Cambridge Polymer Group

Material Properties of Silly Putty™

Liquid or Solid? It Depends…

Introduction

Silly Putty™ is a material that vividly demonstrates the richness and complexity of behavior that that polymers can exhibit. When first handled, the initial impression given by Silly Putty™ is that of a dough-like "plastic" material. It can be easily kneaded and deformed into any shape desired. On short time scales of a minute or less, these molded shapes appear to be permanent. However, over times longer than a few minutes, the material starts to sag under its own weight and spreads onto surfaces, acting like a viscous liquid at these long timescales. In contrast, if rolled into a ball and dropped, the material bounces like an elastic ("rubbery") material. In addition, if a shock or impulsive load is applied to the putty, it will shatter like glass.

Both these latter experiments, lasting less than a second, are examples of short timescale experiments. Over the range of seconds to minutes of deformation rates, the Silly Putty™ transitions from a liquid-like material to an elastic-like material. The behavior of this fascinating material gives insight into the deformation rate sensitive behavior of many materials. In rheological terms, the experimenter is distorting the Silly Putty™ over a range of *Deborah numbers*. This non-dimensional parameter describes the ratio of the fluid relaxation time scale to that of the experimental time scale. A high Deborah number therefore corresponds to a fast experiment in which the load or impulse is applied over a very short time scale.

Composition of Silly Putty™

Silly Putty™ is a silicone material produced by Dow Corning® Corporation (under the name of Dow Corning® 3179 Dilatant Compound). According to Dow Corning, the composition (by weight percentage) is as outlined in the table to the right.

PDMS	65%
Silica	17%
Thixotrol	9%
Boric Acid	4%
Glycerine	1%
Titanium Dioxide	1%
Dimethyl Cyclosiloxane	1%

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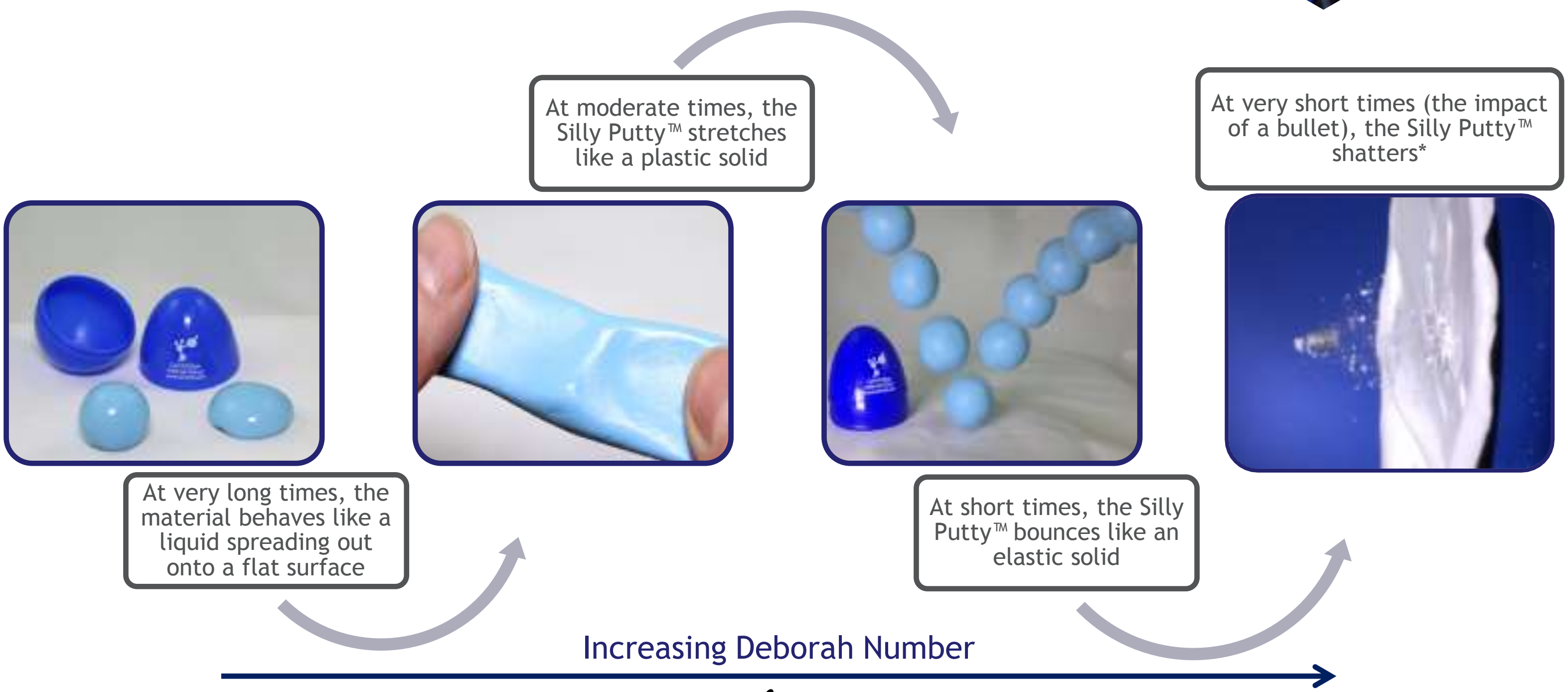

$$De = \frac{\lambda_{material}}{t_{flow}}$$

Rheology

As the name "Silly Putty" suggests, this material possesses some unexpected mechanical properties. It is an example of a dilatant material where the viscosity (i.e., the resistance to flow) increases faster than the strain rate (i.e., the faster one pushes this material, the harder it is to make flow). Although not common, a number of materials exhibit dilatant behavior (concentrated aqueous corn starch suspensions, known as "oobleck", for example). However, this phenomena on its own is not enough to explain the behavior of Silly Putty™. In fact, there are two mechanisms (and hence two characteristic time scales) at work in this material. The high molecular weight silicone polymer (PDMS) that is the primary ingredient has a characteristic polymeric relaxation time, λ_{relax} (defined by the time that a random walk allows the chain to relax from a stretched state through thermal vibrations). However due to the boric acid there are also transient boron mediated "crosslinks" arising from associating boron linkages. These act to give the Silly Putty™ a behavior more like an elastic solid than a liquid, acting like a vulcanized rubber (a natural latex that has been crosslinked to prevent it flowing). However, since these boron "crosslinks" are dynamic, with a characteristic time, λ_{assoc} that is much shorter than λ_{relax}, the material is not permanently locked in place and can consequently flow under slow deformation rates where the boron linkages can freely disassociate and then reassociate. Therefore, at time scales longer than λ_{assoc}, the Silly Putty™ behaves like a high molecular weight polymeric fluid (with a characteristic relaxation time of λ_{relax}) while over time scales much shorter than λ_{assoc}, Silly Putty™ behaves like a crosslinked elastic solid (a "rubber").

Silly Putty™ is a registered trademark of Binney and Smith

*courtesy of MIT Edgerton Strobe Laboratories

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