COMPARISON METHOD OF CUTTING HONEYCOMB CORE

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree. This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organizations.

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ABSTRAK (BM)

Tujuan projek ini adalah untuk mengenalpasti keadah pemotongan honeycomb tanpa memerlukan sebarang proses tambahan untuk menghasilkan permukaan potongan yang baik justeru dengan membandingkan satu keadah dengan keadah yang lain. Dalam projek ini, kaedah potongan laser, miling dan dawai panas telah dipilih untuk memotong bahan ujikaji seperti nomex, polyproplin, dan termoplastic honeycomb core. Eksperimen ini menunjukkan kaedah pemotongan dari pelbagai aspek seperti jumlah tenaga yang digunakan, masa yang diambil, kelajuan potongan, dan juga ketebalan bahan yang diuji. Keputusan ujian terhadap pemotongan mengunakan 5 watt laser telah menghasilkan potongan dimana permukaan potongan tersebut boleh dikatakan agak baik, Cuma perlu dibersihkan mengunakan kertas pasir untuk mendapatkankan permukaan yang terbaik. Memotong dengan mengunakan keadah dawai panas pula menunjukkan permukaan potongan adalah sangat baik dengan tidak membazirkan bahan ujikaji seperti termoplastik dan polypropylene, tetapi ia tidak dapat memotong nomex kerana kekurangan tenaga, dan dipengaruhi dengan ciri-ciri yang ada pada bahan nomex. Keseluruhannya, dengan mengunakan 5 watt laser adalah sesuai untuk memotong honeycomb kerana ianya memerlukan kalibrasi pada titik focal laser bagi mendapatkan diameter yang paling kecil bergantung pada tahap ketebalan bahan. Pada akhirnya, keadah pemotongan laser mampu memotong nomex honeycomb, ianya akan menjadi keadah terbaik sekiranya laser jenis karbon dioxide digunakan untuk memotong nomex honeycomb core.

ABSTRACT (BI)

The aim of this project is to determine the method for cutting honeycomb core without need any additional process with zero defect, and to compare the cutting quality with another method of cutting. In this project laser cut, milling cutters, and hot wire cutting method is preferred to cut the nomex honeycomb core, polypropylene honeycomb core, and thermoplastic honeycomb core. This study is seeking better ways to producing smooth cutting finish when cutting the nomex honeycomb core. This study represents the method of cutting of nomex honeycomb core with various parameters such as power, time, speed and thickness of the specimen. The results shows that using 5 watt of laser cut, it produces better surface finish without many burr produced, compared using milling cut but, there have burn spot that can be smooth up by sand paper. For hot wire cutting result, it shows smooth surface finish with less material wasted for material polypropylene and thermoplastic honeycomb core, but it has a problems with nomex honeycomb core due to less energy of power supply. For this experiment, the hot wire was used dry cell as their power supply so it cannot cut the nomex honeycomb core due to properties in nomex material and less power consumption. Overall, using 5 watt laser machine are suitable for cutting honeycomb core, because the focal point of laser need to be adjusted in getting the smallest diameter of focal length due to thickness of materials. Lastly, laser cutting method are able to cut nomex honeycomb core, and it can be the best method for cutting nomex materials if it was using carbon dioxide laser type to cut nomex honeycomb core.

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CHAPTER 1

INTRODUCTION

1.0 Introduction.

In this chapter contain overview of overall structure of project, aim of the project, problem statements, and scope of project.

1.1 Overview of Structure of Project.

Honeycomb core are inspired by honeybee structure, they are man-made structure that have the geometry of honeycomb, the purpose is to minimal the weight and material cost. The geometry of honeycomb can vary widely but common feature is hollow cells formed between thin vertical walls, it can also columnar and hexagonal in shape. The form of honeycomb core are made by layering between two thin layers of aramid papers that provides strength in tension. There have many type of honeycomb core such as Nomex honeycomb core, Kevlar honeycomb core, Aluminum honeycomb core, and KOREX honeycomb core, there have special honeycomb such as carbon honeycomb and polyurethane honeycomb [1]. Nomex honeycomb is the standard for light weight nonmetallic composite construction, there are made by aramid fiber paper (DuPont Nomex) where is coated with heat resistant phenol resin have excellent resiliency, low density, low pricing, formable and high strength to weight ratio. Therefore, honeycomb core are widely used in industry such as aerospace industry, automotive industry, and furniture to package and logistic [2].

1.2 Problem Statements.

When cutting the honeycomb core, there are some problem occurred, such as poor form accuracy of cutting surface, this is because the hollow tubular cells of honeycomb core are not sufficient in hardness and strength, thus the cells wall in cutting surface result inappropriate deformation such as crumping, collapsing, and burring.

Next is, paraffin is used in honeycomb core to solidified it, but it is a difficult when honeycomb core are cut due to paraffin is often difficult to remove from the honeycomb core, that make the core damaged after cutting.

Furthermore, after cutting process is completed it observed that the honeycomb core will produce burr, and need to be sand off to remove the burr. Even using CNC machine, it need tool change such as core cut to valve type, profile cut, pocket cut to make sure final form of cutting of honeycomb core are excellent.

