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DETERMINE TENSILE PROPERTIES OF DRY CARBON REINFORCED EPOXY COMPOSITE USING HAND LAYUP METHOD

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fulfillment for the award of
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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

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Special thanks to my family members, supervisor, panels and friends for helping me throughout the project towards achieving my goals

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ABSTRACT

Current production units of the Airbus A320 family are using metal hinge for their spoiler centre hinge which is both heavy and susceptible to corrosion over time. Composite materials are lighter in weight and less susceptible to environmental factors. To address this problem, a new composite hinge design will be developed using composite materials. The objective of this project is to determine tensile properties of dry carbon reinforced epoxy composite using hand layup method which will be compared to specimen from RTM method. The advantage of using hand layup method is that the more complex shape can be produced relatively easier when compared to other production method such as resin transfer moulding (RTM). The properties of dry carbon reinforced epoxy composite will be tested using tensile test methods according to ASTM D3039 standards. Due to the complex nature of the centre hinge design, hand layup is a very promising method of production. It can be said that based on the tensile test conducted, the higher the number of woven carbon fibre used to higher the strength of the composite. However, the RTM was able to fabricate specimen with a better surface finishing and shows better tensile properties when compared to hand layup and thus it more desirable method to produce the composite hinge.

ABSTRAK

Pengeluaran semasa bagi pesawat A320, Airbus menggunakan logam untuk engsel tengah spoiler yang mana ini adalah lebih berat dan terdedah kepada hakisan persekitaran. Bahan komposit adalah lebih ringan dan kurang terdedah kepada faktor-faktor alam sekitar. Untuk menangani masalah ini, reka bentuk engsel baru dibangunkan menggunakan bahan komposit. Objektif projek ini adalah untuk menentukan sifat-sifat bahan komposit epoksi diperkukuhkan dengan gentian karbon dengan menggunaka cara bengkalai tangan atau “hand layup” yang akan dibandingkan dengan RTM. Kelebihan menggunakan cara bengkalai tangan untuk menghasilkan bahan komposit adalah bentuk yang lebih kompleks lebih mudah untuk dihasilkan jika debandingkan dengan menggunakan kaedah pengeluaran komposit seperti RTM. Ciri-ciri bahan komposit epoksi diperkukuhkan dengan gentian karbon akan diuji dengan ujian tegangan mengikut standard ASTM D3039.Oleh kerana sifat engsel pusat yang direka adalah rumit, cara bengkalai tangan merupakan kaedah pengeluaran yang menjanjikan hasil yang baik. Boleh dikatakan bahawa berdasarkan ujian tegangan yang dijalankan, semakin tinggi jumlah serat tenunan karbon digunakan, lebih tinggi kekuatan komposit. Walau bagaimanapun, RTM dapat menghasilkan spesimen dengan kemasan permukaan yang lebih baik dan menunjukkan sifat-sifat tegangan yang lebih baik jika dibandingkan dengan bengkalai tangan dan dengan itu kaedah yang lebih wajar untuk menghasilkan engsel komposit adalah RTM.

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LIST OF ABREVATIONS

ASTM	American Society for Testing and Materials
CF	Carbon Fibre
CTRM	Composites Technology Research Malaysia Sdn Bhd
NEO	New Engine Option
PAN	Polyacrylonitrile
PEO	Polyethylene Oxide
PVA	Polyvinyl Alcohol
RCC	Reinforced Carbon-Carbon
RTM	Resin Transfer Moulding
UTeM	University Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The Airbus A320 family is known to be a commercial passenger jet airliners which are mainly single-aisle. The manufacturer, Airbus, are also known of producing A320ceo (current engine option). The Airbus 320 family typically seats 150 passengers in a two class cabin or up to 180 in a high density layout for low cost chartered flights. The A320 widespread service around the world varying from short commuter sectors around Europe, Asia and elsewhere to trans-continental flights across the United States of America.

Composite materials are mainly used and developed in the aerospace and automotive industry because composite materials are generally lighter in weight, stronger, more rigid and less susceptible to environmental factors when compared to its metallic counterparts. With this reason in mind there are ongoing efforts to replace metallic parts in the aircraft industry which clearly provides better fuel savings due to lower overall weight as well as increased reliability due to the strength of composite material.

