

A STUDY OF IMPACT RESPONSE OF LAMINATED COMPOSITE SHELLS INCLUDING IMPACT INDUCED DAMAGE

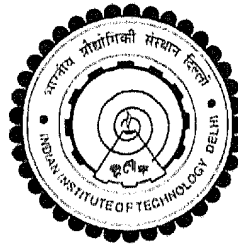
by

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Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy
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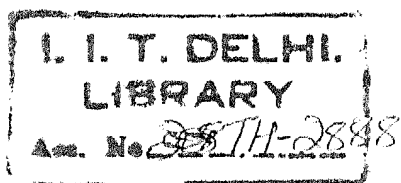
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Shells - stressed

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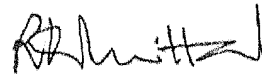
Certificate

This is to certify that the thesis entitled "**A study of impact response of laminated composite shells including impact induced damage**" being submitted by Mr. K.S.Krishnamurthy to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard fulfilling the requirements for the award of the degree of Doctor of philosophy.

The research report and the results presented in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.



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ABSTRACT

The vulnerability of structural components such as beams, plates and shells made of laminated composite materials to damage in the form of cracking of fibers and matrix material, and delaminations under low velocity impact loads such as projectile hits or dropping of heavy objects on their surface is well known. Low velocity impact, e.g., due to a blunt-nosed object, causes a region of high stress concentration in the vicinity of contact area leading generally to a localized damage and adversely affecting the integrity of the structural member. While considerable work has been carried out especially in understanding the impact response and damage in the case of laminated composite plates, that concerning laminated composite shells, however, is relatively small. In the present work impact response of cylindrical laminated composite shells including the prediction of impact induced damage has been studied. Impact response is represented by the variation of the contact force and the deflection of the shell (under the point of impact) with time and the impact-induced damage. Two approaches to solving the impact problem have been followed. First, the impact response is determined by the analytical method, viz., by the classical Fourier series procedure for a cylindrical shell. After the mathematical formulation of the problem, the solution is obtained by means of an alternative numerical procedure instead of the Laplace Transforms technique used in an earlier work. The present procedure incorporates the non-linear Hertz's contact law which enables consideration of local indentation produced by the indenter on the impacted surface. The above procedure is also extended to the problem of impact on a cylindrical shell panel. Secondly, impact response is determined by the finite element method for the problem of impact on a cylindrical shell and on a cylindrical shell panel.

The finite element method includes a prediction of the impact-induced damage using the semi-empirical damage prediction model of Choi-Chang developed for impact on composite plates. Further, a number of parametric studies have been made to determine the effect of varying various parameters of the impact problem, both on the impact response and on the impact-induced damage. Some of the important parameters are: viz., impactor mass, approach velocity, elastic properties as well as the geometric characteristics of the laminate. The impact responses obtained from the Fourier series method and the finite element method have been compared. The Series method, which provided information regarding natural frequencies of vibration of the impacted structure, helped in selecting the size of the time step. The Series solution also lent confidence in accepting the accuracy of finite element solutions which are known to be significantly affected by the choice of mesh used, element type, grading, etc. The finite element method, however, proved to be a powerful numerical tool as it enabled us to incorporate the effect of damage produced in the shell on its impact response, simultaneously as the solution progressed. This helped us in obtaining a quantitative measure of the extent to which the structural member has been weakened due to a given impact situation. Computation of the coefficient of restitution, the energy absorbed by the impacted structure and that required for forming the indentation has also been made to understand the manner in which the energy imparted by the impactor gets apportioned during impact.

Contents

Page No.

Certificate	i
Acknowledgements	ii
Abstract	iii
Contents	v
List of figures and tables	vii
Nomenclature	x
Chapter 1 Introduction, Literature review and Objectives	
1.1 Introduction	1
1.2 Low velocity impact on laminated composite plates and shells	2
1.3 Modelling and understanding of impact on composites	4
1.4 Literature on impact on laminated composite plates and shells	5
1.4.1 Impact on laminated composite plates	6
1.4.2 Impact on laminated composite shells	7
1.5 Objectives of the present work	9
1.6 Organization of the thesis	13
Chapter 2 Theories of impact, contact deformation and damage in composites	
2.1 Theory of elastic impact and contact laws	15
2.2 Hertz's theory of contact	18
2.3 Other contact theories	21
2.4 Modified contact laws to consider permanent deformation	22
2.5 Using Hertz law in impact problems	23
2.6 Damage in laminated composites due to low velocity impact	25
2.6.1 Damage initiation and growth	27
2.6.2 Predicting impact-induced damage	31
Chapter 3 Impact loading on laminated composite shells	
3.1 Shell theories for use with laminated composite shells	36
3.2 Consideration of transverse shear deformation	40
3.3 Governing equations from the theory of shells	42
3.3.1 Hamilton's principle	42

3.3.2	Governing equations for a cylindrical shell	45
3.3.3	Strain-displacement relations for a cylindrical shell	47
3.4	Lateral loading of a laminated composite cylindrical shell and impact	48
3.5	Solution for lateral loading of a laminated composite cylindrical shell	50
3.5.1	Impact loading and solution by the integral approach	58
3.6	Lateral loading on a cylindrical shell panel and impact	59
3.6.1	Solution for impact loading	64
Chapter 4	Impact response and prediction of impact-induced damage by the finite element method	
4.1	Equations of equilibrium for the shell	66
4.2	Computation of contact force	70
4.3	Prediction of impact-induced damage	76
4.4	Energy transferred to the shell during impact	80
4.5	Parametric studies	82
Chapter 5	Effect of various parameters on the impact response and damage – Results and discussion	
5.1	The method of Fourier series expansions for the problem of impact on a composite cylindrical shell and a shell panel	
5.1.1	Cylindrical shell	84
5.1.2	Cylindrical shell panel	85
5.2	Determination of impact response and impact-induced damage by the the finite element method.	86
5.2.1	Cylindrical shell panel- parametric studies, results & discussion	87
5.2.2	Cylindrical shell- parametric studies, results & discussion	94
5.2.3	Comparison of impact response of cylindrical shell and shell panel	98
5.4	Impact energy, energy absorbed and damage	99
Chapter 6	Conclusions and suggestions	151
	References	157
	Appendix A	162
	Appendix B	170
	Appendix C	183