International Research Journal of Natural and Applied Sciences
ISSN: (2349-4077)
Impact Factor 7.032 Volume 10, Issue 05, May 2023
Website- www.aarf.asia, Email : editor@aarf.asia , editoraarf@gmail.com

Basics of Newtonian and Non-Newtonian Fluids

Vishal Gohokar, Dept. of Physics
Janta Mahavidyalaya Chandrapur

Abstract:
This article has an objective to introduce the Newtonian and non-Newtonian fluids. The difference between both of these fluids is discussed based on the shear stress and rate of strain. Starting from the definition of Newtonian and non-Newtonian fluids, the Newtonian law of viscosity, many aspects regarding the dynamics and characteristics of these fluids has been studied in this article.

Introduction:
When referring to something that is liquid, like water, we typically use the terms "liquid" and "fluid" interchangeably. In any case, there is an unmistakable distinction in the two terms. The term "fluid" is used in physics to describe any liquid, gas, or other material that undergoes constant change in form under the influence of any force or stress. Fluids have a shear modulus of zero, meaning they cannot withstand any force. Although the term "fluid" generally refers to everything that flows, including the gas and liquid phases, its definition frequently varies by scientific discipline. Based on the relationship between the rate of strain and shear stress, fluids are divided into two main categories. The two kinds of fluids are as follows:

Newtonian Fluids- those liquids for which thickness doesn't rely upon the pressure rate. Water is one instance.

Non-Newtonian Fluids - Liquids that are non-Newtonian include those whose viscosity can be affected by the stress rate. A few models are blood and paint.

The majority of low-molecular-weight substances, including molten metals and salts, organic and inorganic liquids, solutions of low-molecular-weight inorganic salts, gases, and liquids, exhibit Newtonian flow characteristics, meaning that the shear stress in simple shear is proportional to the rate of shear at constant temperature and pressure and the familiar dynamic viscosity is the proportionality constant. Even though the concepts of flow and viscosity precede Newton, these fluids are commonly referred to as *Newtonian fluids*. The viscosity of the majority of liquids falls with temperature and rises with pressure. It rises with both pressure and temperature for gases.

The Newtonian postulate of the linear relationship between and P in simple shear, for example, has not been consistently observed in many industrially significant substances, particularly those that are multiphase in nature (such as foams, emulsions, dispersions and suspensions, and slurries), as well as polymeric melts and solutions (both natural and synthetic). As a result, these fluids are sometimes referred to as *non-Newtonian, non-linear, complex or rheologicallycomplex fluids.*

Newtonian Law of Viscosity:

The link between the shear stress and velocity gradient of fluids is explained by Newton's law of viscosity. Shear stress is the quantity of force per unit area operating on a certain fluid parallel to the fluid surface. The velocity differential between fluid layers that are next to one another is known as the velocity gradient.

The shear stress is exactly proportional to the velocity gradient, according to Newton's equation of viscosity.

The equation of newton's law of viscosity is

$\tau = \mu \, du/dy$

Where τ= shear stress

μ= viscosity

du/dy= velocity gradient.

Derivation of Newton's Law of Viscosity:

Shear stress (τ) = Force(F)/ Area(A)

Velocity gradient = du/dy. Here, du is the velocity difference, and dy is the distance between the layers.

According to Newton's law of viscosity, shear stress is proportional to velocity gradient.

$\tau \propto du/dy$

$\therefore \tau = \mu \, du/dy$

Newtonian Fluids:

Newtonian fluids are named after Sir Isaac Newton, who discovered the relationship between the shear stress rate and strain rate for fluids using a differential equation for the first time. One of Newton's many well-known contributions was the discovery of the fundamentals of viscosity. Newton's findings show that a fluid's viscosity depends on temperature and shear stress.According to Newton, stirring or other similar movements won't alter a fluid's viscosity. This does not always occur, though. You may have seen that curd grows thinner as it is beaten for a lengthy period of time. However, even after vigorous stirring, the viscosity of water remains unchanged. Therefore, it might be claimed that Newton only saw one half of the overall image.

As a result, a Newtonian fluid is one in which the stress generated by its flow has a linear relationship with the local strain rate. The strain rate is the rate at which deformation changes over time, as was previously mentioned. Newtonian fluids are the most straightforward and viscous fluids in mathematics. The Newtonian fluids include substances like water and petrol.

Non- Newtonian Fluids:

The term "non-Newtonian fluids" refers to fluids that do not adhere to Newton's viscosity law. Newton's law of viscosity states that the viscosity must be constant and unaffected by stress.

The viscosity of non-Newtonian fluids changes with time. Any external force alters the viscosity of non-Newtonian fluids. Here, the fluid's viscosity may alter under strain, becoming either more liquidy or more solid. Common foods like custard and starch suspensions are examples of non-Newtonian fluids, as are other substances including salt solutions, blood, paint, and shampoo.

Numerous factors can cause fluids to behave in a non-Newtonian manner. They might be simply viscous, meaning that there is no nonlinear relationship between the stress and the rate of deformation depending on the deformation's previous history. They could be viscoelastic in the sense that the stress relies on the history of the deformation in a well-defined fashion; viscoelastic liquids are also known as memory fluids, and fundamental physics invariance principles demand that their stress dependence be nonlinear for any finite deformation. The term viscoelasticity is employed because these fluids behave like elastic solids when deformed over short time scales yet behave like regular liquids when deformed over long time scales. Because these fluids act like elastic solids when distorted over short time scales yet behave like conventional liquids when deformed over long time scales, the word viscoelasticity is used to describe their behaviour.

