COMPOSITE HONEYCOMB CORE SANDWICH PLATE WITH FACESHEET INDENTATION MODEL SUBJECTED TO LOW-VELOCITY IMPACT

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This project report is dedicated to my beloved parents.

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ABSTRACT

The composite sandwich structures are applied in many engineering fields due to their high strength and stiffness but lightweight properties. The purpose of this study is to obtain the top facesheet indentation and strain failure of a fixed-end composite sandwich plate with honeycomb core when it is subjected to low-velocity impact by using MATLAB software. The faceheets are made from Hercules AW193-PW prepreg consisting of AS4 fibers in a 3501-6 matrix (carbon/epoxy) with fiber orientation of [0/90]. The honeycomb core is made from HRH 10 1/8-3.0 Nomex honeycomb (Ciba-Geigy). Type of the impactor used in this study is flat-ended cylinder, which is made from case-hardened steel. The composite sandwich plate is modeled as a two-dimensional problem with five and three degree-of-freedom per node for the facesheets and honeycomb core, respectively. Only the stiffness matrix, $[K]$, and the mass matrix, $[M]$, are considered in determining the responses of the plate. The force is applied at the center of the plate only. Responses in terms of indentation, strain failure and displacement are explored. It was found that the most efficient stacking sequence of facesheet is [±45]. Also, the most effective parameter in improving the strain failure of the top facesheet is crushing resistance of the core.

ABSTRAK

Struktur sandwic komposit banyak diaplikasikan dalam bidang kejuruteraan kerana mempunyai kekuatan dan kekakuan yang tinggi serta ringan. Kajian ini dilakukan bertujuan untuk mendapatkan lekukan di lapisan atas dan kegagalan ketegangan pada plat sandwic komposit berteraskan heksagon yang hujungnya diapit apabila terdedah kepada impak halaju rendah dengan menggunakan perisian MATLAB. Lapisan atas dan bawah struktur sandwic komposit diperbuat daripada prepreg Hercules AW193-PW yang terdiri daripada serat AS4 dalam matriks 3501-6 (karbon/epoksi) dengan orientasi serat [0/90]. Teras heksagon pula diperbuat daripada HRH 10 1/8-3.0 Nomex heksagon (Ciba-Geigy). Jenis beban yang digunakan dalam kajian ini adalah silinder yang rata pada hujungnya dan diperbuat daripada keluli yang keras. Plat sandwic komposit dimodelkan sebagai masalah dua-dimensi dengan lima darjah kebebasan bagi setiap nod untuk lapisan atas dan bawah, manakala tiga darjah kebebasan bagi setiap nod untuk teras heksagon. Hanya matriks kekukuhan, $[K]$, dan matriks jisim, $[M]$, yang dipertimbangkan dalam memodelkan plat. Daya dikenakan di tengah plat sahaja. Variasi dalam parameter lapisan atas dan bawah serta teras heksagon diperhatikan untuk mendapatkan tindak balas plat. Tindak balas yang dikaji adalah dari segi lekukan, kegagalan ketegangan dan anjakan. Kajian mendapati bahawa turutan lapis yang paling efisien untuk lapisan atas adalah [±45]. Selain itu, parameter yang paling berkesan dalam memperbaiki kegagalan ketegangan pada lapisan atas adalah ketahanan penghancuran teras.

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CHAPTER 1

INTRODUCTION

1.1 General

Composite structure is a combination of two or more components as one structure which makes it better than that of individual components. A structure that consists of two facesheets that are separated by a core is known as composite sandwich structure (Figure 1.1). The facesheets are also known as composite skins. The facesheets and core component are bonded by matrix/adhesive materials such as resin. The core layer is usually made of lightweight and thick but less stiff materials, such as Nomex honeycomb cores, fiberglass reinforced thermoplastic, aluminium and foam-type cores. The top and bottom facesheets are commonly thin but stiff material from light alloys, e.g., aluminium and fibre-reinforced composites (Chai and Zhu, 2011).

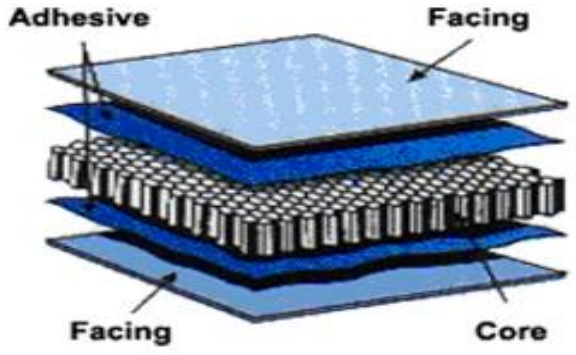

Figure 1.1: Composite sandwich structure (Engineered Materials Inc., 2012)

The application of composite sandwich structure is very beneficial in engineering field especially in aircraft and aerospace industries. This is because of their excellent properties, which are high in strength and stiffness as well as low in weight (lightweight), e.g., the airplanes are mainly built from composite sandwich structures. Besides that, this lightweight structure is widely used due to its cost effectiveness and environmental friendly. For example, a vehicle fabricated from lightweight structures will require less energy to move and indirectly consume less fuel. This means that the use of lightweight vehicle will reduce environmental impact as well as service cost of the vehicle. In construction field, the application of composite sandwich structure is widely used in the lightweight construction.

