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ORIGINAL PAPER

Transient Behaviour and Impact Induced First-Ply Failure of Delaminated Composite Conical Shells

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Abstract

Background Dynamic behaviour of composite materials under impact is a severe concern as it results in premature failure of the structural components. Most of the damages arising due to impact are undetected by visual inspection; therefore prediction of impact response is very crucial.

Purpose The existence of delamination reduces the strength and stiffness of the composite structures and enhances the damage phenomenon. The critical impact velocity at which the first-ply failure (FPF) and the associated transient response is a major engineering concern and needs significant attention.

Methods A finite element method (FEM) based investigation is carried out to analyse the dynamic response of delaminated cantilever composite conical shell impacted centrally at random points by a spherical impactor. An eight-noded isoparametric shell element is used based on Mindlin's shallow shell theory. The indentation laws proposed by Hertz are used to evaluate the contact force, displacement and identification of the failure zones. Newmark's time-integration scheme is used to obtain the dynamic response of the impacted shell. The Tsai-Wu failure criterion which is the most general and consistent criterion for biaxial stresses is used to predict the critical velocity of impact for first-ply failure initiation in composite conical shells.

Results Results include the effects of different parameters like size and number of delamination, aspect ratio, fibre-orientation angle and impact location on the dynamic behaviour of conical shell at maximum safe impact velocity beyond which first-ply failure will commence.

Conclusions On increase of the aspect ratio, size and number of delamination, the contact force, shell displacement, impactor displacement and the critical velocity at which the FPF initiates are found to decrease. When the impact location moves from near fixed end to near the free end, the contact force, shell displacement, impactor displacement and impactor velocity decreases.

Keywords FEM · Composite · Conical · FPF · Critical velocity of impact · Delamination · Aspect ratio

Introduction

Composite materials are widely used in various industries like automobile, aerospace, marine, defence, etc. due to their light weight combined with high strength and excellent ability to be tailored to meet desired properties. Dynamic behaviour of composite materials under random impact is a serious concern the impact phenomenon inevitably arises during manufacturing, maintenance, transport, and hostile operating conditions. The damage occurring in the composite laminates due to low-velocity impact mostly remains undetected by visual inspection owing to its insidious nature. The presence of delamination intensifies the damage caused by impact which in turn significantly reduces the strength and stiffness of the composite structure. Therefore, impact behaviour of composite shell structures received a great research attention in the last few decades. The critical impact velocity at which the first-ply failure may initiate is of utmost engineering concern, since failure will propagate at an enhanced rate due to reduced strength of the resulting composite structure. An analytical method to predict such occurrence of impact-induced failure is extremely useful for reliable and predictive design of composite laminates

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