Using Gas Diffusion And Cohesive Zone Modeling To Assess Voids In Spacecraft Radiator Panels

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Abstract

Radiator panels are used on spacecraft as a method of thermal management. The radiator must both reject waste heat from spacecraft electronics and minimize absorption of radiant heat loads from the environment. As such, radiator surfaces that maintain high infrared (IR) emittance and low solar absorption over mission life are required. Thermal control mirrors often satisfy this requirement where other options, such as paints, fail.
While mirrors are a good choice, they do represent manufacturing challenges. Covering a large surface with smaller individual mirrors require a significant amount of time both in mirror layup and attachment to a surface.
This work investigates observed voiding/detachment/separation in the interface between the mirror and the bonding adhesive and the potential for mirror cracking and blowout during testing as a result of that separation. The COMSOL Multiphysics® simulation software was used to model a variety of physics related to this investigation.
Initially, the Structural Mechanics Module was used to assess the bending stresses in a mirror subjected to pressure and volume changes of an air-containing void underneath the mirror. This model abstracted the assumed ideal gas behavior of the air by calculating the void volume via Gauss's theorem and a surface integral on the bottom of the mirror and the detached adhesive. The hyperelastic properties of the adhesive were previously calculated with the use of the Optimization Module on available test data.
Additionally, the Chemical Reaction Engineering Module was used to develop a multicomponent gas diffusion from the results of an ASTM E1559 Contamination/Outgassing test to determine the potential pressure that may develop under a mirror due to outgassing of the adhesive. The Structural Mechanics model of the partially detached mirror and adhesive was augmented with differential equations describing the additional pressure load generated from the diffusion process.
A testing process was developed to screen out weak mirrors with large voids. This process involved applying and then peeling tape from the surfaces of the mirrors. For mirrors with voids, this would generate bending stresses on the mirror. The stresses from peeling the tape from the mirror surface were simulated with a cohesive zone model describing the progressive detachment of the tape. The loads from the tape peeling over a voided portion of mirror were compared to the previous pressure/temperature/outgassing stresses. The results indicated that these stresses would be larger than those that the mirrors would experience on-orbit.

Figures used in the abstract

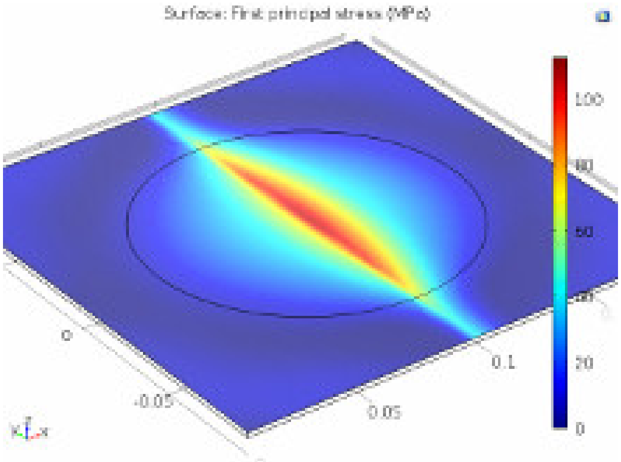

Figure 1 : Stress distribution in a thermal control mirror due to traction load from peeling tape off surface