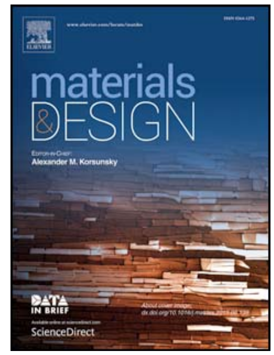

Indentation failure of circular composite sandwich plates

A. Rajaneesh, I. Sridhar, A.R. Akisanya

PII: S0264-1275(15)30480-9
DOI: doi: 10.1016/j.matdes.2015.09.070
Reference: JMADE 640

To appear in:

Received date: 28 April 2015
Revised date: 20 July 2015
Accepted date: 14 September 2015

Indentation failure of circular composite sandwich plates

A. Rajaneesh[1], I. Sridhar[1],*, A. R. Akisanya[2]

[1]School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Singapore.
[2]School of Engineering, University of Aberdeen, Aberdeen AB24 3UE, United Kingdom

*Corresponding author. msridhar@ntu.edu.sg

Abstract

Ski boards, helmets are sandwich structures and prone to core indentation failure under localised loads. In this work, axisymmetric response of a circular composite sandwich plate subjected to indentation by a rigid flat/hemi-spherical punch is examined. Flat punch is assumed to impose an axisymmetric line load, whereas spherical indentor imposes point load. Small deformation response is investigated by solving the equilibrium equations exactly, while large deformation response is estimated using Berger's method. The indentation behavior is predicted numerically by modelling core as (i) a continuum foam and (ii) a plate on foundation with reaction force (i.e. interaction problem) by employing user interaction subroutine in commercial finite element package Abaqus ® . Derived analytical estimates for the indentation loads and the corresponding finite element predictions are found to be in good agreement with the experimental measurements.

Keywords

Composite Sandwich Plates; Non-linear behavior; Indentation; Flat/Spherical Punch

1. Introduction

Sandwich construction has gained acceptance as sport sticks [1] and ski boards [2], protective helmet (head-gear) because of their superior specific strength and stiffness compared to monolithic plates made from either core or faceplate materials. The protective head-gear (helmet) is also a sandwich structure. The core of the sandwich structures is susceptable to indentation failure due to its relatively low modulus and strength when loaded locally. Stress and failure analysis of sandwich structures under quasi-static localized loads and low velocity impact using experimental tests can be expensive while finite element (FE) predictions are computationally intensive. Hence, there is a need for analytical modeling of the deformation and failure behavior of composite sandwich plates for design purposes. The impact of the relevant studies can be seen from the recent works [3,4,5,6] in a wide range of applications.

Considerable research has been carried out on the response of sandwich beams and plates subjected to quasi-static indentation loading [7]. Current methodology differs from the higher order sandwich plate theory (HSPT) [8] in which the core is considered to be elastic, while in current study the emphasis is on the post core indentation failure behavior. Several indentation models [9,10,11,12,7] ignored the bottom faceplate deflection to effectively investigate the local deformation and post indentation failure response in the sandwich structures and these studies have shown reasonable comparison with experiments for circular sandwich plates. These contributions motivate the methodology implemented in the present study. The following discussion is confined only to sandwich plates with composite faceplates, which are usually considered as linear elastic in nature. To investigate thelocal indentation of the sandwich plates, the core is in general treated as a deformable foundation (viz., elastic; rigid perfectly plastic (RPP); or elastic-perfectly plastic, EPP). Existing indentation failure models from the literature are summarized in Table 1 for flat punch (FP) as well as spherical punch (SP) loading.

Table 1. Literature on the indentation response of composite sandwich plates.

Punch	Deformation	Core	Literature	Remarks and assumptions
Spherical	Small	Elastic	[13] †‡§♮	Arbitrary elastic foundations.
(SP)			[14,15] †§♮	Strength of materials approach.
			[16] §‡	Exact solutions in terms of Bessel