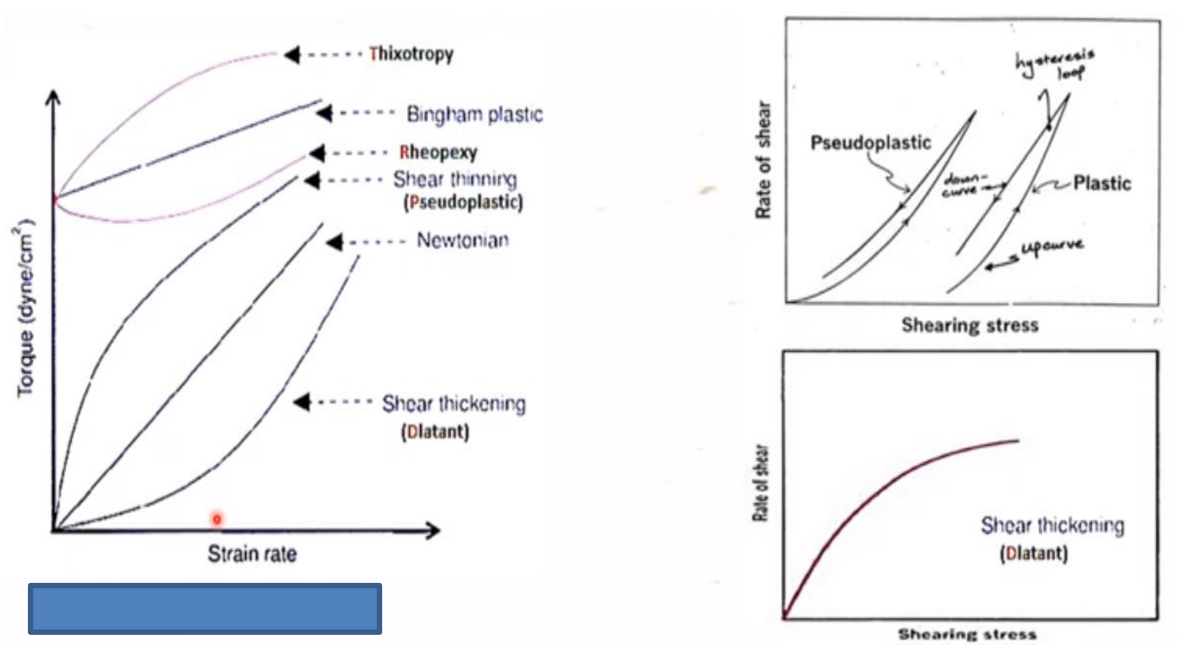

Fig.5: Shear flow types with Thixotropy and Rheopexy flows.(Flow curve or Rheogram).

Non-Newtonian flows (Time dependence) are:

A-Thixotropy(Printer ink). **B**-Anti- Thixotropy. **C**-Rheopexy or Rheopectic, (Gypsom paste). **D**-Negative-Rheopexy or Rheopectic).

The basic flow types	
Newtonian flow	**Non-Newtonian flow**
Follow Newton's low of viscosity The constant of proportionality is viscosity μ. $\tau = \mu\gamma^{\cdot} = \mu\left(\frac{dv}{dy}\right)$ n =1	They follow the power low fluids $\tau = \mu\gamma^{\cdot n} = \mu\left(\frac{dv}{dy}\right)^n$ v is the velocity of flow m/s. n is flow index, the value of **n** depends on the non-Newtonian flow type.
The shear stress linearly dependent on the shear rate or velocity gradient and passes through origin point.	The shear stress is not linearly dependent on the shear rate or velocity gradient and passes through origin point.
The viscosity does not depends upon the shear stress and shear rate varies.	The viscosity does depends upon the shear stress and shear rate varies.
Newtonian flow such as castor oil, water, chloroform, ethyl alcohol, simple organic solutions, dilute suspensions ,kerosene , and true solution.	polymer melts and solution, Deflocculated suspension containing 50% solid contain, flocculated particles in concentrated suspensions 1-10%, ointment, gels, pastes, colloidal dispersion, liquid suspension, blood, milk, toothpaste, and emulsion.