Thixotropic fluids have material characteristics that change over time even under constant stress or deformation rates. (The distinctions between the first two classes and thixotropy can be subtle; hence, several observers may categorize a phenomenon as belonging to one of the groups or the other.) Some liquids are difficult to classify into any of these groups. Yield stress fluids are solely viscous or viscoelastic before a critical stress level is achieved, at which point they begin to flow. Although low molar mass liquid crystals, which are employed in display technologies, are anisotropic at rest and can withstand a stress like an elastic solid, they have no memory in flow.

Microstructure and Macroscopic Fluid Phenomena

The majority of non-Newtonian fluids are characterized by an underlying microstructure that largely determines the fluid's macroscopic characteristics. Particulate suspensions, which are Newtonian solvents like water but contain particles of another substance, are one type of non-Newtonian fluid. The microstructure that forms in such suspensions is the result of interactions between particles or between particles and solvent, which are frequently chemical or electrostatic in nature. An everyday illustration of such a suspension is a water-based kaolin (clay) slurry.

Physically, kaolin particles are around the size of a micron and resemble flat, rectangular plates with varying electrostatic charges on the faces and sides. The plates fit together like a huge house of cards in static fluid. This structure grows to such a size that the electrostatic forces that hold it together produce a macroscopic effect, in which the microstructure can offer some flow resistance.

Of fact, it is a massive idealization to think of the kaolin structure within the slurry as a huge house of cards. Without a doubt, the kaolin produces an uneven, flawed structure with a range of length scales. The key concept is that fluid flow may be affected by microstructure in ways that are macroscopic and visible. If the shearing (rate of deformation) is not too high, we estimate that microstructure will increase the barrier to flow for the kaolin slurry.

However, the microstructure must breakdown if the fluid starts flowing and shearing over relatively long timescales; the house of cards falls. The fluid starts to flow more freely at increased shearing (larger rates of deformation). This well-documented "shear thinning" non-Newtonian macroscopic phenomenon is a crucial one in suspension mechanics. Making the fluid viscosity a decreasing function of the rate of strain is the crudest explanation for the occurrence. The shear stress is subsequently made a nonlinear function of the strain rate in this straightforward divergence from the normal fluid behaviour.

Concluding remarks:

The ability to flow and the lack of resistance to permanent deformation are characteristics of fluids. There are two main categories of fluids: Newtonian fluids and non-Newtonian fluids.

The fluids that follow Newton's law of constant viscosity are known as Newtonian fluids. These liquids have constant viscosities and no shear stress or rate of shear. Non-Newtonian fluids are ones whose viscosity is not constant and whose relationship to shear stress varies.

According to the Newtons law of viscosity, the shear stress is exactly proportional to the velocity gradient, according to Newton's equation of viscosity.

The microstructure that forms in non-Newtonian suspensions is the result of interactions between particles or between particles and solvent, which are frequently chemical or electrostatic in nature.

References:

Lindner, A., Bonn, D., Poiré, E. C., Amar, M. B., & Meunier, J. (2002). Viscous fingering in non-Newtonian fluids. *Journal of Fluid Mechanics*, *469*, 237-256.

Balmforth, N.J., Craster, R.V. (2001). Geophysical Aspects of Non-Newtonian Fluid Mechanics. In: Balmforth, N.J., Provenzale, A. (eds) Geomorphological Fluid Mechanics. Lecture Notes in Physics, vol 582. Springer, Berlin, Heidelberg.

Chhabra, R. P. (2010). Non-Newtonian Fluids: An Introduction. Rheology of Complex Fluids, 3–34. doi:10.1007/978-1-4419-6494-6_1

Barnes HA (1989) Review of shear-thickening (dilatancy) in suspensions of non-aggregating solid particles dispersed in Newtonian liquids. J Rheol 33:329–366

Chhabra, R. P. (2006). *Bubbles, drops, and particles in non-Newtonian fluids*. CRC press.

Metzner, A. B., Vaughn, R. D., & Houghton, G. L. (1957). Heat transfer to non-newtonian fluids. *AIChE Journal*, *3*(1), 92-100.

Rajagopal, K. R., Gupta, A. S., & Wineman, A. S. (1980). On a boundary layer theory for non-Newtonian fluids. *International Journal of Engineering Science*, *18*(6), 875-883.

Cho, Y. I., &Harnett, J. P. (1982). Non-Newtonian fluids in circular pipe flow. In *Advances in heat transfer* (Vol. 15, pp. 59-141). Elsevier.

Lindner, A., Bonn, D., Poiré, E. C., Amar, M. B., & Meunier, J. (2002). Viscous fingering in non-Newtonian fluids. *Journal of Fluid Mechanics*, *469*, 237-256.

Ai, L., &Vafai, K. (2005). An investigation of Stokes' second problem for non-Newtonian fluids. *Numerical Heat Transfer, Part A*, *47*(10), 955-980.

Coleman, B. D., Markovitz, H., & Noll, W. (2012). *Viscometric flows of non-Newtonian fluids: theory and experiment* (Vol. 5). Springer Science & Business Media.

Garg, V. K., & Rajagopal, K. R. (1991). Flow of a non-Newtonian fluid past a wedge. *Acta Mechanica*, *88*, 113-123.

Huilgol, R. R., &Kefayati, G. H. R. (2016). From mesoscopic models to continuum mechanics: Newtonian and non-Newtonian fluids. *Journal of Non-Newtonian Fluid Mechanics*, *233*, 146-154.