Study of Non-Newtonian Fluids and Their Applications

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Abstract

Non-Newtonian fluids show complicated flow behaviors that do not adhere to the linear connection between stress and strain that distinguishes Newtonian fluids. Several categories of non-Newtonian fluids and their distinctive flow patterns are discussed. Difficulties and problems associated with working with non-Newtonian fluids are examined. To better comprehend the flow behavior of non-Newtonian fluids, the project is concluded with a review of current research in the area. The overall goal of this project is to give a thorough grasp of non-Newtonian fluid flow characteristics and applications.

Introduction

Newton's law of viscosity stipulates that a fluid's shear stress is proportional to its shear rate. Non-Newtonian fluids, on the other hand, have viscosities and flow characteristics that do not follow this rule. Non-Newtonian fluids are fluids whose viscosity varies depending on the applied shear stress or strain rate. The behavior of these fluids is more complex than that of Newtonian fluids, which have a constant viscosity.

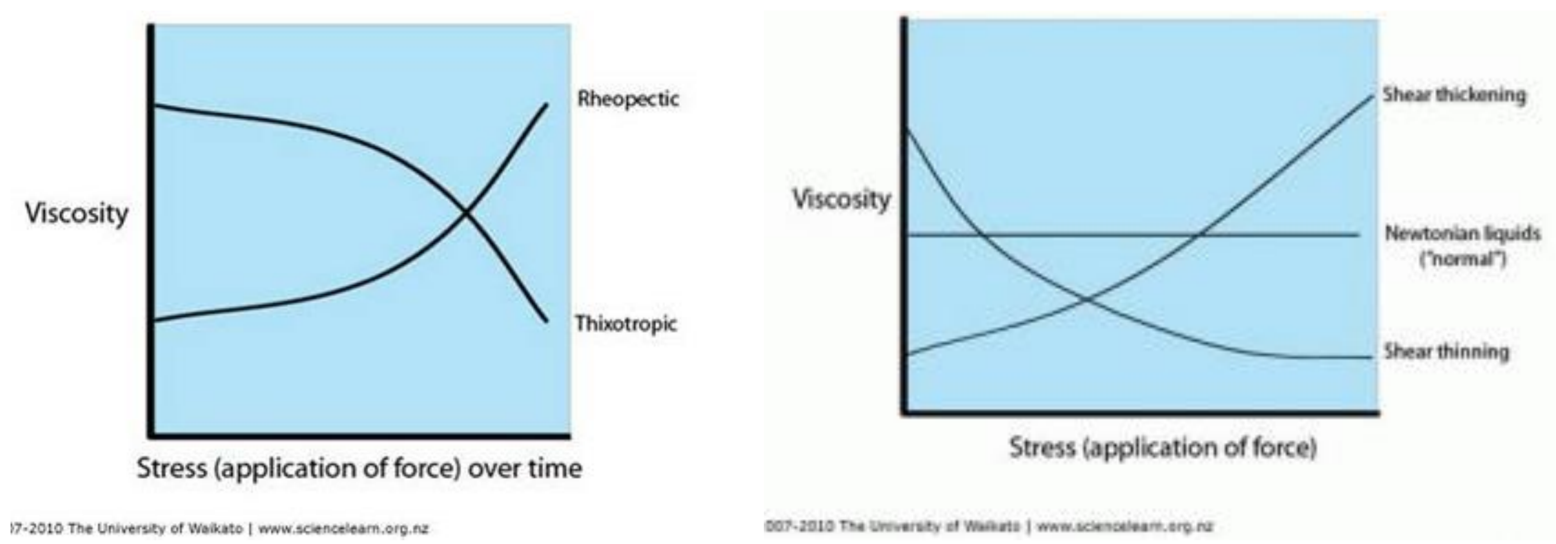

Figure 1 (Above)
This graph shows the relationship between Viscosity and Stress on a fluid

Adhesives	Peat slurries
Biological fluids	Plastic melts
Cement slurries	Polymer solution
Chalk slurries	Printing inks
Chocolate	Quicksand
Coal slurries	Rock slurries
Detergent slurries	Rubber solutions
Food sauces	Sand slurries
Greases	Sewage sludges
Hand creams	Shampoo
Margarine	Soap slurries
Mayonnaise	Starch solutions
Metal oxide slurries	Tomato paste
Oil well drilling muds	Toothpaste
Paints	Wet beach sand
Paper pulp	

Figure 2 (Left)
This list has examples of fluids that exhibit non-Newtonian behaviors

