Crack Bifurcation in Laminar Ceramics Having Large Compressive Stress

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Crack bifurcation is observed in laminar ceramics that contain large residual compressive stress. In such composites, alternating material layers have tensile and compressive residual stress, due to thermal expansion mismatch or other sources. The compressive stress ensures that crack growth leading to failure in the laminar system is mediated by threshold strength, but, in some cases, it also leads to bifurcation of the propagating flaw. This phenomenon takes place when the crack tip is propagating in the compressive layer, and occurs typically at a distance equal to a few laminate thicknesses below the free surface and beyond. The observation of this phenomenon is usually associated with the presence of edge cracking in the compressive layers of the laminar ceramic, although it can also occur in the absence of such edge cracks. In the few cases where bifurcation occurs without edge cracks, the residual stresses and layer thicknesses are close to the condition in which edge cracks will occur. In addition, in this case the bifurcation is confined to near the specimen free surface, and below the bifurcation plane, the cracks are straight. The energy release rates for the straight and bifurcated cracks are calculated from the results of finite element computations and compared. When edge cracking is ignored, the crack is simulated as a through-thickness crack in an infinite body, and the energy release rate is used to predict crack deviation and bifurcation. Based on this, the finite element model successfully predicts bifurcation in only one material combination that was investigated in experiments. However, the experimental bifurcation takes place in two additional material combinations. When the effect of edge cracking is incorporated into the finite element simulations, the energy release rate calculations successfully predict the phenomenon of bifurcation in three material combinations, as observed in the experiments. Since no edge cracks are present in the fourth material combination tested experimentally, its lack of bifurcations is automatically predicted by the model. The presence of edge cracking, or its incipience, is thus concluded to be critical to the occurrence of crack bifurcation in laminar ceramic composites.

References

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