Therefore there is an increasing demand for composited to replace traditional metals in order to achieve greater weight reduction, increase reliability and increase the total lifespan of the aircraft. In this case, the project will be focused on replacing the middle hinge from metal to a composite material.

Hand layup is the most widely used method to develop composite materials and has been used for many years. Hand layup applies simple principles and it is relatively easy to understand and teach but hard to master. Hand layup cost less especially for tooling requirements and usually done with room temperature cure resins. Hand layup is ideal to fabricate more complex parts since it is easier to layup the composite material according to the desired shape.

So in order to determine which method is best suited to develop the composite hinge, this project was carried to compare the tensile properties of carbon fibre reinforced epoxy composite by means of hand layup versus reverse transfer moulding (RTM).

1.2 PROBLEM STATEMENT

The current centre spoiler hinge (plane) is made out of metal, which is both heavy and susceptible to corrosion over time. . The composite material is lighter in weight, more rigid and less susceptible to environmental factors. To combat this problem, a new design for a composite middle hinge was developed. This would involve knowing the material properties on how the material would behave under stress must be known so that the design of the composite hinge can be made according to the material's property. The aim of the project is to determine the tensile properties of dry carbon fibre that is currently used by CTRM to fabricate the composite hinge. Since the design of the composite hinge is quite complex, hand layup would seem a feasible idea to produce the composite hinge. In order to realize this goal, a project to test the tensile test of dry carbon layup is to be carried out.

1.3 OBJECTIVE

To test the tensile properties of the dry carbon composite materials that are currently in use at CTRM using hand layup method. Several objective has been develop for this project. Those objectives are:

1. Fabricate testing specimen using hand lay-up method
2. To determine the tensile properties of dry carbon fibre according to ASTM D3039

1.4 SCOPE

The following are the scope of this project:

1. The dry carbon reinforced epoxy composite specimen will be made using the hand lay-up method
2. Only the tensile properties of the dry carbon reinforced epoxy composite such as Ultimate Tensile Strength, Young's Modulus as well as tensile strength would be determined.

CHAPTER 2

LITERATURE REVIEW

2.1 AIRBUS A320 FAMILY

The Airbus A320 family is known to be a commercial passenger jet airliners which are mainly single-aisle. The manufacturer, Airbus, has the A320 Family product line consisting of the A318, A319, A320 and A321, and the ACJ business jet. The A320 are also known as A320ceo (current engine option). The final assembly of the family is taken place in Europe in places such as Toulouse, France, and Hamburg, Germany. Beginning in 2009, the production plant in Tianjin, China have been manufacturing aircrafts for the local Chinese airlines. Beginning in April 2013, construction on a new production facility in in Mobile, Alabama has begun in order to produce the A319, A320, and A321 variants. The Airbus 320 family typically seats 150 passengers in a two class cabin or up to 180 in a high density layout for low cost chartered flights. The A320 widespread service around the world varying from short commuter sectors around Europe, Asia and elsewhere to trans-continental flights across the United States of America.

The pioneer of the Airbus A320 family is the A320 itself. Launched in March 1984, it first took to the skies on 22 February 1987 (first delivered March 1988). The family then expanded to include the likes of A321 (delivered on 1994), A319 (1996) and the A318 (2003) variants.

The advanced technology pioneered by the Airbus A320 includes the extensive use of light-weight composite materials for weight saving, an optimized wing design that is 20 percent more efficient compared to previous iterations, a centralized fault display unit for troubleshooting ease as well as lower maintenance cost. The A320 pioneered the use of digital fly-by-wire flight control systems, as well as side-stick controls, in a commercial aircraft. The advantage of implementing such flight control systems are that they provide total flight envelope and airframe structural protection for reducing the pilot workload, improved safety along with smoother flight experience and stability and with fewer mechanical parts which are susceptible to wear. (Adapted from Airbus main website)

Beginning December 2010, Airbus had officially launched the latest generation of the A320 family, the A320 neo “New Engine Option”. In the latest iteration of the A320, customers can have a selection of either the CFM International LEAP-X or Pratt & Whitney PW1000G turbofan engine with various improvements on the airframe and the addition of winglets, named “Sharklets”. The company claims of better fuel savings by up to 15 percent based on the previous model. Virgin America would be launching customers with the A320 neo in the springs of 2016. A total of 1196 A320 aircraft has been ordered by 21 separate airlines around the globe making it the fastest selling commercial aircraft in history (press release by Airbus on 16 NOVEMBER 2011).