Types of behavior	Description	Examples
Newtonian	Normal Newtonian liquids	Water, crude oil
Thixotropic	Viscosity decreases w/ stress over time	Honey – When mixed honey gets thinner
Rheopectic	Viscosity increases w/ stress over time	Heavy cream – Gets thicker when whipped
Shear Thinning	Viscosity decreases w/ increased stress (inversely proportional)	Ketchup, Paint, Blood
Dilatant/Shear thickening	Viscosity increases w/ increased stress (directly proportional)	Oobleck, Silly Putty, Quicksand

Figure 3
This graph shows the different types of flow behaviors of Non-Newtonian fluids

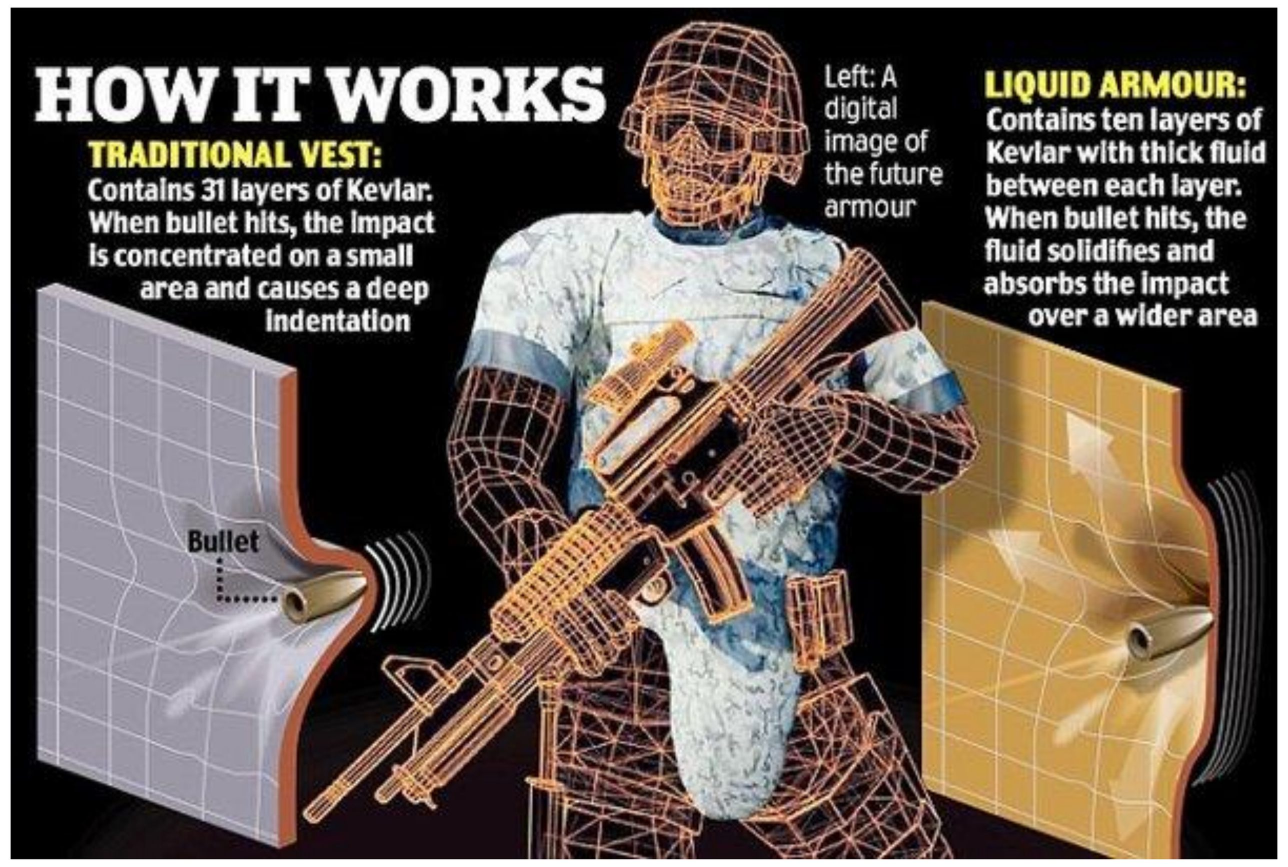

Figure 4
The above image depicts how Non-Newtonian fluids can be used as armor to protect from a bullet, more effective than Kevlar (In Theory)

Difficulties

- Varying viscosity, harder to predict behavior.
- Can become more viscous under sudden impact.
- Properties can change with time, temperature, and pressure.
- Can exhibit non-uniform flow patterns, such as flow separation and recirculation, resulting in inefficient mixing and processing.

