KOLEJ UNIVERSITI TEKNIKAL KEBANGSAAN MALAYSIA

BORANG PENGESAHAN STATUS TESIS*

JUDUL: DEVELOPMENT OF HONEYCOMB STRUCTURE WITH ALUMINIUM SKIN FOR LIGHT WEIGHT STRUCTURAL APPLICATION

SESI PENGAJIAN : 2006/2007

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ABSTRACT

This study on honeycomb structure is done to find the best materials for honeycomb structure that have the outstanding properties. Firstly the previous researches about honeycomb properties and materials are studied. This is to get a better knowledge on this study. Besides that the product that uses this sandwich structures are identified. This study of honeycomb is for the usage in the aircraft industry. It is studied in which part of the aircraft is the sandwich structure applied.

This study to find the best material for lightweight application will use 3 types of material. Among the three materials are aluminium cans, aluminium sheet and straw. Before carrying out the study the physical properties of those materials are studied. The honeycomb structures are built using the materials. The composition of each material had been planned first. After each model has been constructed it will be tested. The testing is done according to ASTM standard (American Society for Testing and Materials).

There were 3 test conducted which is the bending test, compression test, and tensile test. For the tensile test the mechanical properties obtained are yield strength, tensile strength and modulus of elasticity. For the bending test the mechanical properties obtained are flexural modulus and flexural yield strength. Lastly for the compression test the mechanical properties obtained are compressive strength and modulus of compression. Between the two materials which are aluminium can and straw it is proved that the aluminium can is better than the straw. This is due to the good results of compressive, yield and tensile strength.

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LIST OF ABBREVIATIONS AND SYMBOLS

Al	aluminium
K	temperature in Kelvin
F	temperature in Fahrenheit
GPa	gigapascal
MPa	megapascal
E	Young's modulus
σ	electrical conductivity
σt	tensile strength
λ	heat transfer coefficient
α	linear expansion coefficient
ASTM	American Society for Testing and Materials
in	inch
ρ	density
r	radius
σ_y	Yield strength
σ_T	Tensile strength
£bf	pound
σ_b	Flexural strength

CHAPTER 1
INTRODUCTION

1.1 Background

The honeycomb is a geometrical figure with remarkable uniformity that divides the spherical surface into hexagonal cells, like those of a bee's honeycomb. Such uniformity is useful when making objects with a spherical shape. Honeycomb cores have been used extensively in the aircraft industry for many years. Marine applications of honeycomb cores are limited due to the difficulty in bonding to complex geometric shapes and also due to the potential for water absorption. However it is possible to achieve very lightweight and stiff panels, which may be useful for interior structures and deck plates, although the usage in these applications is rare.

Honeycomb materials were first introduced in the 1940's for the manufacture of furniture and aircraft structures. In these initial applications, the honeycomb cores were fabricated from a wide variety of materials that included paper, cotton duck fabric, glass fabric and aluminium foil. Since the 1940's, progress in developing and improving new honeycomb structures has been steadily increasing. Today honeycomb cores can be fabricated from most types of materials such as papers, plastics, metals and ceramics. However as the technology behind the production of honeycomb improves, the ability to innovate new honeycomb materials become more difficult.

Sandwich constructions are being considered for application to aircraft primary structures, where durability and damage tolerance is a primary consideration, therefore, understanding the adverse effect of in-service impact events (impact damage and penetration damage) has become vital for applications where structural durability and damage tolerance are primary considerations.

1.2 Problem statement

In the world of composite manufacturing the manufacturer always face the problem's to find the best materials for honeycomb structure that have the outstanding properties. This study will use three types of materials for honeycomb structure followed by mechanical testing in order to investigate the mechanical properties and the compability of the aluminium skin.

1.3 Objectives of the research

a) To investigate the mechanical properties of the honeycomb structure for possible use in aircraft structure.
b) To explore some alternatives about honeycomb material .
c) To find the best parameter for honeycomb structure.

