

Stress Cracking of Polycarbonate Exposed to Sunscreen

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ABSTRACT

Pushbuttons, knobs and plastic faceplates in automotive interiors are constantly exposed to chemicals such as sunscreen. In some instances, structural degradation of the plastic may occur with specific chemical agents and degradation can also be accelerated by high temperatures. A study of the propensity of commercial polycarbonate (PC) to craze and ultimately crack when exposed to sunscreen is outlined in this paper. Three-point bend testing per ASTM D3929 results in permissible bending strain limits for prolonged exposure to sunscreen at elevated temperatures. The paper outlines implementation details of these strain limits applied to a button surface, including finite element analyses identifying strain at the observed failure locations. Design considerations for related parts and products are also outlined.

INTRODUCTION

Aggressive exposure of plastics to chemical contaminants to detect instances of environmental stress cracking (ESC) [1, 2, 3] is a regular feature of automotive product validation. The cadence of such chemical exposure tests does not always allow *a priori* testing on prototypes to allow susceptible designs to be identified before tooling and production. Moreover, as outlined in this paper, plastics with even moderate amounts of designed-in stress are at risk under prolonged exposure to certain chemicals, which makes design and manufacturing of such parts a challenge.

The automotive interior is richly populated with plastics for decorative, structural and functional purposes. Pushbuttons serve the important interface function of transmitting finger-imposed instructions to internal electronics for a variety of radio, telematics, HVAC and navigation options. Therefore, it

is conceivable that the surface of a pushbutton is repeatedly exposed to water, oils, greases and other contaminants that can be found on the surfaces of fingers and gloves. In this paper, we address the concern of prolonged exposure of buttons to sunscreen and arrive at maximum permissible strains (and computed stresses) to minimize crazing and eventual cracking through the plastic.

BACKGROUND AND MOTIVATION

The specific problem of interest concerning buttons with a polycarbonate cap mating to an acetal actuator provides the motivation for this investigation. The cap is snapped onto the actuator. The cap-actuator assembly mounts to a trimplate using snaps and uses a keypad on a printed circuit board to provide the actuation when the cap is depressed by a finger.

As designed, the cap stays attached to the actuator by virtue of snap hooks that mate with slots in the actuator body. However, to accommodate tolerances and to minimize the possibility of a loose cap could pull-off easily or a rattle, the cap is designed with lateral interferences at crush ribs. The result is a constant non-zero imposed stress on the cap driven by the interference. Note that tensile stresses are seen on the *inside* corner, and are not directly exposed to the outside.

To test the design to meet sunscreen exposure requirements, sunscreen is brushed over the surface of the cap and the assembly is then placed in an oven at 80°C for a day (24 hours) to simulate the effects of temperature exposure. Owing to the stress imposed by the interference, the cap sometimes fails this test by cracking near the corners at the high-stress areas.

