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Quasi-Static Brittle Fracture in Thermally Loaded Bimaterial Beam Specimen

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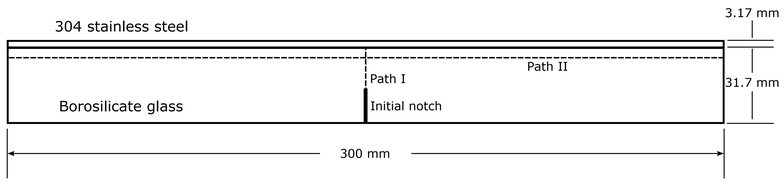
Summary

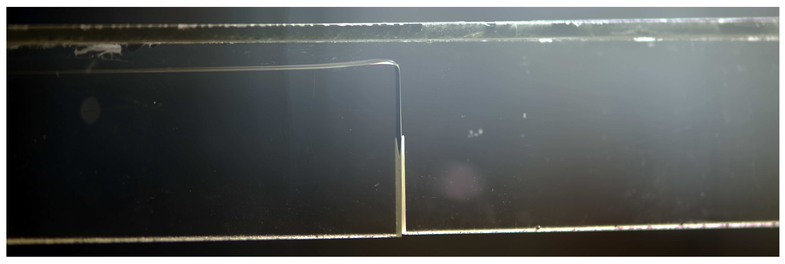
A specimen has been designed to study crack paths near interfaces in brittle materials. We are studying what factors affect crack propagation near interfaces and how the crack transitions from being directionally stable to unstable. The specimen also provides a simple but challenging test case for numerical methods predicting crack propagation.

Specimen description

The specimen consists of stainless steel and borosilicate glass bonded with epoxy at room temperature. It is loaded by cooling from room temperature and the difference in CTE between the glass and steel puts the specimen in a state of bending with the bottom of the glass in tension.



A crack initiated at the center of the bottom of the specimen initially propagates upwards along Path I. As it nears the interface it switches to Path II with no nominal preference toward turning left or right. A naive application of the rule that a crack will propagate in a direction where $K_{\mathrm{II}} = 0$ would not predict this turning path.



The final distance between the crack and interface in the FRANC3D simulation matches an analytical model of substrate cracking and agrees with experiments to within 10%.

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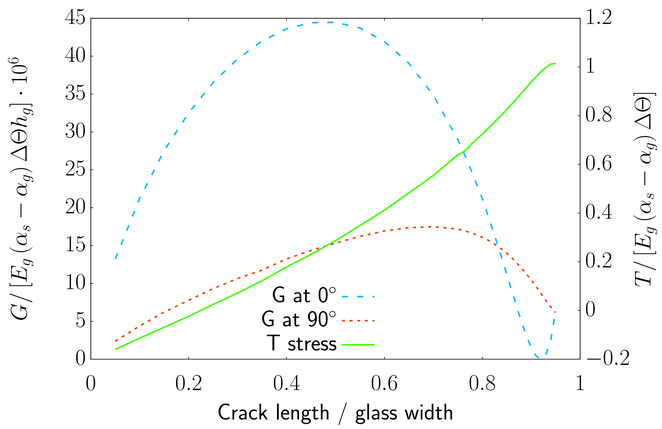
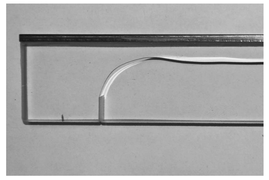
Why does the path turn?

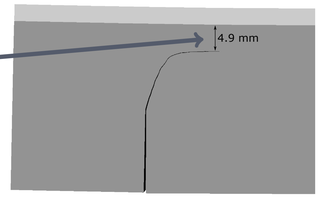
Near the interface, energy release rate is greater parallel to the interface. In addition, T stress becomes high, which is often associated with path instability. In this case, stability means the crack tends to move back to its original path when its path is slightly perturbed.



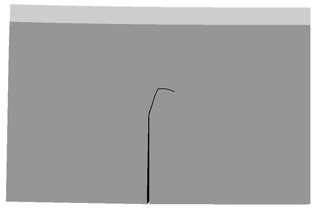
FEA crack path predictions

When crack is initiated near the end of the specimen, it stably turns toward the center. Accurate numerical prediction of crack paths is difficult, even in this simple case. A variety of methods exist for predicting crack paths; two popular methods are shown here.





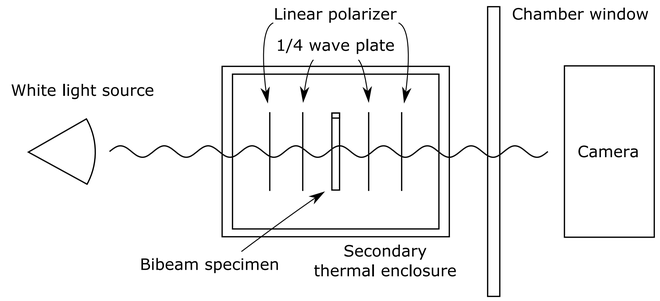
Crack path predicted using the mesh restructuring fracture code FRANC3D with SIERRA/SM

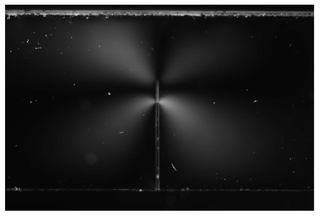


Crack path predicted using XFEM in Abaqus/Standard

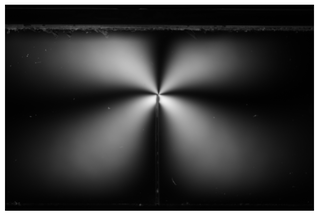
Cracks visualized with photoelasticity

Stress affects the polarization of light passing through glass. The resulting fringe pattern can be used to precisely locate the crack tip and estimate fracture parameters.

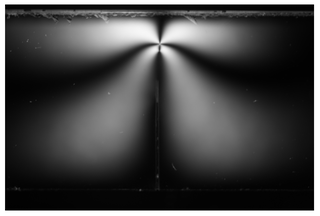




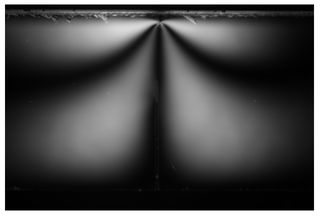
Initial loading



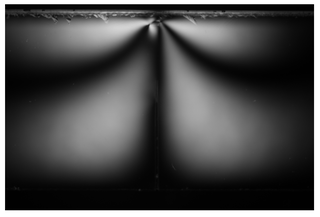
Chevron notch fills



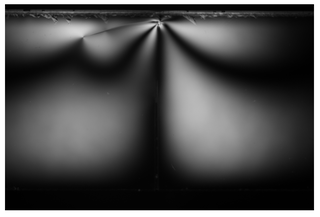
Crack propagates along Path I



Crack nears interface



Crack begins to turn



Crack propagates along Path II

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