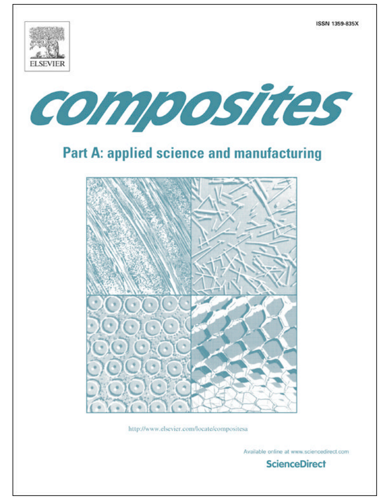
Accepted Manuscript



Progressive Damage and Failure Analysis of Single Lap Shear and Double Lap Shear Bolted Joints

Ashith P.K. Joseph, Paul Davidson, Anthony M. Waas

PII: S1359-835X(18)30281-1
DOI: https://doi.org/10.1016/j.compositesa.2018.07.018
Reference: JCOMA 5113

To appear in: *Composites: Part A*

Received Date: 25 May 2018
Revised Date: 13 July 2018
Accepted Date: 14 July 2018

Please cite this article as: Joseph, A.P.K., Davidson, P., Waas, A.M., Progressive Damage and Failure Analysis of Single Lap Shear and Double Lap Shear Bolted Joints, *Composites: Part A* (2018), doi: https://doi.org/10.1016/j.compositesa.2018.07.018

Progressive Damage and Failure Analysis of Single Lap Shear and Double Lap Shear Bolted Joints

Ashith P. K. Joseph, Paul Davidson, Anthony M. Waas*

William E Boeing Department of Aeronautics and Astronautics, University of Washington, 3940, Benton Ln NE, Seattle, WA, 98195

Abstract

Intra-inter crack band model (I2CBM) is proposed for studying the progressive damage and failure of laminated composite bolted joints. The model combines Schapery theory for matrix microcrack modeling with crack band theory for lamina macroscopic failure modeling in a standard 3D finite element framework and is implemented as material laws at element integration points. Three different failure planes defined by material orthotropy are considered for the modeling of macroscopic failure using crack band theory. This procedure allows the model to be used either as an intraply element or as an interply element of finite thickness by an appropriate choice of the crack planes of interest. Localized bearing failure, observed in bolted joints, is modeled using a residual strength approach in the post-peak response of individual ply elements. Simulation results for single lap shear and double lap shear bolted joint problems are compared against experiments for model validation.

Keywords:
Composite laminates, Bolted joints, Progressive failure analysis, Virtual testing

1. Introduction

Even though composite material are finding increasing use in aviation and automotive sectors, bolted joints remain the primary joining mechanism in most applications. Unlike bonding, bolted joints provide ease in maintainability and are less prone to failure due to manufacturing induced deviations from specifications. However, wherever there is a joint, bolted or bonded, it will likely be a site of damage and failure initiation in a structure. This is due to the fact that bolts require holes (or cut-outs) which act as a stress raiser within a structure. Hence, the need to properly size the bolted joint becomes of utmost concern in structural design.

Bolted joint analysis, using a computational framework, and that which is applicable for modern aerospace structures, is a significant challenge owing to the complex nature of loading, and subsequent damage and response of the damaged material[1, 2, 3, 4]. There are two parts to a bolt load, first the contact load on the hole inside surface, which is largely compressive. Second, the overall tensile load experienced by the bearing by-pass ligament. Hence, if one were to isolate the failure regions, it would be the compressive/shear damage and failure due to the bolt contact load and the tensile/shear damage and failure in the bypass ligament. There is however, significant interaction between the two regions, which can cause net section failure, shear-out failure, bearing failure or any combination of the above [5].

Considerable literature is available which have identified the influencing parameters on failure of bolted joints. As with general application of laminated composites, bolt bearing strength is influenced by stack-up, hole size, ratio of hole diameter to width, ratio of hole diameter to free edge distance from hole center, in loading direction [6, 2]. In addition, bearing strength of bolted joints is significantly influenced by clamp up load [7, 8, 9]. Higher clamp up loads tend to increase bearing strength, however it also can change the mode of failure. Clamp up loads introduce both

*Corresponding author
Email address: awaas@aa.washington.edu (Anthony M. Waas)