1.4 Scope of the thesis

This thesis will require student to do a study on the best material for honeycomb. This thesis will also help us to understand the current problems in all the lightweight honeycomb application. But before understanding the material problem in honeycomb we need to explore the possible usage and applications of the honeycomb. There will be three type of materials used for this study. Other than aluminium the two other things that will be used are box and straw. A few models of honeycomb will be made. Besides the mechanical structure of honeycomb using each material will be studied. There will be a few tests performed to find out the tensile strength, compression and bending of each of the honeycomb structure.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

The development of honeycomb core in structural composites in aircraft engineering began in the 1940's when there was a growing interest in sandwich construction, using thin strong skins bonded with a very low-density honeycomb core material [Nakada *el at*.,1999] . Honeycomb core can be made out of almost any thin sheet material and is usually made in a form in which, as the name implies, hexagonally shaped cells are arranged in a geometrical pattern by bonding foil or sheet adhesives.

Honeycomb cores are available in a variety of materials for sandwich structures. These range from paper and card for low strength and stiffness, low load applications to high strength and stiffness, extremely lightweight components for aircraft structures. Honeycombs can be processed into both flat and curved composite structures, and can be made to conform to compound curves without excessive mechanical force or heating [Gowan and Ambur , 1996].

Honeycomb cores can give stiff and very light laminates but due to their very small bonding area they are almost exclusively used with high performance resin systems such as epoxies so that the necessary adhesion to the laminate skins can be achieved.

Honeycomb sandwich structures comprise a layer of honeycomb core sandwiched between two skin sheets by means of a thin film of adhesive. It has very high strength-to- weight and stiffness-to-weight ratios and can withstand high service stresses and adverse environmental conditions [Teagle, 1985] .The main use of honeycomb is in structural sandwich panels, and the bonded honeycomb sandwich construction has been a basic feature

of the space industry since the early 1940s. Virtually all modem aircraft depend upon the integrity and reliability offered by this structural approach.

2.2 Honeycomb Panels

A honeycomb panel is a thin lightweight plate with a honeycomb core with hexagonal cells. Layered laminates are bonded to both sides of the core as shown in Figure 2.1. Each component is by itself relatively weak and flexible. When combined into a sandwich panel the elements form a stiff, strong and lightweight structure[Cawley, 1990]. The facings carry the bending loads and the core carries the shear loads. In general, the honeycomb core is strongly orthotropic.

The types of core materials in the panels used for the measurements presented here are Nomex or aluminium. Nomex is an aramid fibre paper dipped in phenolicresin with low shear modulus and shear strength. A typical thickness of the Nomex honeycomb panels investigated is 10 mm with the thickness of the laminate being between 0.3-0.7 mm. The weight per unit area is of the order of 3 kg/m_/unit area. Each laminate consists of 3-5 different layers bonded together to give the best possible strength [Horrigan *et al.*, 2000].

The laminates are not necessarily symmetric and are usually orthotropic. The core acts as a spacer between the two laminates to give the required bending stiffness for the entire beam. The bending stiffness of the core itself is in general very low. The cells in the core give an orthotropic structure [Allen, 1969]. The dynamic characteristics should be expected to vary in all directions. The shape of the honeycomb cells of a typical aluminium core is generally very irregular which makes it impossible to describe its geometry in a simple way. Nomex cores have very regular shapes as compared to Al-cores [Horrigan *et al*., 2000].

The normal deflection of a honeycomb panel is primarily caused not only by bending but also by shear and rotation in the core. A honeycomb panel could be compared to a three-layered panel [Nemes and Simmonds , 1992].

