Cambridge Polymer Group

The Cambridge Polymer Group Silly Putty™ "Egg"

Introduction

Silly Putty™ is a material that vividly demonstrates the richness and complexity of behavior that apparently simple materials can produce. When first handled, the initial impression given by Silly Putty™ is that of a plastic material. It can be easily kneaded, much like dough, into any shape desired. On short time scales these complex shapes appear to be permanent distortions of the material. However, upon longer inspection the material is seen to sag under its own weight although the putty does not flow indefinitely on a flat surface. If rolled into a ball and dropped, the material bounces like an elastic material. In addition, if a shock or impulsive load is applied to the putty, it will shatter. The behavior of this fascinating material gives insight into the rheological 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

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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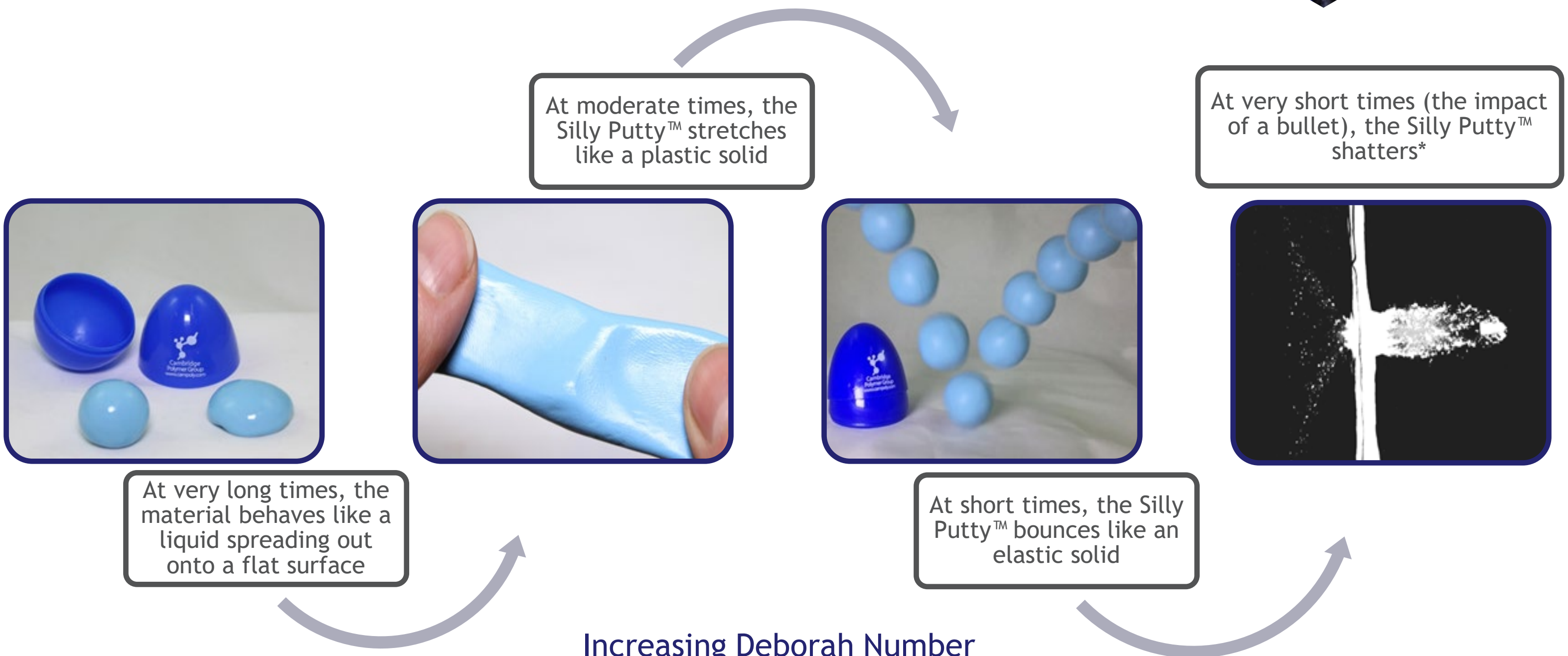

$$De = \frac{\lambda_{material}}{t_{flow}}$$

Rheology

As Dow Corning's name suggests, this material possesses some interesting mechanical properties. A dilatant material is one where the viscosity (*i.e.* the resistance to flow) increases faster than the strain rate. Although not common, some materials do exhibit dilatant behavior (concentrated aqueous corn starch suspensions 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 PDMS 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. However, since these "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 the correct conditions. 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}). Over time scales much shorter than λ_{assoc} Silly Putty™ behaves like a crosslinked elastic solid.

Silly Putty™ is a registered trademark of Binney and Smith

*courtesy of MIT Edgerton Strobe Laboratories

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