However, this project will discuss and analyze the effects of cutting honeycomb core using laser cutting machine. It will observed the results and what type of damages occur. What will be parameter need to be consider while cutting it using laser.

1.3 Objective.

1) To determine whether laser cutting machine can probably cut the honeycomb core.
2) To find either laser, milling or hot wire method can reducing operation in cutting honeycomb core.
3) Comparing between laser, milling and hot wire method of cutting nomex, polypropylene and thermoplastic honeycomb core and observe their different.

1.4 Scope of Project.

1. Determine the best approach for cut the nomex honeycomb core without the need any additional process, laser cutting machine are choose to cutting test of the nomex, polypropylene and thermoplastic honeycomb core at various methods and parameters.
2. Validate either it possible to cut the nomex honeycomb core using laser, because it's made up of paper, there have reaction with heat produced by laser.
3. Type of materials and specification
4. Cutting parameters used such as power, speed, and cutting time.
5. Expected result and limitation.
6. Identify the defect occur on surface of materials
7. Producing results when method of cutting have been done, and make observation and comparison with others method of cutting.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter review the significant of this project being addressed and showed the previous published research article information. This indicate awareness of other work relevant to the research, and show clearly what the area that has not being solved. This chapter also describe the theory associated with the existing problems, and the existing solution relevant to the problems.

2.2 History of Nomex Honeycomb Core

Structure of honeycomb have many in real life such as section of iris leaf, section of bird wing, section of human skull, honeybee comb. The Arcemedes lay the foundation of engineering and discover beside density with the law of lever the first element in understanding the moment of inertia of sandwich construction (230 BC). Next is roman bridge, 1000m long over the Danube build by Apollodorus under the emperor Trajan. The last example is, Marcus Varro, geometrician has proved that with the same amount of materials the hexagonal will be able to hold most honey [3].

The structure of honeycomb core are exist about 2000 years ago, but it has no strong references to state that, the first paper of honeycomb core structure are be made by Chinese and the purpose in that time as ornaments. After that, the paper honeycomb and the production of honeycomb core structure are expended and first invented in Halle/Saale in Germany by Hans Heilbrun in 1901, the application of paper honeycomb core are for decoration. It expended the honeycomb production as remarkable degree of automation in the first decade of the 20^{th} century. There have three process stages which is expansion, corrugation and molding. All these technique are already developed by 1901 for non-sandwich application. The first sandwich structure are developed on Airplane Company in 1915 by the German Hugo Junkers.

All the widespread use of core materials and honeycomb in composite industries are in 1970's, where is the construction have recognize that the honeycomb structure can provide stiffer, stronger, and lighter solid laminates. After that, nomex fiber material was first marketed by DuPont at early 1967, and the application of the nomex fiber on that time are for construct diving suits for race car driver to protects against fire and heat when accident happened[4].

There was others people has discover about honeycomb pattern such as [4]:

- 60 BC Diodorus Siculus reports a golden honeycomb manufactured by Daedalus via lost wax casting.
- 36 BC Marcus Varro reports most efficient use of space and building materials by hexagonal shape.
- 126 The Pantheon was rebuilt in Rome using a coffer structure, sunken panel in the shape of a square structure, to support its dome.
- 1638 Galileo Galilei discusses hollow solids and their increase of resistance without adding weight.
- 1665 Robert Hook discovers that the natural cellular structure of cork is similar to the hexagonal honeybee comb.
- 1859 Charles Darwin states that the comb of the hive-bee is absolutely perfect in economizing labor and wax.
- 1877 F. H. Küstermann invents a honeycomb moulding process using a paper paste glue mixture.
- 1890 Julius Steigel invents the honeycomb production process from corrugated metal sheets.
- 1901 Hans Heilbrun invents the hexagonal paper honeycombs and the expansion production process.
- 1914 R. Höfler and S. Renyi patent the first use of honeycomb structures for structural applications.

- 1915 Hugo Junkers patents the first honeycomb cores for aircraft application.
- 1931 George Thomson proposes to use decorative expended paper honeycombs for lightweight plasterboard panels.
- 1934 Edward G. Budd patents welded steel honeycomb sandwich panel from corrugated metal sheets.
- 1937 Claude Dornier patents a honeycomb sandwich panel with skins pressed in a plastic state into the core cell walls.
- 1938 Norman de Bruyne patents the structural adhesive bonding of honeycomb sandwich structures.
- 1941 John D. Lincoln proposes the use expanded paper honeycombs for aircraft radomes
- 1948 Roger Steele applies the expansion production process using fiber reinforced composite sheets.
- 1969 Boeing 747 incorporates extensive fire-resistant honeycombs from Hexcel Composites using DuPont's Nomex aramid fiber paper.
- 1980s Thermoplastic honeycombs produced by extrusion processes are introduced.

2.3 Sandwich Structure.

Nomex honeycomb core are normally used in manufacture sandwich structure of aircraft, in industries, every extra kilogram of structural mass were taken off, by doing that it will increase in payload mass at the same time decrease in fuel mass which trick down to an increase in profit [5]. Why using sandwich construction, by sandwich construction this can be achieved with very little increase in weight as shown in figure 1[2].