A total of 6,285 Airbus A320 family aircraft have been delivered as of 31 October 2014 and of which 6053 are still in service. An additional 4079 airliners are currently on firm order making it ranked as the world's fastest-selling jet airliner family according to records from 2005 to 2007, and as the best-selling single-generation aircraft program (Rahul Bhandari, Jun 19 2007, Airbus steals the Paris air show). The A320 family line has been very popular with low-cost carriers around the world. Airliners such as Easy Jet which purchased A319s, and A320s, to replace its Boeing 737 fleet. The aircraft family are competing directly with the Boeing 737 and has competed with the 717, 757, and the McDonnell Douglas MD-80/MD-90.

2.2 AIRCRAFT SPOILER (HINGE)

The advancement of aerospace technology provides a significant weight saving possibilities by replacing traditional metal materials to composite materials. In aeronautical terms, spoilers are sometimes called lift spoiler is a device that has the purpose to produce lift in an aircraft. Spoilers are usually a plate that is usually installed with a hinge that is installed flush to fit the profile of an aircraft wing. When a pilot intends to decrease in altitude, the pilot will activate the hydraulics causing the spoiler to pivot up along the hinge which disturbs the air stream flowing above the wing. By doing so, the spoiler creates a controlled stall over the portion of the wing behind it and thus reducing lift on that part of the wing.

At maximum deployment, the spoilers can be almost 50° from the flush position. The spoiler acts as a multifunctional tool to maintain flight controls by using it as inflight braking for speed reduction, inflight roll control by augmenting the ailerons during turning. Spoilers are different to airbrakes because airbrakes are designed to increase drag force on the aircraft without affecting the lift on the aircraft. Spoilers however reduces lift and increases drag force.

This is where the hinge plays a role to attach the aircraft spoiler to the wing of the aircraft. The hinge also act as a pivot point where the aircraft's hydraulic is able to raise and deploy the aircraft spoiler during inflight. During this time, stress is placed on the hinge as the airflow pushes down on the spoiler.

2.3 COMPOSITE MATERIALS

Advanced and composite materials can be seen to be rapidly developing in almost every industry. Scientists are working together with industries to conduct research to develop new materials that are lighter, stronger tougher but at the same time at a lower cost. This can be seen especially in the automotive and aerospace industries. This demand is driven greatly by the ever increasing fuel cost. Thus, manufacturer go to great effort to increase fuel efficiency at the same time trying to keep the production cost to a minimum. Therefore non-traditional materials such as composites are quickly replacing traditional materials like metallic material

Composite material are generally consists of two or more materials often ones that have very different properties that would be combined together to achieve the advantage of both materials. The two materials work together to give the composite unique properties. The advancement of composite materials is greatly made by the aerospace and automotive industries whereby it is found that composite materials are lighter, stronger, more heat resistant and generally more rigid when compared to its metallic counterpart. The goal is to increase product performance and achieve a low cost target. This can be done by achieving better fuel efficiency and reliability of current parts by using composite materials.

By definition, composite materials also include metal alloys, plastic co-polymers, minerals and wood. The difference is that fibre-reinforced composites is that the constituent materials at the molecular level are mechanically separable (Campilho, 2015). However, in bulk, the constituent material work together with the advantage of each material but still remain in their original form. The final properties of composite materials are more advantages than that of its constituent materials.

Natural composites exist in both animals and plants. Wood for an example is a composite that is made from long cellulose fibres (a polymer) held together by a much weaker substance called lignin. Cellulose is also found in cotton, but without the lignin to bind it together it is much weaker. The two weak substances, lignin and cellulose together form a much stronger material. Bone in the body are also composite. It is made from a hard but brittle material called hydroxyapatite (calcium phosphate) and a soft and flexible material called collagen (a protein). Collagen is also found in hair and finger nails. As in the case of our skeleton, it can combine with hydroxyapatite to give bone the properties that are capable to support the body.

