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An Overview of Non-Newtonian Fluid

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Abstract

A non-Newtonian fluid is a fluid with a viscosity that varied under the action of applied stress or forces. It has novel properties that make them potentially useful in many applications in industrial process. Their various types of characteristics have led to much excitement in the field of environment. Non-Newtonian fluids are categorized as numerous types of that due to several behaviors. Several types of behavior under appropriate state of affairs have been presented.

Keywords: Non-Newtonian fluid, stress, strain rate, yield stress, visco-elasticity

During the past 300 years, Newtonian fluids have come a long way in the fluid dynamics in the field of turbulence and multi-phase flows. Most low molecular weight substances such as organic and inorganic liquids, solutions of low molecular weight inorganic salts, molten metals and salts etc. exhibit shear stress is proportional to the rate of shear at constant temperature and pressure and these constant of proportionality is the viscosity. Such fluids are classically known as the Newtonian fluids. In general, the viscosity decreases with temperature and increases with pressure most liquids on the other hand for gases it increases with increases of both temperature and pressure[1]. But, during the past 50-60 years, there has been a growing appreciation of the fact that a lot of substances of industrial significance, especially of multi-phase nature, polymeric melts and solutions do not conform to the Newtonian postulate of the linear relationship between shear stress is proportional to the rate of shear. Accordingly,these fluids are known as non-Newtonian fluids. These types of fluids exhibit different kinds of behavior with varying strictness of non-Newtonian flow behavior[2]. So the non-Newtonian fluid behavior is more valuable than the Newtonian fluid behavior in nature and in technology. A brief introduction the different kinds of non-Newtonian flow characteristics and implications in engineering applications are provided in this article.

Definition of a Non-Newtonian Fluid

A non-Newtonian fluid is one whose properties are different from Newtonian fluids i.e. apparent viscosity changes with applied stress or forces. In non-Newtonian fluid the correlation between the shear stress and the rate of strain is non-linear. For these types of fluids the constant of proportionality, viscosity, may change with time.

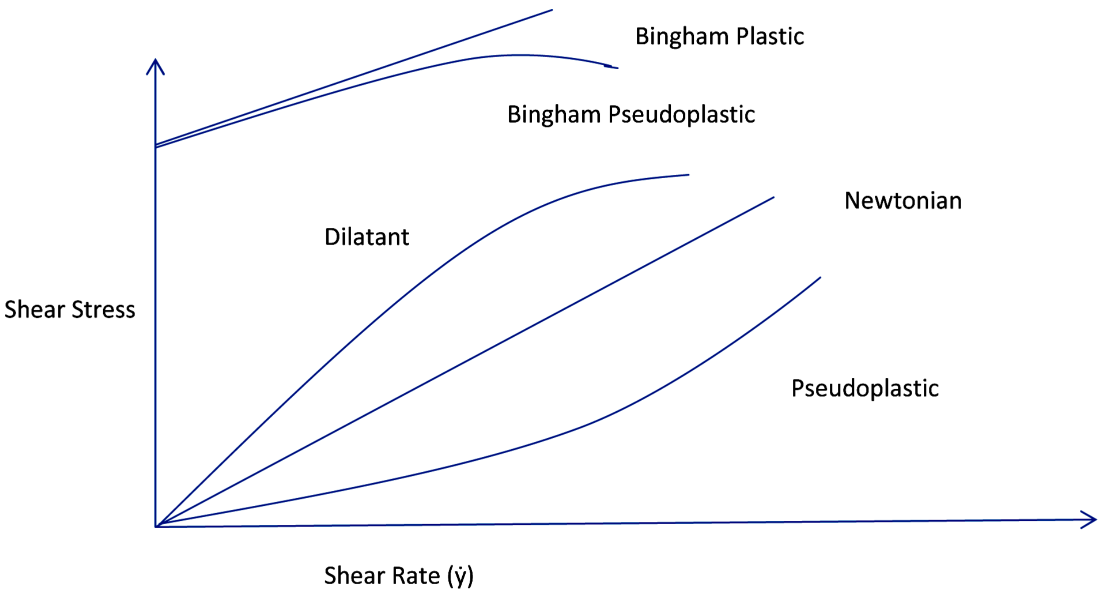

Fig. 1: Classification of fluids with shear stress as a function of shear rate

Many salt solution, solution of polymers as well as liquids in which fine particles are suspended, are non-Newtonian, as are most commonly found substances in our everyday life such as ketchup, toothpaste, paint, blood and shampoo.

Classification of Non-Newtonian Fluid

Non-Newtonian fluid has been classified by Shenoy and Mashelkor[3] into two main categories: (A) Inelastic Non-Newtonian fluid and (B) viscoelastic Non-Newtonian fluid. The first one can be subdivided into two types (i) time independent and (ii) time independent.

(A) Inelastic Non-Newtonian fluid

(i) Time independent Non-Newtonian fluid

In the Time-independent fluids properties such as viscosity does not depends on time. The non-linearity relation between the shear stress and strain rate at a given point is solely written by the following way:

$$\tau = f\left(\dot{Y}\right)$$

Where, τ and $\dot{Y}$ are the shear stress and shear rate.

