Observing Interfacial Creases in PDMS

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Objective

To experimentally prove the existence of the theoretically simulated creation of an interfacial crease that is formed in Polydimethylsiloxane (PDMS) when compressed.

Background

Soft materials are abundantly present in biological systems and in daily life. They deform greatly in response to stimulus, a characteristic that provides many useful functions. Despite these facts, research on soft materials is still at a nascent stage. Our overarching goal is to better understand the properties of these materials.

One relatively unstudied property is called the interfacial crease. This structural formation present in two bonded layers of material. Bonded materials are pervasive, found in composite materials, geological strata, electronic devices, biological tissues, and soft actuators. It is common for stresses to arise from thermal differences, chemical reaction, growth, swelling, or mechanical pre-strains. These may cause buckling instabilities, leading to the weakening of the interfacial bond between the two layers. Additionally, the interface might have defections caused by scratches or impurities. The interface would slightly separate at the site of the defection.

When the interfacial bond is at a certain strength (weak enough to allow for tears and strong enough to keep the material intact under stress) and when there is a defection on the interface, the scenario for interfacial crease formation is born. When the material is compressed at a perpendicular direction to the interface, a particular shape is formed to maintain the lowest possible energy in the material. The interface slightly separates and creates a diamond shaped opening. The formation of interfacial crease causing by a prior separation of the interface has not yet been studied experimentally; it has only been simulated with computer programs. It has been shown to be affected by the existence of a defection, strength of the interfacial bond, and percentage of compression. It is not affected by the stiffness of the material. Our goal was to create the conditions under which the crease will form and validate its existence using the widely prevalent and purposive material, polydimethylsiloxane.

PDMS: Properties and Preparation

Polydimethylsiloxane (PDMS) belongs to a group of polymeric organosilicon compounds that are commonly referred to as silicones. PDMS is the most widely used silicon-based organic polymer and is particularly known for its unusual rheological (or flow) properties. It is viscoelastic, meaning that during low flow times or under high temperatures, it acts like a viscous liquid, and under short flow times, or under low temperatures, it acts like an elastic solid. PDMS is translucent and, in general, inert, non-toxic, and non-flammable. It is also biocompatible, meaning it does not harm living tissue. Solid PDMS samples have external hydrophobic surfaces. PDMS’s applications include use in cosmetics, contact lenses, medical devices, caulking, lubricating oils, and heat-resistant tiles, and as an anti-foaming agent for external hydrophobic surfaces. PDMS’s applications include use in cosmetics, contact lenses, medical devices, caulking, lubricating oils, and heat-resistant tiles, and as an anti-foaming agent.

Cook time:

1. Mix PDMS and curing agent.
2. Stir vigorously for 5 minutes.
3. Let mixture sit until air bubbles disappear.
4. Fill the dish with the new batch of PDMS.
5. Place back in the oven and let PDMS cross-link.
6. Take dish out of the oven.
7. Fill the rest of the Petri dish with the new batch of PDMS.
8. Place back in the oven and let PDMS cross-link.
9. Repeat steps 1-3.
10. Fill the rest of the Petri dish with the new batch of PDMS.
11. Place back in the oven and let PDMS cross-link.

Optimizing Sample Preparation

Cook time: The 1st layer of PDMS was baked in the oven for various times to uncover the minimum amount of time that was required to crosslink the first layer. 90 minutes was found to be the minimum time needed at 50 °C.

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Interface</th>
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<tbody>
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</tr>
<tr>
<td>60</td>
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<td>120</td>
<td>Visible</td>
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<td>150</td>
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Creating Defeotions: Various materials were used to create deformations. First, a glass needle was placed on the first layer before the second layer of PDMS was poured on. The needle was too heavy and sunk into the first layer. Ultimately, a plastic string was used. The defection was still asymmetrical along the interface, as the string rested on top of the first layer. However, the hole was still at a location where it could form a crease under compression.

Varying Stiffness: The stiffness of the PDMS can be controlled by the amount of curing agent that is added. More curing agent creates a stiffer material. Most samples where made of two layers with a 20:1 ratio of base to agent. However, some samples had one layer with a 30:1 ratio of base to agent, making one layer softer. The stiffness of the softer layer seemed to prevent deformations from fully forming, so no interfacial crease formed. Large surface creases formed on the softer half when these samples were compressed.

Comparison of Theoretical and Experimental Results

Our results showed a separation of the interface. However, the inward crease was larger and asymmetrical. There were three main differences between the simulation and our experimental setup:

1. In the simulation, the defection is distributed symmetrically along the interface. In experiments, there is some error in aligning the defect, making the crease grow differently on the two sides.
2. In the simulation we assume the material is plain strain, meaning the direction perpendicular to the compression has zero strain. However, in the experiment, we could not avoid strain in this direction.
3. In the simulation, we assume a uniform compression along the interface, but in experiment, due to the limit of the compression mechanism, the compression is not uniformly applied to the material.

Conclusions and Future Directions

Accomplishments:

• We created conditions under which an interfacial crease can form by using a specific stiffness of PDMS and plastic string to create a defection.
• We experimentally validated the presence of an interfacial crease in PDMS at the site of a defection.

Future Goals:

• Use a compression machine that can more evenly distribute force along the sides of the material.
• Find a method for varying and quantitatively measuring the adhesiveness of the interfacial bond to observe how bond strength effects crease formation.
• Observe interfacial creases in other materials.

References