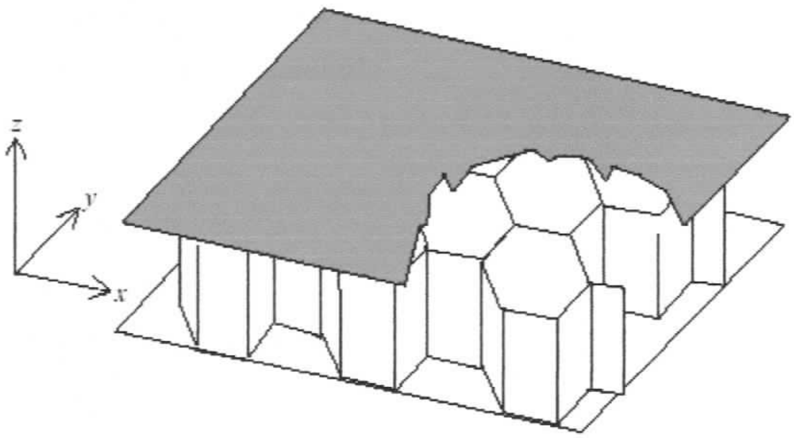

Figure 2.1 Sandwich panel with a honeycomb core [Teagle ,1985]

2.3 Applications

Applications in sandwich panels:-

- Building cladding panels
- Commercial vehicle panels
- Railway floors, doors, interiors, fairing panels
- Boat hulls and interior panels and furniture
- Racing car chassis and body panels
- Cable car structural panels
- Specialist flight cases
- Helicopter blades
- Aircraft engine structures
- Aircraft doors and hatches
- Aircraft floor panels
- Racing car structures and aerofoils
- Energy absorbers

Non Sandwich Panel:-

- Energy absorption
- Flow straighteners for air or fluids
- Heat exchangers
- Light collimation
- Sacrificial profile cutting beds (water / laser)

Sandwich panel constructions with honeycomb cores are widely used in the structural applications such as aircraft flight control surfaces and stabilizers [Karlsson *et al.*, 1988]. The sandwich panels are made by bonding graphite which are strengthened by using epoxy skins to an aluminium core using a thin layer of epoxy adhesive [Karlsson *et al.*, 1988]. Due to their high stiffness against weight ratio sandwich structures are considered high performance materials. When the epoxy adhesives have contact with water, it starts to degrade. This condition can exist inside of sandwich panels in some aerospace applications [Giguere, 2000].

The number of applications for sandwich structures is steadily increasing. This trend is dictated by demands for higher load capacity for civil and military aircraft, reduced fuel consumption for passenger cars, increased speed for passenger and navy vessels of catamaran types and increased acceleration and retardation for trains to increase the average velocity.