Current research

Due to their distinct characteristics and prospective uses, non-Newtonian fluids have recently gained a lot of study attention. The creation of novel materials and technological advancements based on non-Newtonian fluids, such as smart fluids that can react to changes in temperature or pressure, is one field of research. The use of non-Newtonian fluids in biological applications, such medication delivery systems and tissue engineering, has also been the subject of research. In the food business, non-Newtonian fluids are also employed to alter the texture and appearance of meals.

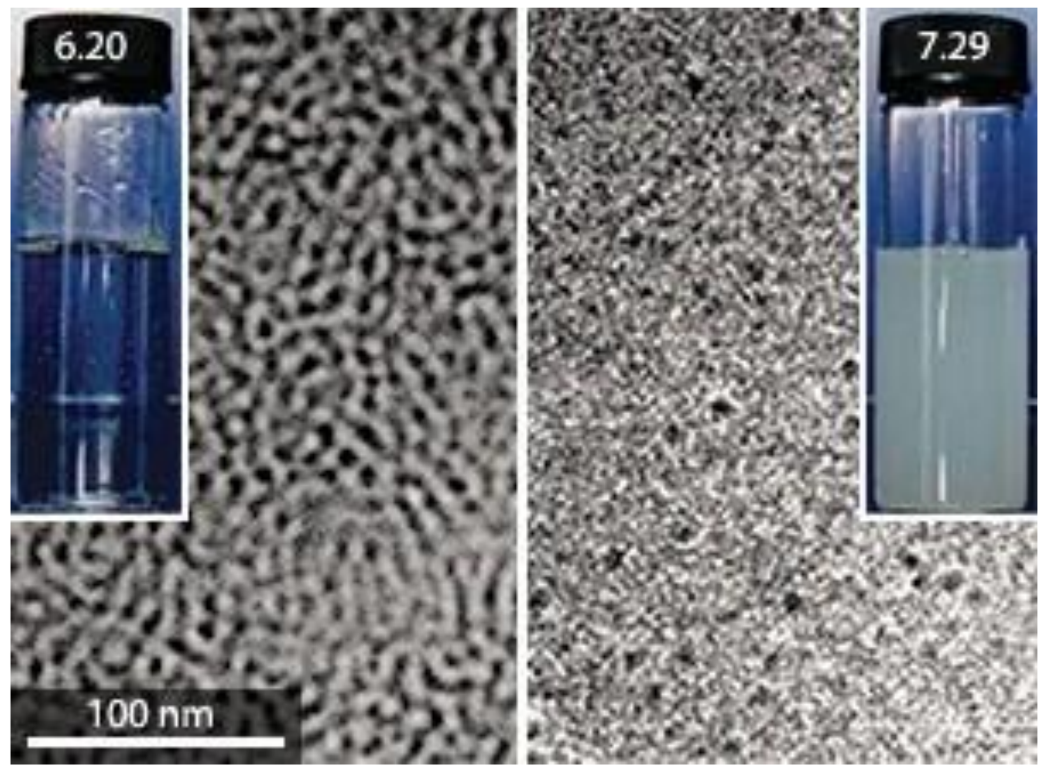

Figure 5
Images captured by Transmission Electron Microscopy depict the development of a micellar liquid that is clear and very viscous at a low pH (left) and the dissolution of that structure to produce a murky, fluid at a high pH level (right).

Equations of Non-Newtonian

Shear Stress Equation: $\tau_{yx} = \frac{\Delta P * y}{L}$

Herschel-Bulkley (Thixotropic) Model: $\sigma = K\dot{\gamma}^{n} + \sigma_y$

Bingham Plastic Model: $\tau = \tau_0 + \mu(\frac{du}{dx})$

References

[1] Science Learning Hub. (2010, April 12). *Non-Newtonian Fluids*. Science Learning Hub; Science Learning Hub.
[2] Armstrong, R. C. (2007). Rheology: Concepts, methods, and applications (2nd ed.). John Wiley & Sons, Inc.
[3] Barnes, H. A. (1999). The yield stress - a review or 'παντα ρει'--everything flows?. Journal of non-newtonian fluid mechanics, 81(1), 133-178.
[4] Chhabra, R. P., & Richardson, J. F. (2008). Non-Newtonian fluids: An introduction. CRC Press.
[5] Tanner, R. I., & Walters, K. (2000). Non-Newtonian fluid mechanics. Elsevier Science Ltd.
[6] Nwachukwu, V. A., Adesina, A. Y., & Mamba, B. B. (2019). Recent advances in the synthesis, properties, and applications of non-Newtonian fluids. Materials Today Chemistry, 12, 231-245. doi: 10.1016/j.mtchem.2018.10.004