

# **A Review on Effect of Viscosity on Liquids, Gases and Solid**

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## **1. Introduction**

The viscosity is a measure of its resistance to deformation of a liquid at a given rate and corresponds to thickness<sup>[1]</sup> Viscosity can be conceptualized as quantifying the frictional force that arises between adjacent layers of fluid that are in relative motion. Experiments show that some stress is needed to sustain the flow of the liquid. This is because a force is required to overcome the friction between the layers of the fluid which are in relative motion and the strength of this force is proportional to the viscosity. A fluid that has no resistance to shear stress is known as an ideal or inviscid fluid. Zero viscosity is observed only at very low temperatures in superfluids. Otherwise, the second law of thermodynamics requires all fluids to have positive viscosity;<sup>[2][3]</sup> such fluids are technically said to be viscous or viscid<sup>[4]</sup>. A fluid with a relatively high viscosity, such as pitch, may appear to be a solid. Dynamic and kinematic viscosity is common in fluid dynamics, which is ratio of the viscosity to the density of the fluid. The viscosity is frequently called the dynamic viscosity or absolute viscosity. The purpose of present study is to compare the viscosity of different forms of matter.

## **2. Momentum transport**

In terms of momentum transport, viscosity is the material property which characterizes momentum transport within a fluid.<sup>[5]</sup> This can be interpreted the flow of momentum in the direction from one fluid layer to the next and momentum flows from high velocity to low velocity. The fact that mass, momentum, and energy (heat) transport are among the most relevant processes in continuum mechanics is not a coincidence: these are among the few physical quantities that are conserved at the microscopic level in interparticle collisions. Thus, rather than being dictated by the fast and complex microscopic interaction timescale, their dynamics occurs on macroscopic timescales.

## **3. Newtonian and non-Newtonian fluids**

Newton's law of viscosity is not a fundamental law of nature, but serves to define the viscosity. It is independent of strain rate. Such fluids are called Newtonian. Gases, water, and many common liquids can be considered (Figure 1). Newtonian in ordinary conditions and contexts. However, there are many non-Newtonian fluids that significantly deviate from this behavior. The

Trouton ratio or Trouton's ratio is the ratio of extensional viscosity to shear viscosity.<sup>[6]</sup> For a Newtonian fluid, the Trouton ratio is 3.<sup>[7]</sup> Shear-thinning liquids are very commonly, but misleadingly, described as thixotropic.<sup>[8]</sup> Even for a Newtonian fluid, the viscosity usually depends on its composition and temperature. For gases and other compressible fluids, it depends on temperature and varies very slowly with pressure. The viscosity of some fluids may depend on other factors. A magnetorheological fluid, for example, becomes thicker when subjected to a magnetic field, possibly to the point of behaving like a solid.

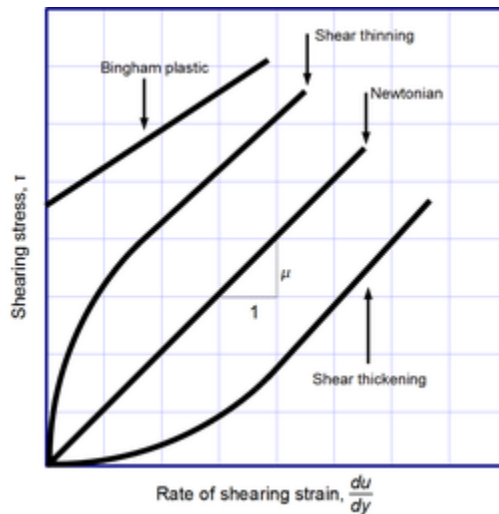


Figure 1 Viscosity, the slope of each line, varies among materials.

