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RESEARCH ON THE DAMAGE TO AIRCRAFT COMPOSITE MATERIAL FUEL TANKS DUE TO PENETRATING PROJECTILES (HYDRAULIC RAM) AT THE NAVAL POSTGRADUATE SCHOOL

R. E. BALL
Naval Postgraduate School, Monterey, CA 93940, U.S.A.

Abstract—Metal aircraft fuel tanks that are subjected to ballistic impact and penetration by small arms fire and missile fragments can be severly damaged, with large petalling of the tank walls occurring at the entrance and exit points of the projectile. The damage mechanism, called hydraulic ram, is a very high pressure wave in the fuel caused by the passage of a ballistic penetrator through the fuel. Fluid pressures and wall strains have been experimentally measured and analytically predicted at NPS for rectangular tanks with aluminum walls. A summary of this work is given in Ref. [1]. Due to the fact that aircraft fuel tanks made of composite materials are now being seriously considered, the effect of hydraulic ram on composite material tank walls has been investigated. In Ref. [2], the various effects of hydraulic ram on a clamped 11-in. square, 0.067-in. thick, graphite/epoxy wall due to penetration by a .22 caliber projectile were examined. Shots at 2600 fps caused only light damage to the plate. At 2800 fps, the hydraulic ram caused considerable damage, including total severance of the plate from its clamped support over much of the outer perimeter.

The objectives of the research in Ref. [3] were to show the relative importance of the transverse shearing forces produced by hydraulic ram loading on military aircraft fuel tank joint designs for composite materials, and to propose fuel tank test section designs based upon specific composite material fuel tank design concepts for the F-16, F-18 and a Navy V/STOL delta wing. With the use of a finite element analysis, the transverse shearing force at a metal fastener was shown to be a major cause of failure at the attachment, primarily by an out-of-plane push-out mode of failure. This type of failure could have a significant effect on the structural integrity of a major load crrrying member of the aircraft, such as the wing box beam. In this situation, a large portion of the wing skin over the fuel tank may become detached from the spars, ribs and stringers, causing a serious degradation in the strength and stiffness of the wing. Future research will be devoted to the study of the amount of resistance to out-of-plane push-out shown by various composite attachment designs and to the determination of the amount of area over which push-out may occur. This work has been supported by the Joint Technical Coordinating Group for Aircraft Survivability and the Naval Weapons Center, China Lake, California.

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A FUNDAMENTAL ANALYSIS FOR CRACK GROWTH IN A FIBER REINFORCED COMPOSITE

M. R. KANNINEN, E. F. RYBICKI, W. I. GRIFFITH and P. C. GEHLEN
Battelle–Columbus Laboratories, Columbus, OH 43201, U.S.A.

Abstract—This abstract describes work in progress to develop an analysis procedure for crack growth in a fiber reinforced composite material. The work is supported by NASA, Ames Research Laboratory.

Unlike metals, fracture in composite materials is determined by a sequence of distinct micromechanical processes. The long-range goal of this work is a mathematical model that will permit predictions of the strength of fiber reinforced composites to be made from the basic mechanical properties of the constituents. The approach merges a general anisotropic homogeneous material representation with a local heterogeneous region (LHR) surrounding the crack tip.

The unique feature of the mathematical model described in this paper stems from the interactive manner in which individual local rupture events are permitted to occur in the local heterogeneous region. Specifically, the model has the capability to represent the fracture process as a sequence of localized events determined from the analysis. The LHR consists of elements representing the matrix, the fibers, and the fiber-matrix interface. The basis for the prediction of local rupture is related to an intrinsic critical energy density. In the model, each constituent (and interface) of a fiber composite can rupture independently at any point where the energy criterion is met.

Previously, computations were performed for unidirectional composites under tensile loading using assumed properties for the composite constituents. It was shown that fiber breakage, crack bridging, matrix-fiber delamination, and axial splitting can all occur during a period of (gradually) increasing load prior to catastropic fracture. Of most importance, the computations revealed the sequential nature of the stable-crack growth process in fiber composites.