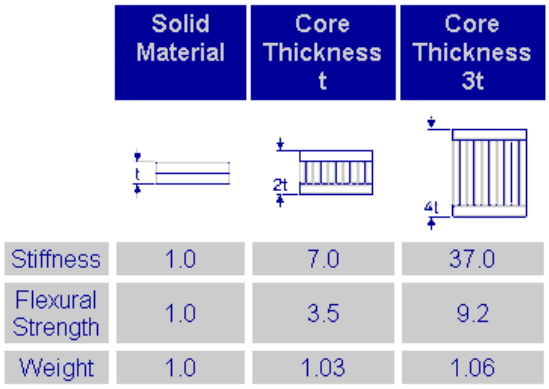


Figure 1. Bending Stiffness of sandwich construction [2].

Honeycomb is available in many type of materials and pattern such as polymer, carbon, aramid, and Kevlar. There have common type of honeycomb been used in aerospace applications likes, aluminum and nomex (aramid fiber paper with impregnated with phenolic resin) [2]. Honeycomb sandwich panel have been extensively over the years, for application where their stiffness and strength benefits cannot be beaten such as [6].

- Aircraft Flooring

  Most of aircraft in the world have honeycomb sandwich flooring especially nomex and aluminum type of honeycomb core.
- Aircraft Interior

  Can be fitted in all type of modern aircraft and high market in industries.
- Ship Interior

  Increasingly, new ship are design for higher speed and commonly demand for low weight materials panel but strong
- Construction Industries

  For light weight cladding and support for stone veneers. Purpose for reducing overall construction time and lower building construction cost.

2.4 Characteristic of Nomex and Others Type of Honeycomb.

Nomex honeycomb core are normally used in industries because of their properties have high value of specific stiffness, there have been applied in sandwich structure, most of aircraft structure applied this concept and structure for reduce weight. Honeycomb core is 90-95% air [2].With that

properties, it provides a high in-plane bending stiffness with low weight. The sandwich structure is consist of layers of metal or composite such as carbon woven, fiberglass, Kevlar or others materials [7]. Honeycomb core are commonly build from aramid papers which is provide great degree of freedom. There have some obstacles such as, there must have highly quality of adhesive between core and face sheet. Delamination of layers with core may happened if it not properly handle or cure. When the flexural rigidity of a composite material is not sufficient, the sandwich concept offers an alternative without a significant weight penalty [8].

2.5 Type of Honeycomb Core.

Honeycomb core are available in many type of materials based on their used and properties of strength to weight ratio and it's has their own benefits. The most common core materials used in aircraft honeycomb structure are Nomex or Korex, while the fiberglass are used for higher strength application. There have many type of honeycomb core such as [10].

2.5.1 Kraft paper.

Figure 2 shows the Kraft paper there are relatively low strength, good insulating properties, and it also available in large amount of quantities and have low cost.

Figure 2. Kraft paper honeycomb core [10]

2.5.2 Thermoplastics.

There have several special properties such as good insulating, good in energy absorption and redirection, smooth cell wall, moisture and chemical resistance. It's also environmental compatible and relatively low cost as shown in figure 3.

Figure 3. Thermoplastic honeycomb core [10]

2.5.3 Aluminum.

This type of honeycomb core as shown in figure 4 are commonly used in aircraft industries because of the properties of best strength to weight ratio and energy absorption, has good heat transfer properties, electromagnetic shield properties, has thin cell wall, machinability and low cost.

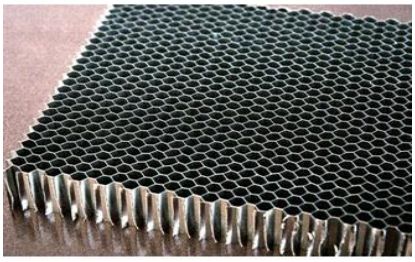


Figure 4. Aluminum honeycomb core [10]

2.5.4 Stainless Steel.

Figure 5 shows the stainless steel honeycomb core, as known, steel has good heat transfer properties, electromagnetic shielding properties, and heat resistant, but it's rarely used in industries because steel are quite expensive and high machinability.

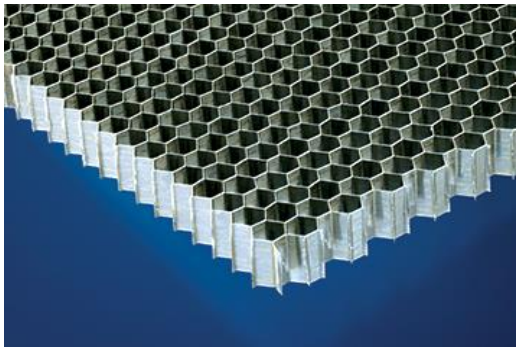


Figure 5. Stainless steel honeycomb core [10]

2.5.5 Aramid.

Aramid are wood based material as shown in figure 6, where it's has properties like flame resistance, fire retardant, good insulating properties, low dielectric properties and good formability. Thus, this type of honeycomb core are mainly used in industries to reducing weight.