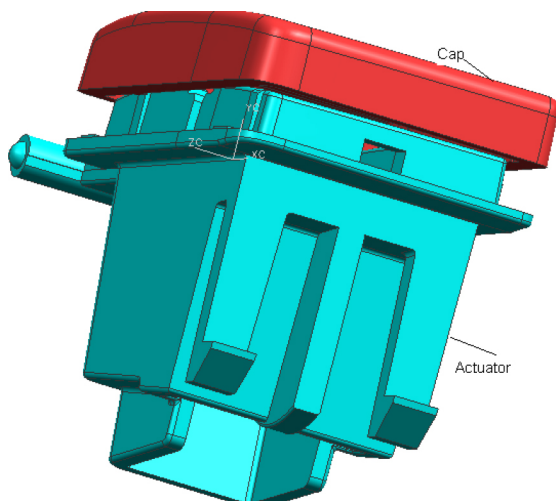


Fig. 1. Cap being inserted onto actuator

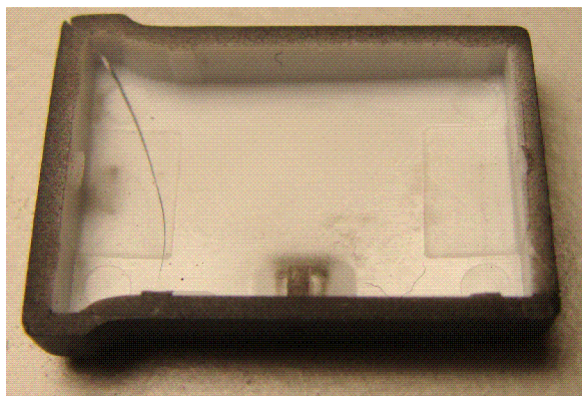


Fig. 2. Cap showing a crack following a typical sunscreen exposure test

DESIGN AND STRESS ANALYSIS

With the objective of quantifying the stress imposed by the interference at the crush ribs, finite element analysis (FEA) is performed. It is observed that under nominal conditions for assembly, imposed stresses are of the order of 44 MPa (Fig. 3), with the corners showing the highest stress. PC has a strength of 60 MPa [2], and while it is possible that the strength degrades with temperature, numerous experiments *without* sunscreen indicate that the part shows no tendency to break near the corners. Indeed, experiments indicate that it is possible to significantly distort the cap side walls without causing the cap to break when the only loads imposed are temperature, insertion stresses and interference-induced stresses.

A comprehensive investigation of the failure mode helps drive the resolution toward two main contributors:

- Continuously imposed stress
- Continuous exposure to sunscreen at high temperature

The mechanical design approach employed is to minimize the continuously imposed stress by reducing the interference or by redesigning with no imposed interference. While various designs lend themselves to such approaches, the underlying concern about the usage of polycarbonate in similar applications remains and motivates an experimental study of the propensity for sunscreen-driven cracking.

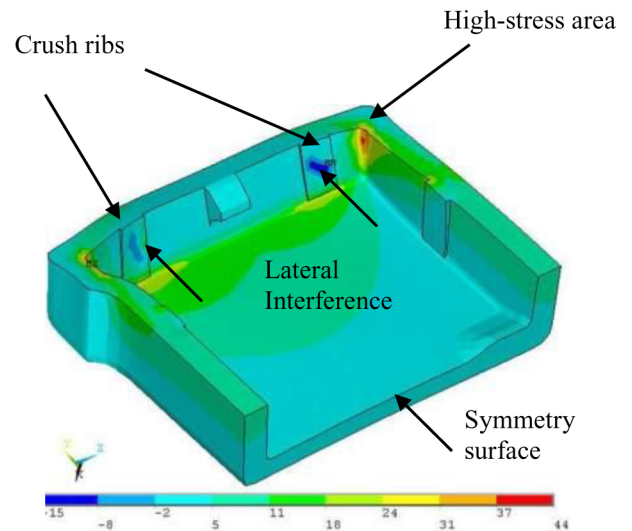


Fig. 3. Portion of cap showing stresses predicted by finite element analysis (FEA) due to interference at the crush ribs

EXPERIMENTAL STUDY

A 3-point bend fixture (Fig. 4) per ASTM D3929 is used to flex coupons (beams) to a known state of strain along the long axis. The center bar is adjusted vertically to change the strain on the beams by changing the imposed deflection of the middle of the beam. The outer fiber strain for a beam in flexure is given by

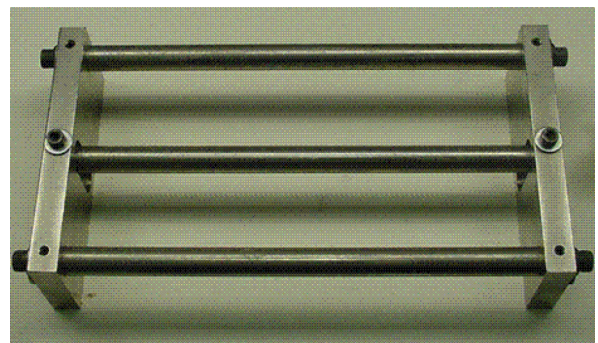


Fig. 4. Three-point bend fixture to impose strain on specimens