2.3.1 Parts of An Aircraft

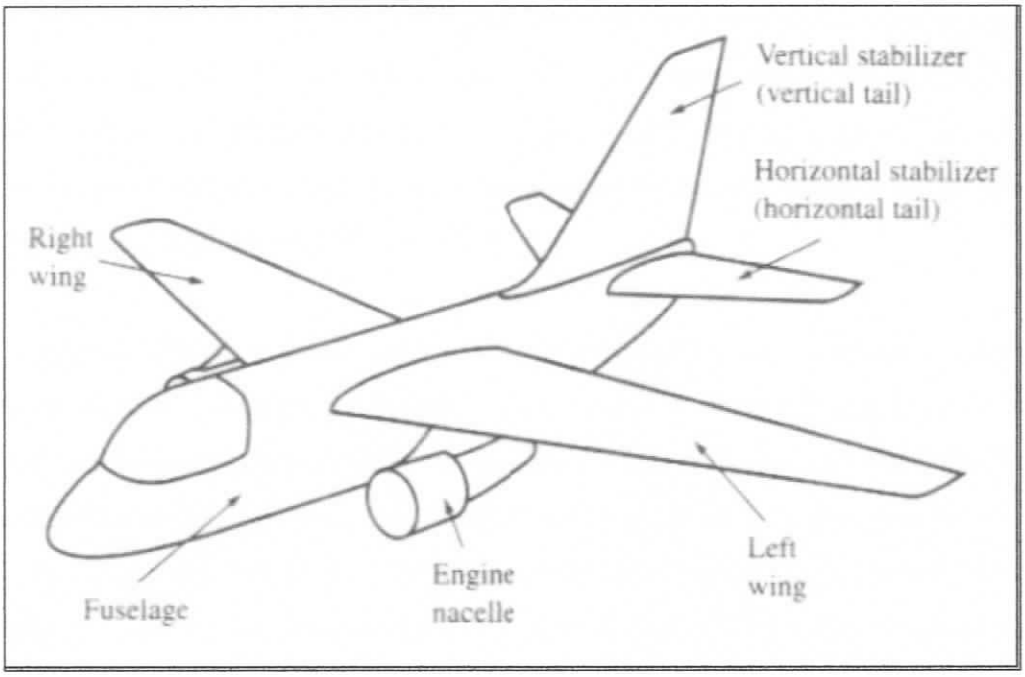

Figure 2.2 : Basic components of an aircraft [Binet,1999]

Fuselage : The fuselage is that portion of the aircraft that usually contains the crew and payload, either passengers, cargo, or weapons. Most fuselages are long, cylindrical tubes or sometimes rectangular box shapes. All of the other major components of the aircraft are attached to the fuselage. Empennage is another term sometimes used to refer to the aft portion of the fuselage plus the horizontal and vertical tails[Graham M., 2001]

Wing : The wing is the most important part of an aircraft since it produces the lift that allows a plane to fly. The wing is made up of two halves, left and right, when viewed from behind. These halves are connected to each other by means of the fuselage. A wing produces lift because of its special shape, a shape called an airfoil [Graham M., 2001]

Engine : The other key component that makes an airplane go is its engine, or engines. Aircraft use several different kinds of engines, but they can all be classified in two major categories. Early aircraft from the Wright Flyer until World War II used propeller-driven piston engines, and these are still common today on light general aviation planes. But most modern aircraft now use some form of a jet engine. Many aircraft house the engine(s) within the fuselage itself. Most larger planes, however, have their engines mounted in separate pods hanging below the wing or sometimes attached to the fuselage. These pods are called nacelles [Binet,1999]

Horizontal Stabilizer : If an aircraft consists of only a wing or a wing and fuselage, it is inherently unstable. Stability is defined as the tendency of an aircraft to return to its initial state following a disturbance from that state. The horizontal stabilizer, also known as the horizontal tail, performs this function when an aircraft is disturbed in pitch. In other words, if some disturbance forces the nose up or down, the horizontal stabilizer produces a counteracting force to push the nose in the opposite direction and restore equilibrium. When in equilibrium, we say that an aircraft is in its trim condition. The horizontal tail is essentially a miniature wing since it is also made up of an airfoil cross-section. The tail produces a force similar to lift that balances out the lift of the wing to keep the plane in equilibrium. To do so, the tail usually needs to produce a force pointed downward, a quantity called down force [Graham M., 2001]

Vertical Stabilizer : The vertical stabilizer, or vertical tail, functions in the same way as the horizontal tail, except that it provides stability for a disturbance in yaw. Yaw is the side-to-side motion of the nose, so if a disturbance causes the nose to deflect to one side, the vertical tail produces a counteracting force that pushes the nose in the opposite direction to restore equilibrium. The vertical tail is also made of an airfoil cross-section and produces forces just like a wing or horizontal tail. The difference is that a wing or horizontal tail produces lift or down force, forces that are pointed up or down from the aircraft. Meanwhile the vertical tail produces a force pointed to one side of the aircraft. This force is called side-force [Graham M.,2001]