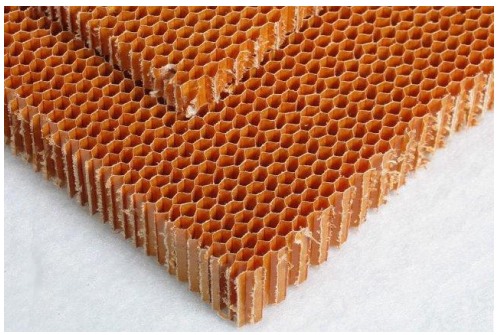


Figure 6. Aramid honeycomb core [10]

2.6 Problem Has Not Been Solved.

There are several group of research found a better way to cut nomex honeycomb core, based on literature search, mostly choose to use knife for cut nomex honeycomb core or others type honeycomb core. Every type of core having their easy cut way is called ribbon direction, when cutting follow that ribbon direction, its make easier to split the unnecessary part of nomex honeycomb core [12]. Other than that, cutting the large size and thick nomex core, normally using CNC are used.

The main problem they faced is when cutting process completed, it produced burr and need additional process to remove burr [13]. It is time consuming for industries and it was found that ultrasonic cutting has better outcome in cutting honeycomb core. Using ultrasonic cutting method, honeycomb core can be cut with extremely accurate without producing dust or waste materials. Currently using ultrasonic cutting method are the best way to cut nomex honeycomb core.

The purpose of this project are to observe by experiment, cutting the nomex honeycomb core, identify which method is better and can produced high quality of cutting surface of honeycomb core. Honeycomb can be cut by many type of machine process such as ultrasonic cut, water jet cut, milling cut, CNC

cut, and Laser cut, but, only aluminum core can be cut by water jet [13]. This is because, nomex honeycomb core are built from two form of aramid paper [8], and it also not conduct electrical and when the surface touch with water, and it maybe cause core damages, the advantages is, it has excellent fire-resistance properties. So in this project, water jet cut are excluded and investigation focus on milling, hot wire, and laser cut. The purpose are to have high quality surface finish because, good product do not have defect occur on the sandwich structure build, such as disbond, or delamination. This is the case because if the top surface of core have burr and adhesive, hence cannot stick properly between core and layers of plies [2].

2.7 Example Applications of Honeycomb in General.

Nomex are used significantly in industries because of their good properties, normally used in firefighter field [14], to protect them from heat and fire as shown in figure 8 and figure 9. Nomex honeycomb core, are also utilized in aerospace part such as wing tip and fan cowl (see. Figure 7) of an airplane because it is light weight and can withstand high pressure and temperature. Other than that, vehicle racing also use the nomex materials to prevent injury when car caught fire, nomex materials suit where a racer wear can help to protect the racer up to 40 seconds in fire [15]. Other application of nomex are nomex glove, and nomex long underwear.

Figure 7. Airplane fan cowl [8]

Figure 8. Nomex Fire Fighter Jacket [14]

Figure 9. Nomex Glove [14]

The price of honeycomb are also expensive based on their manufactured process, for example fan cowl as shown in figure 7, it can cost about Rm 350,000.00 per side, for one small turbine of airplane it need 2 piece of fan cowl panel, so it cost about Rm 1,400,000.00 for both side for a pair of turbine engine of airplane. Price it's very expensive because of it need manually peep prep layup by operator in clean room which based on laser mapping.

Other parts of aero-plane applications:

- Aircraft flooring – varying densities depending on level of duty
- Aircraft interiors – ranging from sidewalls, galleys and ceilings, including commercial aerospace, Business and VIP interiors
- Cargo lining
- Helicopter rotor blades
- Aircraft leading and trailing edges
- Fuselage components

2.8 Laser Cutting Process in General.

Laser machine as shown in figure 10, can cut the material by layers to perform good surface finish, it cannot cut to a significant depth of thickness of materials because it is depends on type of power of the laser machine. If cutting for thick material at single run, it might cause some problem such as, burn, dimensional error, and product fail [16]. When cutting the nomex

honeycomb core, ribbon orientation should be consider because it has mechanical behavior of sandwich structures, orientation from 0° to 90° [16].

Heat affected zone (HAZ), not only occur on metal or polymers, it also occur at composite materials nomex honeycomb core, there are three input that influenced HAZ, laser power, cutting speed, and gas pressure [17]. All parameters need to be correct and suitable for cutting nomex honeycomb core because it is made from wood, and wood contain oxygen and carbon dioxide, laser cutting of wood based materials is based on chemical degradation and complex chemical reaction take place which cause chemical decomposition of cell of nomex honeycomb core [16]. There are limitation when cutting wood based materials using laser or any type of heat base cutting machine. The use of inert gases instead of air is not reasonable since inherent burning of the cellulose cannot be avoided (Powell 1998). Laser cut wood shows oxidized cut surface and strong fume formation take place. Pulse ablation processing of wood was investigated by (Wiederman 1998) who observed a threshold energy 1 J/cm^2 for material removal rate highly depends on the water contain on the wood type [17].

Laser machine are expensive and that make it as a limitation for industries to use, not only cost to buy, it also considered the investment cost, operational cost, and economic aspect. But to produce high surface finish and high accuracy and precision, laser cutting machine are the best method, when nomex honeycomb core are cut by laser machine, firstly its reducing burr and edge broke of the nomex honeycomb. Because nomex honeycomb are made from wood base materials combining with phenolic resin to make it fire resistance, therefore the laser machine can cut without disturbing the physical properties of nomex honeycomb. When cutting with angle such as 45 degree or 60 degree, the ribbon direction of the core need to be consider [16], to avoid core failure occurring.