The composite sandwich structures may expose to several types of impact such as static impact, velocity impact, blast impact, quasi-static impact, vibration and so on. These impacts will result in the damage of the structure and indirectly reduce its strength. Different types of impact will result in different impact responses or failures. One of the impact responses is indentation. Indentation can occur during construction and maintenance of the structure. For example, the composite sandwich structure may experience indentation due to the low-velocity impacts of tools drop, machineries mishandling, heavy materials falls and so on (Hosseini and Khalili, 2013).

Velocity impact is divided into two types, i.e., low-velocity and high-velocity impacts. Both impacts give different responses on the composite structures. In presence of low-velocity impact, an apparent damage is observed in the structure, in which the structural strength and stiffness may reduce by 50% (Ivanez and Saez, 2013). The low-velocity impact response of the composite structure can be categorized on the basis of the impact mass, which are small, medium and large. The larger mass impact will produce longer impact duration as well as larger displacement. Chai and Zhu (2011) mentioned that the response of composite structures due to small mass impact will result in larger delaminations than that of large mass impact with the same kinetic energy.

1.2 Problem Statement

The research on composite sandwich structure is usually done experimentally or numerical modeling using application software, such as ANSYS, ABAQUS, etc. Compared to those approaches, implementing MATLAB software is more efficient. This is because the application of MATLAB software is time and cost effective compared to the experimental study. Also, the application of finite element method in MATLAB software can enhance the basic fundamental and knowledge of those who studied on that particular research compared to the use of the application software.

So far, not many researches consider indentation in composite sandwich plate. Although there was a study on indentation of composite sandwich plate, but it did not consider the strain failure of the structure. Strain failure is related to the indentation in determining the failure of the structure in terms of strain. The occurrence of indentation on the composite sandwich plate does not mean that there will necessarily be a failure in strain. Hence, in this research, the main concerns include:

(i) The formulation that can be used to model the composite sandwich plate.
(ii) The verification of the composite sandwich plate with the model from previous research using MATLAB software.
(iii) Investigation on strain failure, indentation and global displacement of composite sandwich plate.
(iv) Parametric studies on composite sandwich plate.

1.3 Objectives

The objectives of this research are:

(i) To obtain the finite element formulation of composite sandwich plate with facesheet indentation description under low velocity impact.
(ii) To produce the MATLAB code for aforementioned formulation and verify it with the existing model.
(iii) To conduct parametric study on indentation and global displacement for numerous facesheet stacking sequences and core properties.

1.4 Scope of Study

The followings are the scopes of the study:

(i) Formulation for composite sandwich plate considers only the core with a honeycomb layout.
(ii) MATLAB software is used as the programming language.
(iii) Only point load at the center of the plate is considered.
(iv) Only low-velocity impact responses are considered.
(v) The impact responses that will be discussed are only global displacement, indentation and strain failure.
(vi) Only flat-ended cylinder impactor is considered.
(vii) Only one type of materials of facesheets and honeycomb core are analysed.
(viii) Only fixed-end composite sandwich plate is considered.

1.5 Significance of the Study

The application of composite sandwich structure has been widely used since many years ago. Many researches on the composite sandwich structure have been conducted experimentally and numerically. The purposes of these researches are to understand the behaviours and failure mechanisms of the composite sandwich structure as well as to improve it. Numerical analysis is used worldwide since it is more economical and not time-consuming. Besides that, the behaviours and failure mechanisms of the composite sandwich structure can be obtained before manufacturing it. And, the parametric study can be done in a much easier way.

The indentation on the composite sandwich structure due to the low-velocity impact can be very small or very large or even penetrate through the composite sandwich plate. Although the indentation is very small, it may also experience the local strain failure. The local strain failure is obtained in order to know whether the indented part is failed or not. If the indented part is failed, further impact on it will make the damaging of the composite sandwich structure more severe. Hence, it is necessary to conduct analysis considering simultaneously both indentation and strain failure together.

1.6 Report Outline

The main topic in this report consists of five categories namely introduction, literature review, methodology, results and discussion, and conclusion.

Chapter 1 introduces the main topic for this report generally. The problem statement, objective and scope of work are explained in this chapter.

Chapter 2 explains more on composite sandwich structures including their advantages and disadvantages. Besides that, this chapter includes several previous researches that are related to the composite sandwich structures.

Chapter 3 is devoted to research methodology. The model of composite sandwich plate used in the analysis will be discussed in detail in this chapter. All the formulations that will be used in the analyses will also be gathered in this chapter. Also, an overview of MATLAB source code will be included here.

Chapter 4 includes all the results obtained from the MATLAB software. The discussion on MATLAB result verification with previous study as well as the strain failure and parametric study of composite sandwich plate will be covered in this chapter.

Chapter 5 covers the conclusion and recommendation. All the results will be concluded in this chapter. The conclusion is made with respect to the objectives of this report. The recommendation for future research is also outlined in this chapter.

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