FAILURE AT INTERFACES IN COMPOSITE MATERIAL SYSTEMS DUE TO THERMAL EXPANSION MISMATCH

E. S. Folias [1] , M. Hohn [2]

[1&2] *Department of Mathematics, University of Utah, Salt Lake City Utah, 84112, USA.*

KEYWORDS: Thermal stresses, thermal mismatch, thermal cracking, residual stresses, failure at interfaces.

INTRODUCTION

Residual stresses due to curing and thermal stresses due to differences between the thermal expansion coefficients of the matrix and fiber may have a major effect on the micro-stresses within a composite material system and must be added to the stresses induced by the external mechanical loads. Such microstresses are often sufficient to produce micro-cracking even in the absence of external loads, example during the cooling process.

In this investigation, a micro-mechnics approach is used in which the fibers of a composite material system are modeled as cylindrical inclusions that are embedded into a matrix plate. The model is then used to predict, analytically, the residual stresses due to a thermal expansion mismatch, eg. during a cooling process. Additionally, some critical effects due to a load transverse to the direction of the fibers are examined. The analysis provides a better understanding of how residual stresses are developed and how they may be controlled in material systems where small strains are present.

Moreover, the results are used to identify locations of possible crack failure and to derive a fracture criterion for crack initiation at the local level. Comparison with experimental evidence for matrix cracking in intermetallic composites caused by thermal expansion mismatch shows a good agreement.

Finally, the analysis reveals the load transfer characteristics between fibers and matrix, identifies the dependence of the stress field on the fiber volume fraction ratio, identifies the critical locations where a crack may initiate, recovers the interface shear stress profile and provides important guidance for future research on the subject of fiber / matrix interface friction and sliding. The results are then used to derive a fracture criterion for crack initiation at the local level.

Comparison with experimental evidence for matrix cracking in intermetallic composites caused by thermal expansion mismatch shows good agreement. Moreover, the fracture criterion reveals important information that material designers may use for the pre-selection of fiber and matrix materials in order to alleviate some of these residual stresses.