The Time independent Non-Newtonian fluid can be subdivided into three varieties depending on the form of function of above equation:

(i) Pseudoplastic (shear thinning)
(ii) Dilatant (shear thickning)
(iii) Viscoplastics

Pseudoplastic fluids or shear-thinning fluids often exhibit a apparent viscosity which decreases with increasing stress. Polymer solutions, polymer melts, printing inks and blood are the pseudoplastic fluids. Dilatants often referred as shear-thickening fluids, exhibit viscosity increase with increasing shear rate. Gum solution, aqueous suspensions of titanium dioxide, wet sand, starch suspensions are treated as dilatants fluids. Shear-thinning behavior is more common than shear-thickening.

(ii) Time-Dependent Fluids

In these types of fluids apparent viscosity depends on the time of applied shear along with strain train rate. Such types of liquids are regarded as complex non-Newtonian fluid. It is recognized that there are two main classes of time-dependent fluids: (a) thixotropic and (b) rheopectic.

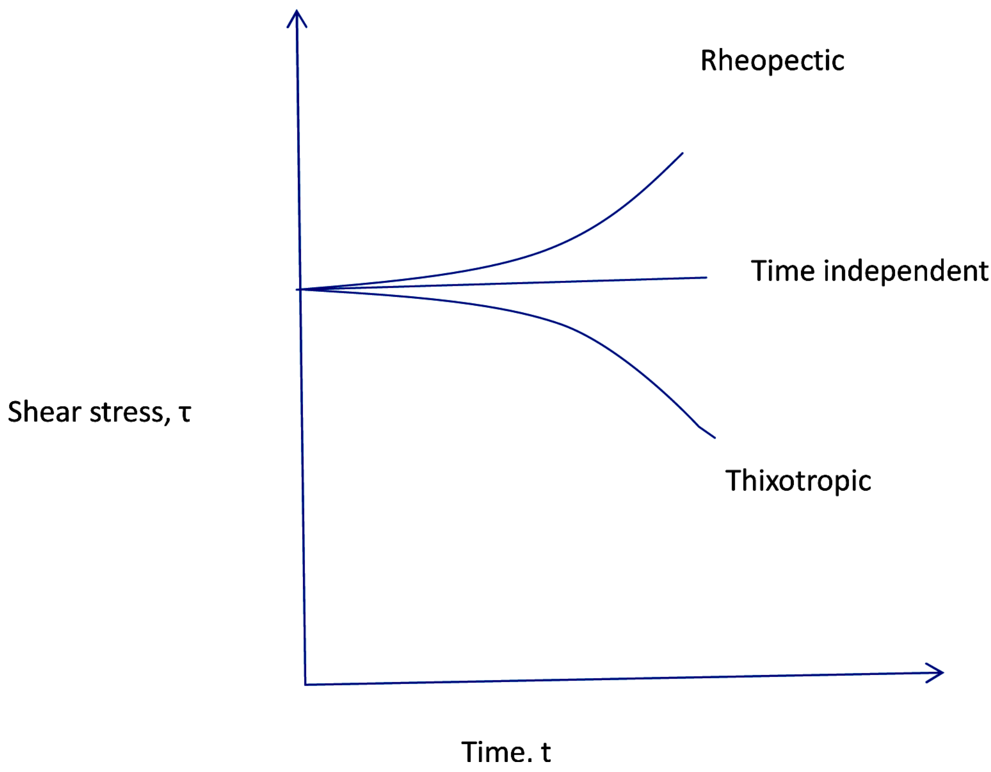

Fig. 2: Classification of fluids with shear stress as a function of time

Thixotropic fluid: In 1927 the termthixotropy was specified by Peterfi[4] after by Schalek and Szegvari[5] and has been derived from the Greek word ‘thixis’ which means shaking and ‘trepo’ means changing It is most important fluid which exhibits time-dependent shear thinning property. Some more viscous fluids such as gels under static conditions cannot flow but when external force applied or stressed. Such types of fluid acquire the property of flow due to low viscosity. They take a stationary time to return to its previous state.

Rheopectic fluid: It is a rare property of a time-dependent of some non-Newtonian fluids in which viscosity increase with time. Examples of some rheopectic fluids are lubricants. The viscosity of these types of fluids increase i.e. thickens or solidifies when shaken for a long time. The longer the fluid undergoes shearing force, the higher its viscosity[6]. Sometimes the rheopectic behavior of fluid may be considered as time-dependent dilatant behavior[7].

The theories of the time-dependent fluids are less developed. In spite of many proposed models for the time-dependent fluids in the several literatures here two common models have been presented.

(B) Viscoelastic fluids

Viscoelastic fluids are those that illustrate partial elastic recovery upon the removal of a deforming stress. Such materials possess properties of both fluids and elastic solids and obey Hooke’s law of elasticity. For viscous fluids constitutive equation[8] can be written as—

$$\dot{Y} = \frac{\tau}{\pi} + \frac{\dot{r}}{\kappa}$$

Where, $\dot{Y}$ and κ are the shear rate and rigidity modulus respectively.

Conclusion

In this article consideration has been given to the different types of non-Newtonian characteristics displayed by foams, emulsions, suspensions and pastes etc., for manifestation of countless characteristics of non-Newtonian fluids. Qualitative explanations for each type of behavior are advanced to provide some insights into the nature of underlying physical processes.

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