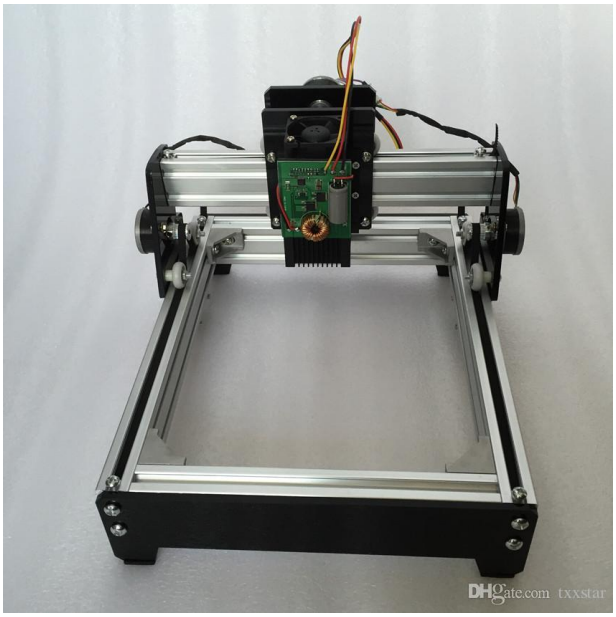


Figure 10. Sample of existing laser cut machine open frame

2.8.1 Limits of Abrasive Water Jet (AWJ), Laser Beam (LB), and Electro Discharge (ED)

All these methods can successful cut nomex honeycomb core composite materials [8]. However, AWJ being by far the most widely used approach due to the following reason; LB results in extremely poor cut quality with excessive burr formation, large dimension errors, large HAZ, and severe thermal damages. On the other side, ED machining strongly dependent on the conductivity of the composite material, but for this nomex honeycomb core, it is not suitable because not conducting material. The ED machining provides the lowest MRR among the three unconventional machining approaches (AWJ, LB, ED) [8].

2.8.2 Physical Comparison between AWJ, LB, and ED.

The properties stated that the AWJ can cut up to 60cm virtually all type of materials, where the laser can go up to 7 cm depending on what type of materials properties, and ED can go up to 30 cm depending on materials properties. From the point of investment budget, it id about RM60,000 – RM300,000 for AWJ, RM200,000 – RM1 million for laser and RM100,00 – 400,000 for EDM [8]. Cost installment is very important factor and must have strong reason and benefit for the company when implement it. These are the challenge for a reseracher to prove the suitable method and machine need to

be utilize in term of reducing cost, time, and increase inventory and reduce backlog.

2.8.3 Method

The ways to diminish the burr problem when cutting nomex honeycomb core is by using laser cutting machine. Based from some ongoing research about laser properties with composite materials, laser machine which is a non-contact materials removal process and its provides minimal thermal damages on composite part materials is a good option [16], for example carbon fiber, does not melt at ambient pressure and has high evaporation temperature up to $> 3500℃$ and polymers have a damages threshold at a temperature 560℃ [18]. Nomex consist of aramid, aramid is fiber calendared to a foil and coated with phenolic resin. The advantages of nomex properties is it have [1]:

- High strength to weight ratio.
- Electrical and thermal conductor.
- Chemical, corrosion, shock, fatigue resistance.
- Fire resistance.
- Flexible.

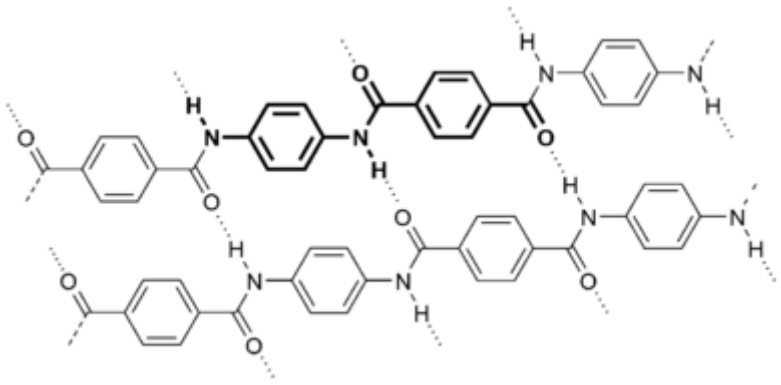


Figure 11. Aramid chemical structure [18]

2.8.4 CNC Method of Cut

In industries, normally used 5-axis CNC machine as shown in figure 12 to cut the nomex honeycomb core, by using special tool to cut it, such as 29-009-HSS Hollow Core Honeycomb Cutter and Disc Honeycomb cutter [19]. HSS Hollow HC, is a specialized cutter designed to vertically cut the honeycomb

cells producing a clean, flag free edge. The core material will remain attached at the bottom and can be removed using one of our valve style honeycomb cutters.

This product along with 31-100 or 30-000 series tools is an effective combination to create pockets in honeycomb core and get a perfectly clean edge. While, Disc Cutter Small diameter honeycomb cutters were designed to offer the flexibility of cutting small slots or pockets in honeycomb core[19]. The tools are versatile and can be used on CNC machines or hand held machines for field or maintenance type repairs.