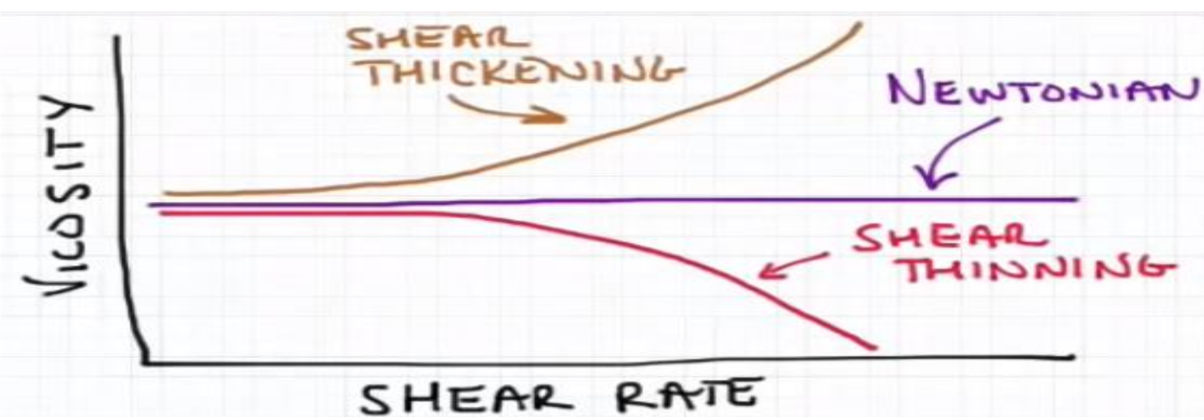

Fig.6: Shows the viscosity versus the shear rate.(Viscosity curve or viscogram)

The parameters effect on the viscosity of polymers:

1- Internal parameters:

a- Molecular weight (MW): the viscosity increases with the MW or molecular size increasing .

b- Intermolecular forces: when the inter molecular force increases the viscosity increasing.

c- Irregular shape: irregular shape of particle or chain show higher viscosity compared with the spherical shape particle.

d- Molecular weight distribution (MWD): narrow NMWD like HDPE is higher viscosity than broad BMWD like LDPE.

e- Branching of chains: polymer with long chain branch LDPE produce lower viscosity at shear thinning region compared with the short chain branch HDPE at the same region.

2-External parameters:

a-Temperature: the viscosity decreases with temperature increasing.

b-Pressure: the viscosity increases with the pressure increasing.

c- Filler : the viscosity increases with the filler increasing.

d- Additives: the viscosity decreases with additives increasing .

e-Vibration : the viscosity decreases with the vibration increasing .

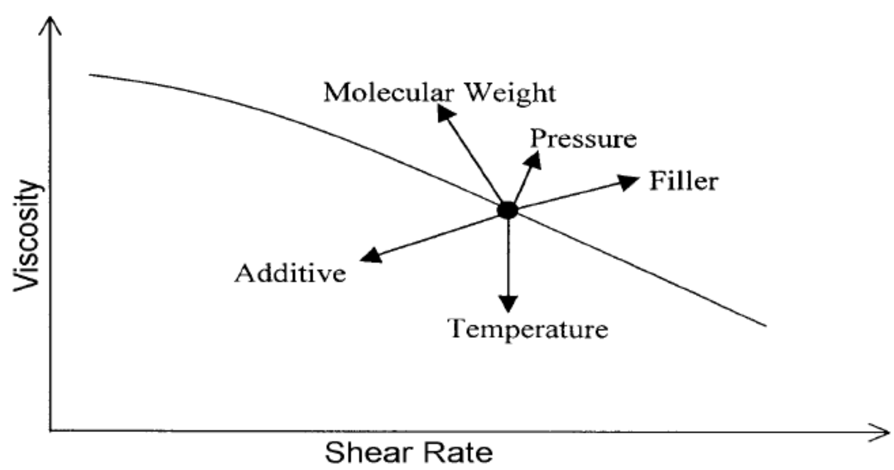

Fig. 7: Shows the influence of different parameters on the viscosity of polymers.