Viscosity scaling in concentrated dispersions

What do water, motor oil, honey and mercury have in common? They are all liquids, and can thus all flow to take the shape of their container. It is however clear that these liquids are very different from one another. In particular, they do not possess the same resistance to flow, property which can be characterized by the *viscosity*. For example, honey has a much higher viscosity than water. This can be seen from a very simple experiment: more force is required to move a spoon in a jar of honey than in a jar of water.

Viscosity is known to depend on a variety of factors, such as the liquid composition (honey can be rather thin or thick depending on its origin) and the temperature (honey flows better when heated).

In our study, we were interested in quantifying the viscosity of a particular type of system, which is termed *colloid*. Colloids are two-component systems constituted of a solvent (for example water) in which small elements (for example oil droplets or solid particles) are finely dispersed. Typical examples of colloids include mayonnaise, cosmetic creams and paints.

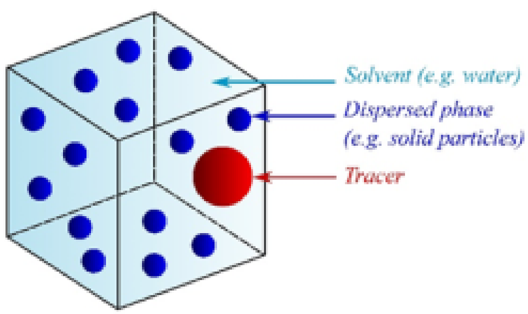

Fig. 1. Schematic representation of a colloidal dispersion.

What we showed in our study is that the viscosity of such colloids does not depend only on typical factors such as their composition or the temperature, but also on the length scale we look at. To better visualize this, consider a tracer particle, i.e. a particle on which we sit to explore the situation (see Figure 1). Imagine first that we are sitting on a particle that is much bigger than the particles constituting the dispersed phase: our movement will be hindered by these particles. If now, we sit on a very small particle, we will easily travel in the solvent, without being disturbed by the surrounding particles. This situation is similar to a traffic jam: while cars are getting blocked, motorbikes can still go through by zigzagging in-between the cars.

Coming back to our colloidal system, this means that large enough tracer particles experience what is called the *macroscopic viscosity* of the colloidal dispersion, which is the one that can be felt when doing the experiment with the spoon. On the other hand, at extremely small sizes, tracer particles will experience the *solvent viscosity*. At this level, tracer particles will diffuse at the same speed whether there are in the solvent (say water) or in a complex colloidal system (like a cosmetic cream). This brings the concept of *scale-dependent viscosity*.

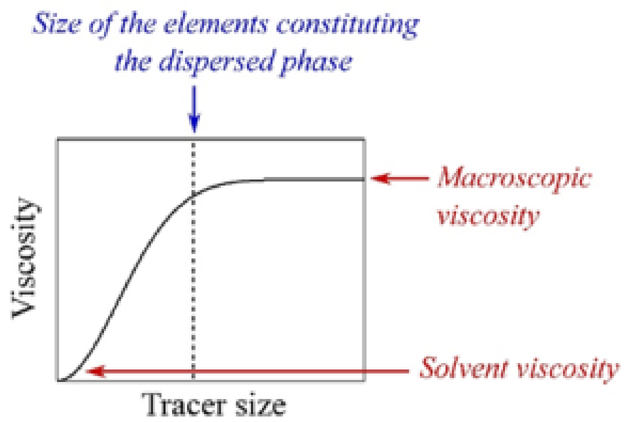

Fig. 2. Scale-dependent viscosity.

While the limiting situations of very small or very large tracer particles are relatively easy to grasp, intermediate situations are more complex and were investigated by means of computer simulations. Results are presented in Figure 2, where it can be seen how the viscosity increases from the solvent to the macroscopic viscosity when the size of the tracer particle is increased.

Unravelling how small objects diffuse in crowded environments has a wide range of applications. For example, understanding how drugs are released through transdermal patches is of primary importance in pharmacy. In the context of biology, it is fundamental to elucidate how proteins are transported through cell organisms.

Publication

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