In school of mechanical engineering USM, it has CNC 5-axis machine with HSS cutter and it is suitable to cut nomex honeycomb core, and this is one of the method will be investigated and observed so that can produced smooth surface. Other than CNC cut, wire cut machine can be used because the nomex honeycomb core are coated with phenolic resin, where the properties of phenolic resin can conduct electricity because the present of Zn metal particle function as filter [20].

Figure 12. CNC 5-axis in existing industries (9).

2.8.5 Ultrasonic Method of Cut

Figure 13 shows the ultrasonic cutting technology is neither new nor experimental. This process has been used long time for specific application such as, the cutting of PVC tiles or others type of materials such as nomex honeycomb core. This machine functions with the blades vibrating at ultrasonic frequencies that had been tested in the mid-1980s at Fraunhofer Institute for production in Aachen, Germany. Ultrasonic cutting has significant benefits likes, no absences of chips, offcuts, dust and noise.

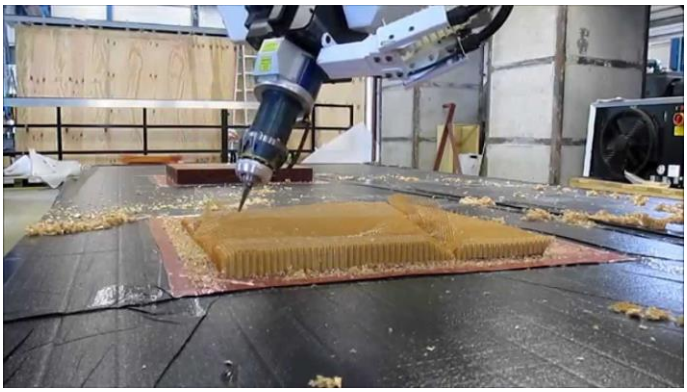


Figure 13. Ultrasonic cutting machine [9]

2.8.6 Knife (Manual Cut).

Based on previous works, cutting the nomex honeycomb core utilized sharp bread knife. There have several problem when using manual cutting, the direction of the cutting will not be straight and inaccurate because of human hand will shake a bit while cutting, especially when repeating the similar motion for long time. But, it has benefit in term of cost and time consuming. In term of cost, it only use a sharp blade or knife to cut the nomex honeycomb core or other type of honeycomb core such as Polypropylene or Thermoplastic type, following the ribbon direction to easily split the part. Using knife when cutting nomex honeycomb core are quite the simplest way in industries, for example in aerospace industries, in composite repair section, normally people repair the core damages in certain spot, they do not require to remove overall core in that panel, just remove the part core damages based on their radius specified and replace it using another new nomex honeycomb core using manually cut using knife at required dimension.

2.8.7 Chosen Method to Perform

Milling

Milling machine are widely used all around the world, it also have CNC milling that can can be used in many process to cut the metal, plastic, and also composite materials, but it demand the special type of tool to run the operation [21]. For milling, attached method at base of the work table milling machine must be considered, it has several method to attached the nomex honeycomb core on that table such as, roll a thin layer of resin on the one side of

honeycomb core with attached with a thin plate to make sure it's does not move when cutting operation. Also, it can simply use double tape at the bottom of the nomex honeycomb core, it is enough to make sure the materials not move because, nomex honeycomb core are lightweight materials, so the probability it moves are higher.

Changing the tool bit from normal metal tool bit to high speed steel cutter (HSS) honeycomb core is also critical because cutting the wood based materials with coated by phenolic resin. It is prefer to use smaller diameter for purpose of reducing waste materials.

Hot Wire

Hot wire are also one of the method can be used in cutting the honeycomb core, and can cut thermoplastic and polypropylene honeycomb core. The disadvantage is that it is not suitable to cut the nomex honeycomb core because of the properties exist in nomex materials. In the positive side, hot wire cut are quite cheap compared with CNC, wire cut, and laser cut. Hot wire such as polystyrene cut can be used in this experiment. But there have the negative side such as, the surface finish of cut are not smooth and may be have over melt in the polypropylene or thermoplastic honeycomb core.

The process of cutting using hot wire do not need to attached the honeycomb core to table work, it just simply hold using hand and cut the polypropylene or thermoplastic honeycomb core using hot wire. After the cutting process done, the specimen is brought to the metrology lab to do some observation on the surface and also might be consider the materials wasted while cutting process occur, by using the weight measure machine. Then the data and analysis will record based on the observation.

Laser Cut

Laser cut has several parameter such as power i.e. 5 watt and 45 watt laser machine which used carbon dioxide as the power generating element. In this project, honeycomb core will be cut using 5 watt laser machine. In order to cut nomex, polypropylene, thermoplastic honeycomb core, firstly, the specimen need to be attach on the work table to make sure it do not move, by using double sided tape. The work table must be a wood or another thing to avoid from others damages, because it is an open frame laser machine which does not have their own work table. Before start cutting, make sure user wear the safety glass to avoid from eye damages from the laser light. Then finally done cutting process, will proceed to metrology lab to observe the surface finish and any defect occur when cutting. Repeat the same step for another specimen, and same observation will be taken from that.

