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Composite Structures 67 (2005) 217–227
COMPOSITE STRUCTURES
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Simulation of impact on sandwich structures

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Abstract

An explicit finite element based simulation tool has been developed to predict the damage within sandwich structures subjected to low velocity impact. The tool, Sandmesh, is capable of automatically generating three-dimensional shell models of both honeycomb and folded structure cores, as well as applying the necessary controls for solution generation. Sandmesh was validated via an experimental test program in which honeycomb sandwich panels were tested for impact resistance and damage. Results showed that for low velocity impact, Sandmesh was capable of accurately predicting both the size and depth of the permanent indentation, as well as providing excellent correlation with the force-time histories. The confidence gained from this program allowed the tool to be applied for the structural and dynamic analysis of folded structure core composites.

Keywords: Impact analysis; Sandwich structures; Explicit finite element analysis; Impact damage

1. Introduction

The continuing need for increased structural performance in the aerospace industry has lead to an increase in the use of innovative fibre reinforced composites and sandwich materials technology. Due to their excellent mechanical properties combined with a high strength to weight ratio, sandwich constructions are particularly suited to aircraft applications. However, considering the inherent disadvantages associated with current commercial honeycomb sandwich materials and the trend to design larger primary aircraft structures, there is a growing need for the development of alternative sandwich materials. To satisfy these goals, folded structure cores have been identified as a possible replacement for conventional honeycomb sandwich materials. Currently, folded structure cores have been primarily designed for acoustic applications, such as noise reduction, and have been implemented within the Russian aerospace industry as well as various oil and gas distribution industries. To date, little research has been published that describes the mechanical properties of these materials for structural applications.

The finite element (FE) software Ansys coupled with the explicit FE software code LS-Dyna (Version 970) are commercial tools employed within various engineering industries. Both the aerospace and automotive industries have accepted simulation as part of the design process to minimise design costs and to create more efficient structures. Prototyping and testing are always performed to verify the design, but simulation has become standard practice throughout the design process.

As explicit FE codes improve and advanced material models become available, such simulations tools will find more widespread application within the aerospace sector with increasing computing power and greater modelling realism. This paper aims to provide an insight into the development of a software tool, Sandmesh, developed by the Technical University of Dresden [1]

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doi:10.1016/j.compstruct.2004.09.018

and allows for the rapid generation of three-dimensional sandwich structures for explicit impact analysis within LS-Dyna.

A design goal of Sandmesh was to enable the prediction of barely visible impact damage (BVID) in sandwich structures using a two-dimensional (2-D) shell modelling approach. The tool can be used to construct FE models of sandwich materials, solve for BVID, post-process the results and compare this to experiment. The ability of the program to model the damage that arises from the impact load will provide a gauge to its suitability for advanced composite design and analysis applications.

In this paper, the procedure used to validate Sandmesh for impact simulation of sandwich materials is detailed. This validation process is illustrated in Fig. 1. Firstly, a series of simulations to predict the impact damage and characteristics of aluminium honeycomb sandwich panels is presented. These results were compared with test data, specifically force-time histories, resulting indentation depth, impact affected area and permanent damage. Following this, a series of simulations were conducted on folded structure sandwich materials with composite facesheets to evaluate their performance for impact damage resistance.

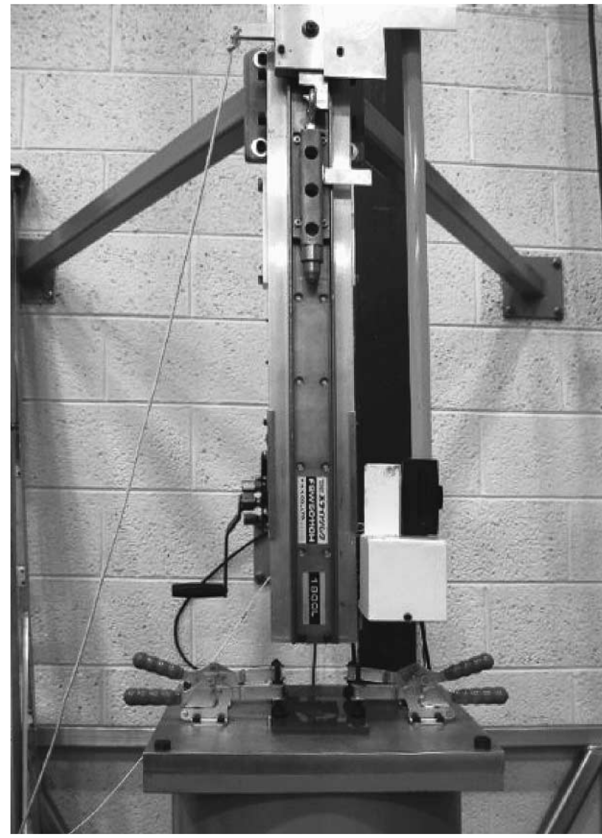

Fig. 2. Drop-weight impact test facility.

2. Impact testing facility

All impact testing was undertaken using a fixed base, drop weight test rig, as shown in Fig. 2. The impactor, which runs on a ball bearing rail, is fitted with a force transducer behind the 25 mm diameter hemispherical tup. The impactor mass can be varied between 0.5 and 2.5 kg with a maximum drop height of 4 m. An aluminium flag fitted to the impactor is used to measure the incident and rebound velocities from which the impact and absorbed energies can be determined. The velocity flag cuts the light beam between the LED and photo detector; the change in the signal produced by the sensor is analysed to determine the velocity.

The experimental data gathered during the impact testing was captured by a data acquisition system (DAS) connected to a personal computer. The signals from the force transducer, via a signal conditioner,

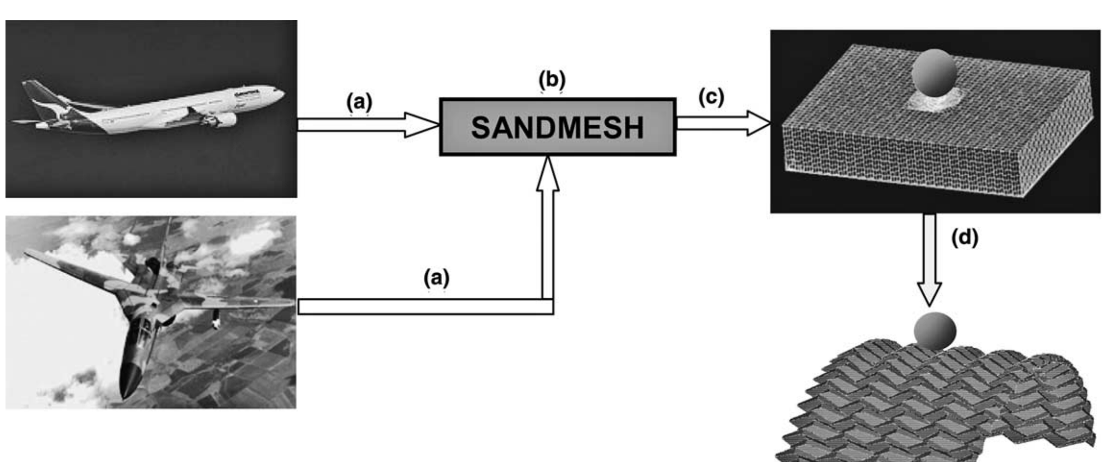

Fig. 1. Validation process for Sandmesh, from (a) identifying industry sandwich applications for impact simulation, (b) generation of the structure in Sandmesh, (c) analysis of the results and comparison with test data and (d) application of the tool to folded core structures.