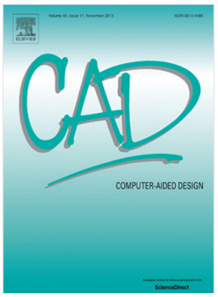
Accepted Manuscript



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PII: S0010-4485(18)30183-0
DOI: https://doi.org/10.1016/j.cad.2018.07.006
Reference: JCAD 2634

To appear in: *Computer-Aided Design*

Received date : 11 September 2017
Accepted date : 26 July 2018

Please cite this article as: Bingol O.R., Schiefelbein B., Grandin R.J., Holland S.D., Krishnamurthy A. An integrated framework for solid modeling and structural analysis of layered composites with defects. *Computer-Aided Design* (2018), https://doi.org/10.1016/j.cad.2018.07.006

An Integrated Framework for Solid Modeling and Structural Analysis of Layered Composites with Defects

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Abstract

Laminated fiber-reinforced polymer (FRP) composites are widely used in aerospace and automotive industries due to their combined properties of high strength and low weight. However, owing to their complex structure, it is difficult to assess the impact of manufacturing defects and service damage on their residual life. Non-destructive evaluation (NDE) of composites using ultrasonic testing (UT) can identify the presence of defects. However, manually incorporating the damage in a CAD model of a multi-layered composite structure and evaluating its structural integrity is a tedious process. We have developed an automated framework to create a layered 3D CAD model of a composite structure and automatically preprocess it for structural finite element (FE) analysis. In addition, we can incorporate flaws and known composite damage automatically into this CAD model. The framework generates a layer-by-layer 3D structural CAD model of the composite laminate, replicating its manufacturing process. The framework can create non-trivial composite structures such as those that include stiffeners. Outlines of structural defects, such as delaminations detected using UT of the laminate, are incorporated into the CAD model between the appropriate layers. The framework is also capable of incorporating fiber/matrix cracking, another common defect observed in fiber-reinforced composites. Finally, the framework can preprocess the resulting 3D CAD models with defects for direct structural analysis by automatically applying the appropriate boundary conditions. In this paper, we show a working proof-of-concept of the framework with capabilities of creating composite structures with stiffeners, incorporating delaminations between the composite layers, and automatically preprocessing the CAD model for finite element structural analysis. The framework will ultimately aid in accurately assessing the residual life of the composite and making informed decisions regarding repairs.

Keywords: Composite Structures Modeling, CAD Model Generation, Automatic Preprocessing, Delamination Modeling, CAD and FE modeling

1. Introduction

Laminated fiber-reinforced polymer (FRP) composite materials are being increasingly used in automobile and aircraft industries due to their high strength-to-weight ratios. Recent developments in composite production allow replacement of the structural elements of high performance air and ground vehicles with composite counterparts. An example of these developments is the composite wings and fuselage of the Boeing 787 Dreamliner. Due to the increasing use of composites in critical structural parts of such vehicles, it is important to assess the residual strength of composites, in the presence of production defects or in-service damage. Ultrasonic Non-Destructive Evaluation (NDE) is the preferred method for identifying composite defects such as delaminations. Although ultrasonic testing can be used to identify the presence of such defects, in order to determine the structural integrity of the composite, the damage needs to be modeled. However, there are no reasonable automated methods to create a concrete CAD representation of the composite structure and then incorporate a model of the damage to evaluate their structural integrity.

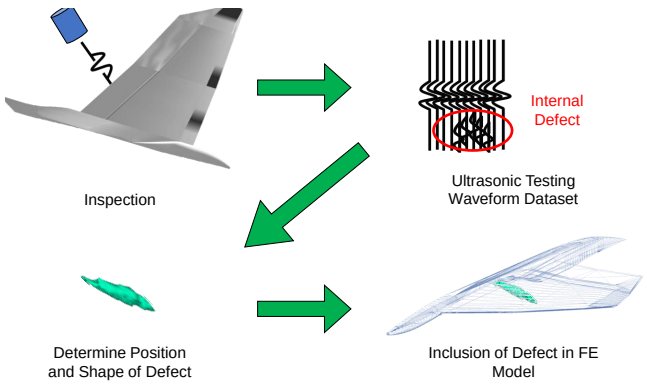

Figure 1: *Illustration of the steps required to incorporate defects into composite models and perform structural finite element analysis.*

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