2.8.8 Comparison between milling, hot wire, and laser cut.

Every method have their advantages and disadvantages. Firstly milling machine is used to cut the metal object or specimen; have their type of tool bit and can perform to cut hard materials [22]. But in this situation, it need to cut soft materials such as nomex, polypropylene, and thermoplastic honeycomb core. For the polypropylene honeycomb core, there have no problem because of it hard compared others. For nomex and thermoplastic have some problem in cutting, due to soft materials. Other than that, laser cutting has no problem to cut the nomex and thermoplastic honeycomb core, but it has a problem to cut the polypropylene because of less power consumption [17]. Finally, the hot wire cutting, it about similar with laser cut just only have less power compared with laser, for rough cut it can probably cut the thermoplastic honeycomb core and polypropylene honeycomb core, and it is impossible to cut nomex honeycomb core due to weak and not enough power to perform the operation. For conclusion, between all three methods, the hot wire cutting method are the better method compared with milling and laser. That do not mean the laser cutting method was not good, but hot wire more economic and save time, compare to laser and milling. Laser cut also need to perform cutting stage by stage and cannot cut for single run because of some factor such as thickness and feed rate. Furthermore, for milling, it has advantages for cutting

others type of honeycomb core such as carbon, and ceramic honeycomb core but for plastic based materials it is not suitable.

2.9 Conclusion.

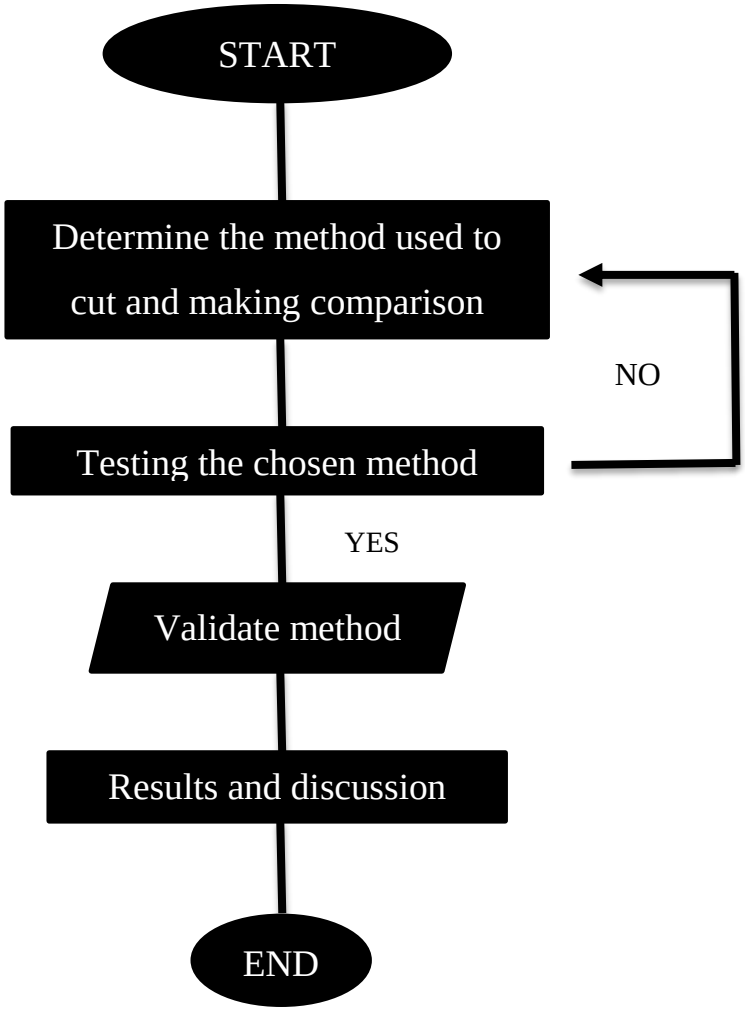
In conclusion for this chapter, there are many type of honeycomb core that are applied all around the world either naturally or for structural purpose. It is used because the structure can withstand high load and also flexible at the same time thus can reduce weight of the structure. There are, many others type of honeycomb core, not only nomex but also aluminum, polypropylene, carbon, thermoplastic and polypropylene. Based on literature review, CNC and manually knife (using template) are commonly used to cut the nomex honeycomb core especially in aircraft industries.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction.

This chapter will discuss the method in detail the important step and parameters in producing smooth surface finish when cutting nomex honeycomb core and others type of honeycomb core. Therefore, this chapter will also describe about the method used and the equipment used in investigating the surface of cutting.



3.2 Preparing Method of Cut

The purpose of performing the cutting test is to identify and observe the cutting surface of various type of honeycomb core with three method of cut that is 5 watt laser machine, conventional milling machine and hot wire cutting method. Three type of materials i.e. nomex honeycomb core, polypropylene honeycomb core, and thermoplastic honeycomb core will be cut to observe their cut surface finish. Microscope will be used to observe the surface, it can also use ALICONA, and Profile Projector but the machine were malfunction and there was not enough facilities to make a good observation of the cut surface finish.

3.2.1 Preparation of Milling Machine

Figure 14 shows the type of milling machine where the milling is the process of machining flat, curved, or irregular surfaces by feeding the workpiece against a rotating cutter containing a number of cutting edges. Low speed of feed rate use to make sure specimen does not move and to avoid from core damage. For this experiment vertical milling machine with 2mm diameter of tool bit are use.

