Final Report for DE-AI05-04OR23065
Reliability Analysis of Brittle, Thin Walled Structures, NASA SAA3-719

Jonathan A Salem and Lynn Powers
NASA Glenn Research Center, Cleveland, OH 44135

One emerging a pplication for ceramics is diesel particulate filters being used order to meet EPA regulations going into effect in 2008. Diesel particulates are known to be carcinogenic and thus need to be minimized. Current systems use filters made from ceramics such as mullite and corderite. The filters are brittle and must operate at very high temperatures during a burn out cycle used to remove the soot buildup. Thus the filters are subjected to thermal shock stresses and life time reliability analysis is required. NASA GRC has developed reliability based design methods and test methods for such applications, such as CARES/Life and American Society for Testing and Materials (ASTM) C1499 “Standard Test Method for Equibiaxial Strength of Ceramics.”

CARES/Life is an integrated software package that predicts the probability of a monolithic ceramic components failure as a function of time in service. It couples commercial finite element programs such as Ansys or Abacus, which resolve a components temperature and stress distribution, to reliability evaluation and strength routines for assessing strength–limiting defects in a structure.

The code does have some limitations that should be kept in mind: It is statistical only in terms of the strength; it never uses fracture toughness or flaw size and thus is not fracture mechanics based; it requires similitude of the flaw distribution between the input data sets and the actual component over the life time; and it lacks bounds on the probability estimates. However, for general design purposes, is considered applicable.

The CARES/Life program was applied to diesel particulate filters as part of ORNL efforts with industry diesel engine producers. Although the result are considered proprietary, one generic result seen in some data sets published in the open literature is the lack of a volume or area effect, implying that Weibull scaling is not needed.

In addition, the double torsion test specimen was investigated as part of fracture toughness measurement efforts with diesel particulate filter materials and fuel cell elements. It has been shown that the double torsion method can produce comparable results to other standardized methods if the appropriate geometric and fixture guidelines are applied. Based on the current results, an American Society for Testing and Materials committee C28 standard is being drafted.

Future work may include detailed fracture toughness testing of filter materials and refined analyses that better account for the scaling effects observed.