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Parametric study of size, curvature and free edge effects on the predicted strength of bonded composite joints

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Abstract

This paper presents the effects of size, curvature and free edges of laboratory lap joints on the debond fracture behaviour of joints that more realistically represent fuselage skin structures than conventional flat, narrow specimens. Finite Element Analysis is used in conjunction with Cohesive Zone Modelling (CZM) to predict the strength of selected joint features. The modelling approach was verified by simple single lap joint geometry. Four realistic joint features were then modelled by this validated modelling approach. The results show that moderate curvature has negligible effect on the peak load. There is a significant difference in the load vs displacement response of flat lab coupon joints with free edges and realistic curved joints with constrained edges. Further detail design features were investigated in this study, including (i) the joint runout and (ii) the presence of initial damage (thumbnail delamination). The modelling results show that the joggle configuration has an effect on the distribution of interlaminar stresses that affect the damage initiation and propagation. Fracture behaviour from different initial crack geometries associated with wider specimens has been simulated. From a design standpoint, an expansion of modelling capability is suggested to reduce the number of component tests in the traditional test pyramid.

Keywords: Aircraft composites; bonded joints; debond fracture; design study; finite element analysis

1. Introduction

There has been an increased use of composite materials in aircraft primary structures, especially of Carbon Fibre Reinforced Plastics (CFRPs) which are chosen for their high specific strength and stiffness. Composite structural components may be joined by adhesive bonding, or by mechanical fastening, or by a combination of adhesive and mechanical fastening. Adhesively bonded joints exhibit distinct advantages, such as ease of application, time and cost savings, and weight reduction [1, 2]. However, uncertainties regarding the quality of bonding, the presence of accidental damage, and the accurate prediction of the strength and damage tolerance performance of bonded composite joints currently require large safety factors to be applied at the design stage supplemented by an extensive testing programme [3].

Aircraft primary structural assemblies experience significant static and fatigue loadings in service. Analysis and testing is essential at the design stage to determine the structural integrity, durability and damage tolerance of the primary structures. However, full scale tests of large components are expensive and time consuming, which makes it impractical and inefficient to include every failure