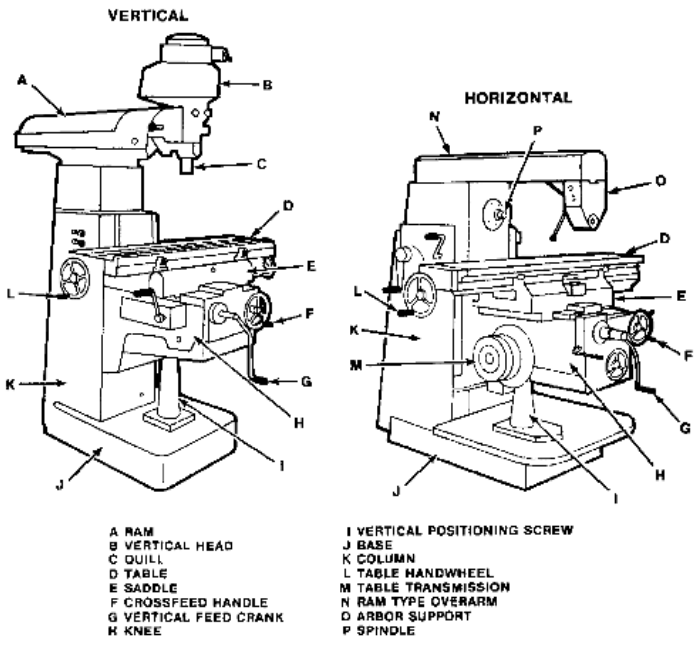


Figure 14. Milling machine [3]

3.2.2 Application of hot wire cut

Figure 15 shows the hot wire cutter. This approach however not enough power to cut the nomex honeycomb core, but it can cut other type of materials such as thermoplastic, and polypropylene honeycomb core. For this experiment, Styrofoam cutter are used as hot wire to cut honeycomb materials. The power are using 1.5v battery and manually control by human hand, human error may occur during experiment but it can be reduce by increasing level of focus when cutting operation.

Figure 15. Hot wire

3.2.3 Preparation of Laser Machine

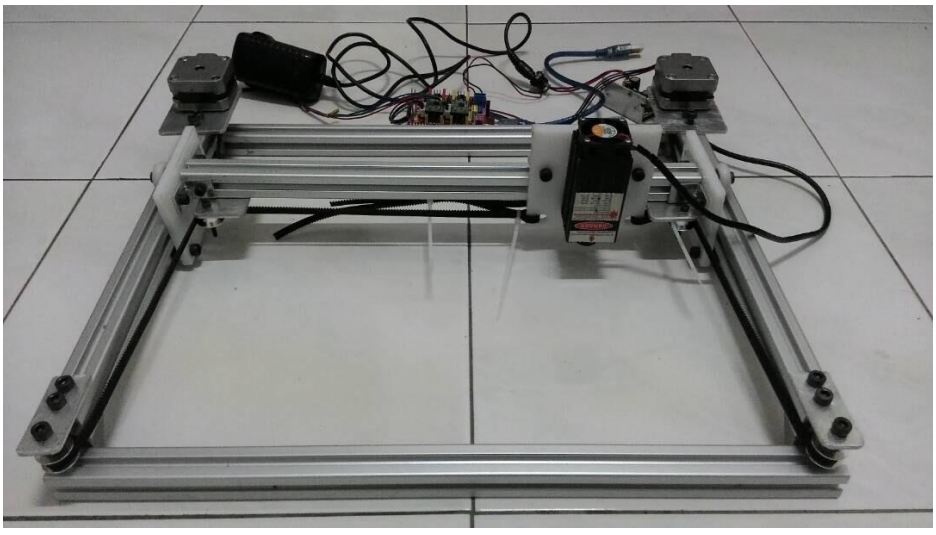


Figure 16. Set-up of a typical laser cutting system

Laser beam as cutting tool is extracted from high power laser source where electrical energy is converted into optical energy. There have several type of

laser such as CO_2 laser and **(neodymium-doped yttrium aluminum garnet; Nd:$Y_3Al_5O_{12}$)** Nd:YAG laser.

The CO_2 laser is where CO_2gas acts as the active medium. The molecule of carbon dioxide are discharged at high voltage and low pressure, and the gas discharged take place in mixture of helium, nitrogen and CO_2 [18]. The Nd:YAG laser (Weber 1998) are solid state laser with neodymium-dropped Yttrium-aluminum-garnet crystal. The action is act as host crystal with high thermal conductivity and become goof optical features [18].

For this experiment, 5 watt power laser machine will be used to investigate whether it is able to cut various type of honeycomb core. The focal point must be manually adjust until it has a smallest diameter of focal point, so it can cut properly. Speed of cut should be determine either 20mm/min or higher.

3.2.4 Preparing Specimens

Nomex, polypropylene, and thermoplastic honeycomb core are cut by 3 x 3 inch using sharp knife as shown in figure 17 for thermoplastic, figure 18 for polypropylene, and figure 19 for nomex.

Figure 17. Random dimension thermoplastic

Figure 18. Random dimendion PP