DYNAMIC BEHAVIOR OF FIBER REINFORCED COMPOSITES UNDER MULTIAXIAL COMPRESSION

Theresa H. Kidd*, Murat Vural, Guruswami Ravichandran***
[Guruswami Ravichandran]: ravi@caltech.edu
*California Institute of Technology, **Illinois Institute of Technology

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1. Introduction

Composite materials have been widely used in aerospace applications since the 1960s. Due to the low weight requirements and expensive manufacturing costs, composite structures were usually “thin,” and therefore, research was limited to their in-plane behavior. With the development of new construction methods, such as resin transfer molding (RTM), thicker composites can be produced in an economically efficient manner, making composites more practical in a wider range of applications including marine structures [1].

Thick composites are being utilized as face plates for sandwich structured hulls, with the intention to replace and compliment current metal hulls. Sandwich structures typically consist of two faceplates on either side of a core material. The faceplate lends protection from foreign object damage to the structures, while the lightweight core reduces the overall weight of the structure. The core material can consist of metallic foams, honeycomb or balsa wood, while the faceplates are usually metallic or made of composite materials. Analysis and design of such structures require constitutive and failure models validated by experiments. Currently there are a large number of phenomenological and micromechanical models for composites [2, 3] but at the same time lacking reliable experimental data to validate these models. This paper focuses on the faceplate composite material, specifically a unidirectional fiber reinforced S2-glass/epoxy composite under transverse compression over a wide range of strain rates and stress states.

2. Experimental

2.1 Material

The material used in this study was S2/8552 glass/epoxy fiber reinforced composite (FRC). The material, has zero degree fiber orientation with a nominal fiber volume of 65%. The specimen dimensions for quasi-static tests were typically around 9.51 ± 0.05 mm in both length and width, and 5.02 ± 0.05mm in height., while for the dynamics tests, the dimensions of the sample were of length and width, 6.00 ± 0.01 mm and a height of 4.00 ± 0.01mm.

2.2 Multiaxial Loading

Low strain rate (10^{-4} to 10^{-1} s^{-1}) tests were performed using a servo hydraulic materials testing system. High strain rate ($\sim 10^{3}$ s^{-1}) tests were performed using a Kolsky (split Hopkinson) pressure bar system [4]. Two unique fixtures were developed to specifically explore the region of biaxial compression of the failure plane for quasi-static and dynamic loading [5, 6]. These fixtures can apply biaxial confinement to a composite specimen. All specimens were loaded perpendicular to the fiber axis, otherwise known as transverse loading. The in-plane confinement was provided by two sets of fingers instrumented with strain gages. The three principal stresses were measured independently during the entire range of deformation. The amount of in-plane confinement was varied by the choice of materials and inserts. The picture of the dynamic confinement setup is shown in Fig. 1.

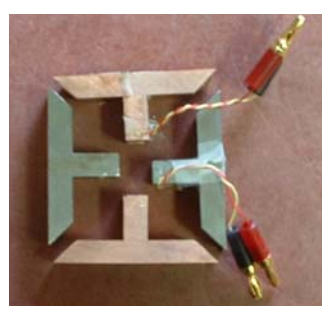

Fig. 1. Photograph of the instrumented biaxial confinement fixture for dynamic characterization of fiber reinforced composites.

3. Results and Discussion

A typical result of an experiment using the polycarbonate pad and aluminum finger combination can be seen in Fig. 2. The data represents a finger pad combination with a pad thickness of 3.81 mm and a finger length of 29.54mm. The values of σ_{11} and σ_{22} (in-plane stress). The axial stress is greater than both the longitudinal and transverse stresses. In addition, the transverse confining tress is greater than the longitudinal confining stress because the composite has a tendency to elongate in the matrix dominated or transverse direction as opposed to the fiber dominated longitudinal direction. Typically, the stress-strain curves initially exhibited a linear elastic behavior followed by nearly perfectly inelastic deformation to a considerable extent (~0.2).

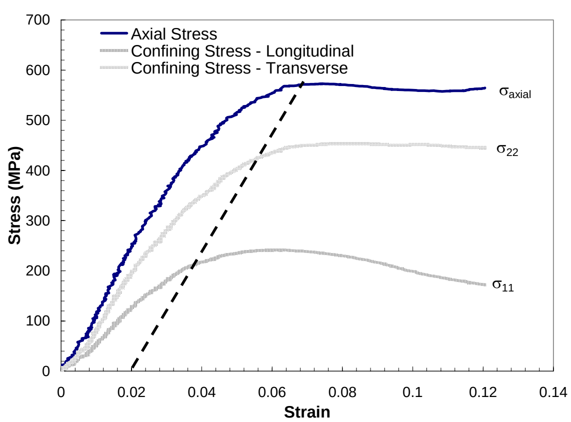

Fig. 2. A typical stress-strain curve for uni-directional fiber reinforced S-glass /epoxy composite under multi-axial loading.

The experiments conducted over a wide range of strain rates, from 10^{-4} to $3x10^{3}$ s^{-1}. The three principal stresses were measured independently and the data was used to construct the failure envelopes following the procedures described in [5, 6]. The plot of maximum shear stress versus pressure showed a linear relationship, suggesting a Mohr-Coulomb criteria as a possible failure envelope for transversely loaded composites. Furthermore, the linear relationship was not affected by the strain rate with in the range of strain rates explored in the present research. Examination of the deformed specimens indicate that the shear failure is highly localized within narrow bands inclined at n angle (~50^{o} to the loading axis) and the deformation was dominated by the matrix.

4. Summary

The quasi-static and dynamic response of the S2-glass/epoxy fiber reinforced composite subjected to transverse compression has been studied under a wide rage of confinements and strain rates. Two unique fixtures were developed to apply and measure longitudinal and transverse confinement stresses independently. Using the experimental data gathered, a failure envelope was constructed and compared with widely used phenomenological and micromechanics based models [2, 3].

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