Early humans have also used composites. One such examples are mud bricks. Mud can form bricks when it is dried out and five shape to a building material. Mud have good compressive strength since it is hard to squash it but have poor tensile strength when you try to bend it. Straw on the other hand is strong when you try to stretch it but can be squashed easily in the hand. By combining the two materials together, it was possible for early humans to create a brick that was both resistant to squeezing and tearing which made it ideal for building blocks.

In India, Greece, and other countries, husks or straws mixed with clay have been used to build houses for several hundred years. Mixing husk or sawdust in a clay is an example of a short-fibre composite (Sanjay, 2011). This reinforcement is done to improve performance.

The main concept of a composite is that it contains matrix materials. Generally, composite material is formed by reinforcing fibres in matrix resin. The reinforcements can be made from polymers, ceramics, and even metals. The fibres can be continuous, long, or short. The reinforcing fibre or fabric provides strength and stiffness to the composites, whereas the matrix gives rigidity and environmental resistance. The properties mainly depends on the orientation of the fibres that are laid in the composites. The main idea about composites are that the fibre carries the load and its strength is greatest along the axis of the fibre. Long continuous fibres in the direction of the load result in a composite with properties far exceeding the matrix resin itself. The same material chopped into short lengths yields lower properties than continuous fibres. Depending on the application of the composite materials, the fibre forms can be selected (Swift K.G., 2013).

2.4 CARBON FIBRE

Carbon fibre, or alternatively known as graphite fibre or CF, are materials made of fibres of carbon atoms ranging from 5–10 μm in diameter. Carbon fibre is widely used in applications requiring outstanding mechanical properties associated to a low density (Vautard F., 2014). The production of carbon fibre, is carried by bonding crystals are mostly aligned parallel to the longitudinal axis of the fibre. Due to the structural alignment of the crystals, it allows the fibre to have high strength to volume ratio which allows high strength relative to its size. These fibres would then be bundled up together in to several thousand to form what is called a tow. This tow can be used by itself or woven to form a carbon fibre fabric.

Carbon fibre is usually supplied in the form of a continuous tow that has been wounded onto a reel. The tow which consists of thousands of continuous individual carbon filaments are held together and protected by an organic coating such as polyethylene oxide (PEO) or polyvinyl alcohol (PVA). The tow can be unwounded from the reel for convenience. The carbon filament has a cylindrical shape with a diameter of 5–8 micrometres. Some of earliest carbon fibre produced such as T300, HTA and AS4 had diameters of 16–22 micrometres (Cantwell W.J., September 1991).

During the carbonization and graphitization process, precursors go through chemical changes that yield high stiffness to weight and strength to weight properties. The successive surface treatment and sizing process improves it's to resin compatibility and handle ability (Ronald, 2011)

The atomic structure of carbon fibre is almost the same than that of graphite. It consists of sheets of carbon atoms arranged in a hexagonal pattern which are known as graphene sheets. The difference here is being how these sheets of graphene sheets interlock. Graphite is a crystalline material whereby the sheets are stacked parallel to one another in a regular and repeating pattern. The intermolecular forces (Van der Waals forces) between the sheets are relatively weak allowing graphite to be soft but brittle at the same time.

Depending on the type of fibre required, carbon fibre can be turbostratic or graphitic, or a hybrid structure with both turbostratic and graphitic parts present. For the turbostratic carbon fiber, the sheets of carbon atoms are folded, or crumpled, together. Turbostatic carbon fibres are derived from Polyacrylonitrile (PAN), whereas graphitic carbon fibres are derived from mesophase pitch after heat treatment at temperatures in excess of 2200 °C. Turbostratic carbon fibres are generally having higher tensile strength, whereas heat-treated mesophase-pitch derived carbon fibres have higher Young's modulus and higher thermal conductivity.