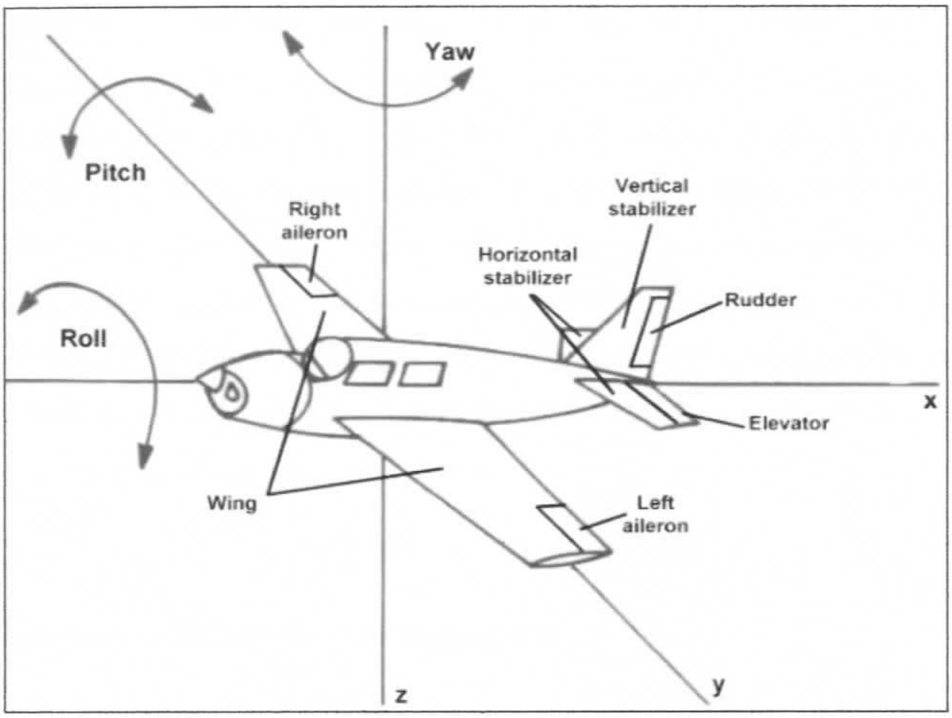

Figure 2.3 : Aircraft control surfaces and axes of motion [Goldsmith and Sackmann , 1992]

Elevator : The elevator is located on the horizontal stabilizer. It can be deflected up or down to produce a change in the down force produced by the horizontal tail. The angle of deflection is considered positive when the trailing edge of the elevator is deflected upward. Such a deflection increases the down force produced by the horizontal tail causing the nose to pitch upward [Goldsmith and Sackmann , 1992]

Rudder : The rudder is located on the vertical stabilizer. It can be deflected to either side to produce a change in the side-force produced by the vertical tail. The angle of deflection is usually considered positive when the trailing edge of the rudder is deflected towards the right wing. Such a deflection creates a side-force to the left which causes the nose to yaw to the right [Goldsmith and Sackmann , 1992]

Aileron : Ailerons are located on the tips of each wing. They are deflected in opposite directions (one goes trailing edge up, the other trailing edge down) to produce a change in the lift produced by each wing. On the wing with the aileron deflected downward, the lift increases whereas the lift decreases on the other wing whose aileron is deflected upward. The wing with more lift rolls upward causing the aircraft to go into a bank. The angle of deflection is usually considered positive when the aileron on the left wing deflects downward and that on the right wing deflects upward. The greater lift generated on the left wing causes the aircraft to roll to the right [Goldsmith and Sackmann , 1992]

2.3.2 Location of honeycomb in an aircraft

A pair of specially reinforced skin-spar joints in combination with a honeycomb core are used to build up a wing spar for a composite airplane wing. A series of contoured mandrels with a covering of fuel resistant material and a wrapped reinforced plastic are aligned one above the other. The wing spar materials are placed between the mandrels, honeycomb core is located alongside as well as wing skins to form a wing buildup. The buildup is placed in a mold, pressure applied to each mandrel forcing all the parts together, and the buildup heated to cure the resins and form a composite wing structure [Graham M.,2001]

2.3.3 **Existing Product**

The design of the primary and secondary structures of commercial aircraft had been carried out using isotropic and anisotropic materials before. But however with the recent development within the aviation industry and the need to benefit from the substantial mass savings, advanced composite materials are being utilized. Therefore it is important for manufacturers to account for orthotropic properties of such material.