#### 4. In case of solids

The viscous forces during fluid flow must not be confused with the elastic forces that arise in a solid in response to shear, compression or extension stresses. While in the latter the stress is proportional to the amount of shear deformation, in a fluid it is proportional to the rate of deformation over time. However, many liquids (including water) will briefly react like elastic solids when subjected to sudden stress. Conversely, many "solids" (even granite) will flow like liquids, very slowly, even under arbitrarily small stress.<sup>[9]</sup> Such materials are therefore best described as possessing both elasticity (reaction to deformation) and viscosity (reaction to rate of deformation); that is, being viscoelastic. Indeed, some authors have claimed that amorphous solids, such as glass and many polymers, are actually liquids with a very high viscosity (greater

than  $10^{12}$  Pa·s).<sup>[10]</sup> However, other authors dispute this hypothesis, claiming instead that there is some threshold for the stress, below which most solids will not flow at all,<sup>[11]</sup> and that alleged instances of glass flow in window panes of old buildings are due to the crude manufacturing process of older eras rather than to the viscosity of glass.<sup>[12]</sup> In geology, earth materials that exhibit viscous deformation at least three orders of magnitude greater than their elastic deformation are sometimes called rheids.<sup>[13]</sup>

## **5. In Case of Gases**

Viscosity in gases arises principally from the molecular diffusion that transports momentum between layers of flow. In this case, momentum is independent of temperature. More fundamentally, the notion of a mean free path becomes imprecise for particles that interact over a finite range, which limits the usefulness of the concept for describing real-world gases.<sup>[14]</sup>

## **6. In Case of Liquids**

In contrast with gases, there is no simple yet accurate picture for the molecular origins of viscosity in liquids. At the simplest level of description, the relative motion of adjacent layers in a liquid is opposed primarily by attractive molecular forces acting across the layer boundary. In this picture, one (correctly) expects viscosity to decrease with increasing temperature. This is because increasing temperature increases the random thermal motion of the molecules, which makes it easier for them to overcome their attractive interactions.<sup>[15]</sup>

## **7. Gaseous mixtures**

The same molecular-kinetic picture of a single component gas can also be applied to a gaseous mixture. For instance, in the Chapman-Enskog approach the viscosity of a binary mixture of gases can be written in terms of the individual component viscosities, their respective volume fractions, and the intermolecular interactions.<sup>[16]</sup> As for the single-component gas, the dependence on the parameters of the intermolecular interactions enters through various collisional integrals which may not be expressible in terms of elementary functions. To obtain usable expressions for which reasonably match experimental data, the collisional integrals typically must be evaluated using some combination of analytic calculation and empirical fitting. An example of such a procedure is the Sutherland approach for the single-component gas, discussed above.

## **8. Blends of liquids**

As for pure liquids, the viscosity of a blend of liquids is difficult to predict from molecular principles. This can be done with varying levels of sophistication. One useful expression resulting from such an analysis is the Lederer-Roegiers equation for a binary mixture. Since blending is an important process in the lubricating and oil industries, a variety of empirical and proprietary equations exist for predicting the viscosity of a blend, besides those stemming directly from molecular theory.<sup>[17]</sup>

## **9. Suspensions**

In a suspension of solid particles (e.g. micron-size spheres suspended in oil), an effective viscosity can be defined in terms of stress and strain components which are averaged over a volume large compared with the distance between the suspended particles, but small with respect

to macroscopic dimensions.<sup>[18]</sup> Such suspensions generally exhibit non-Newtonian behavior. However, for dilute systems in steady flows, the behavior is Newtonian and expressions for can be derived directly from the particle dynamics. In a very dilute system, with volume fraction , interactions between the suspended particles can be ignored. In such a case one can explicitly calculate the flow field around each particle independently. There is a distinction between a suspension of solid particles and an emulsion. The latter is a suspension of tiny droplets, which themselves may exhibit internal circulation. The presence of internal circulation can noticeably decrease the observed effective viscosity, and different theoretical or semi-empirical models must be used.<sup>[19]</sup>

## 10. Conclusion

It is concluded that the viscous stresses in a fluid results from the relative velocity of different fluid particles. As such, the viscous stresses must depend on spatial gradients of the flow velocity. If the velocity gradients are small, then to a first approximation the viscous stresses depend only on the first derivatives of the velocity. As such, their utility for any given material, as well as means for measuring or calculating the viscosity, must be established using separate means.

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