Carbon fibres in general have high stiffness and tensile strength, have low weight, high resistance to chemical attacks, able to withstand high temperature and have low thermal expansion. These properties make carbon fibre the material or choice and has been proven to be very popular especially in the aerospace & civil engineering industry, military application, as well as motorsports other competition sports industry. However, they are relatively expensive when compared to similar fibres, such as glass fibres or plastic fibres.

Carbon fibres combined with other materials to form a composite. Usually, carbon fibre is combined with a plastic resin to form carbon-fibre-reinforced polymer. This will give the composite a very high strength-to-weight ratio, very rigid but brittle. However, carbon fibres are could also be composited with other materials, such as graphite to form carbon-carbon composites which would result in very high tolerance to heat.

Non-polymer materials can be used as the matrix for carbon fibre composites. However, the formation of metal carbides and corrosion concerns, carbon fibre has not been successful in metal matrix composite applications. Reinforced carbon-carbon (RCC) is a carbon fibre-reinforced graphite, is mainly use in structural applications in high temperature conditions. Carbon fibre is also sometimes used to filter high-temperature gases, as an electrode that has high surface area and corrosion resistance, and as an anti-static component. In addition, moulding a thin layer of carbon fibres can improve fire resistance of any polymers or thermoset composites because a layer of compact carbon fibre can act as a heat reflector (Zhongfu Z., 2009).

Carbon fibre composites are quickly replacing aluminium especially from the automotive, aviation and aerospace space industry instead of other metals due to galvanic corrosion issues (David B.). Galvanic corrosion can be defined as damage caused when electrochemical process occurs whereby one metal corrodes when both metals (different metals) are in electrical contact and in the presence of an electrolyte.

Carbon fibre composites global demand was valued to be at almost US$10.8 billion in the year 2009. This however is expected to reach US$13.2 billion by 2012 and would grow to US$18.6 billion by 2015 with an annual growth rate of 7% or more (Acmite Market Intelligence, February 2014). Some of the highest demands is from the aircraft & aerospace industry, wind energy production, as well as from the automotive industry who are using the resin matric systems (Roman W.H., 2012).

2.5 EPOXY

Epoxy is the end product of epoxy resins that has been cured. This includes all the colloquial name of the epoxide functional group. Epoxy is also referred to a type of strong adhesive used for sticking things together and covering surfaces, usually two resins are required to be mixed together before it can be used. Epoxy can also be used as a solver due to its high melting and boiling points.

Epoxy resins, otherwise known as polyepoxides are reactive prepolymers and polymers which contain the epoxide groups in the molecular structure. Epoxy resins react by cross-linking each other through catalytic homopolymerisation, or with other reactants including polyfunctional amines, alcohols, phenols, acids, and thiols (Yoshio T., 1988). These reactants are otherwise known as hardeners. The cross-linking reaction is known as curing. Thermosetting polymer may form by reaction of polyepoxides with themselves or with polyfunctional hardeners. Thermosetting polymers usually have strong mechanical properties, high temperature and chemical resistance. Epoxy is used widely in industry such as metal coatings used in electronic and electrical components, high tension electrical insulators, fibre-reinforced plastic materials, and structural adhesives commonly used in boat building (Clayton A.M., 1988). Epoxy resin has also been used in the dental industry to bind gutta percha in some root canal surgery procedures (Marciano M.A, 2010).

Typical consumer two-part epoxy adhesives for homes, hobbies and non-industrial uses are available in stores. With a wide array of selection depending on the properties desired ranging from fast vs slow curing time, clear vs opaque, water-proof vs water-resistant, and flexible vs. rigid. A common mistake is that all epoxies are waterproof. However, most epoxy are not recommended for long-term submersion such as uses for drain pipe. In addition, some epoxy are able to bond better to different materials.

2.6 HAND LAY-UP PROCESS

Hand layup is the simplest and oldest method used in open moulding method for the composite fabrication process. It is considered a low volume, labour intensive method that is especially suited for larger composites such as the aeroplane hull. The process begins with one side of the mould. The mould could either be a male or a female mould. Figure 2.1 show the comparison between the male and female mould. The male mould dimensions of the inside part and can be precisely controlled. The drawback of the male mould would be that the non-mould surface dimensions will be