The Krueger flap is a deployable leading edge lifting component of the wing. It is located between the first engine and the root of the wing on each side of the fuselage in heavy transport aircraft. When idle it rests on the front part of the lower surface of the wing via two aluminium gooseneck fittings and their hinges. The gooseneck fittings are positioned on each side of the middle transverse rib [Takeda , 1982]. When it is activated the flap rotates about the gooseneck hinges and forms an extension to the upper surface of the wing with its bull nose creating a new leading edge.

In conventional designs of Krueger flaps, a honeycomb stiffened skin is supported by ribs and spars. This type of configuration results in low impact tolerance of the structure and over time , possible delamination of the skin at points of contact. On the basis of the demands expressed by industry to overcome these problems, a large commercial transport aircraft Krueger flap was chosen to be optimized and reproduced entirely from orthotropic laminated structures. The composite laminates were to replace the honeycomb structures of the flap bays as well as the aluminium ribs and spars [Cawley P, 1990].

The early design of the flap constituted a heavy secondary wing structure. Therefore an overall revision of the topology of the component was required prior to performing any lay-up optimization on the flap. Topology optimization was performed on a grid stiffened configuration of the flap by using Ansys [Bayandor, 2000]. The results suggested an initial configuration consisting of two to three spars and three ribs by revealing the areas within which material was required. (Figure 2.4)

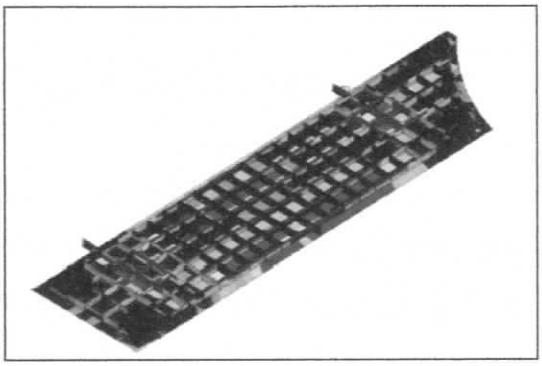

Figure 2.4 : Topology optimization results – light areas indicate where material is needed

[Bayandor *et al.*, 2000]

2.4 Properties of Honeycomb Structure

The term sandwich panel refers to a structure consisting of two thin faces bonded to a thick and lightweight core. The faces are typically of aluminium or some composite laminate. The core could be lightweight foam or a honeycomb structure. Sandwich structures are composite construction of alloys, plastics, wood or other materials consisting of a core laminated and glued between two hard outer sheets (skins). The core is in general lightweight foam or solid core, honeycomb, web core, tubular or corrugated / truss core. The usual foams are plastic / ceramic. To assemble sandwich components, synthetic organic adhesives is used [Lange and Moskovenko, 1988]. Facing sheets are made from high strength materials.

Most of the sandwich structures have superior structural performance. The core separates and stabilizes the outer sheets against buckling under edgewise compression, torsion / bending . Sandwich structures have a high ratio of flexural stiffness to weight, resulting in a higher buckling resistance, lower lateral deformations and higher natural frequencies [Cawley P. ,1990].

The sandwich structures cannot be considered as homogeneous material. They have a specific structural composition. Various experimental approaches have been used to determine the mechanical properties of the cores. The elastic properties as a function of mechanical and geometrical characteristics of basic material can be determined by using finite element methods [Lange and Moskovenko, 1988].

The design of cellular structures requires to understand the response of cellular materials to loading. Type of structure: sandwich constructions, honeycombs, cores, cellular structures, open and closed cellular foams, Z-core sandwich, C-core sandwich, truss-core sandwich, sandwich laminates, hexagonal foams, microsandwich, auxetic honeycombs [Nettles *et al.*, 1993].