THE STUDY OF IMPACT RESPONSE OF COMPOSITE MATERIAL

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Report submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor of Mechanical Engineering.

Faculty of Mechanical Engineering
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NOVEMBER 2008

STUDENT DECLARATION

I declare that this dissertation "The Study of Impact Response of Composite Material" is the result of my own except as cited in the references. This dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date :

To my beloved father and mother

Mr. Mohamad Saleh b Udin

Mdm. Alizah bt Silong

ACKNOWLEDGEMENT

In the praise of Almighty Allah, the Beneficent and Merciful-who showed the right path of righteousness and blessed me to get the strength to embark upon this task of peeping into the realms of facts and events.

First of all, I would to thank with heartfelt gratitude to my thesis supervisor, Dr Thet Thet Mon who has consistently spent her time helping me to create this valuable work and thank to her moral support that she gave me. Without her guide, I cannot achieve our target.

I also feel obliged to general, lecturers staff of Faculty of Mechanical Engineering and my fellow friends especially my co-supervisor Mr. Azmeer Azhari, Mr. Fahmi and Mr. Hazami, for extending their full cooperation and commitment to help me in order to finish my research.

Finally, I express my thanks and immeasurable gratitude for every kind of support that I have from my family, ”Thanks mak and ayah”, to my love “ Thanks for the support, dear”, friends especially all my classmates from section M17,”I love you bro”, during my work which otherwise might not have been possible undertaken by me. Thank you.

ABSTRACT

Composite materials have been increasingly used in automotive engineering, aerospace development, marine technology, electronic devices, and construction industries. This paper highlights a computational model to analyze the behavior of composite material subjected to impact load tensile load. General purposed commercial finite element code was employed to develop the computational model. Fiber glass reinforced composite, one of the commonly used structural composites, was chosen for the test material. Computational model was constructed 2-D axis-symmetric finite elements. Elastic-plastic material model was incorporated into the finite element modeling to reflect material purpose under impact load and relevant material properties were taken from the published report. In order to account for high strain rate effect, load was applied at the nodes of one end while the other end of the model was constrained. Linear Static Stress was then performed to predict deformation and damage zone. For comparison purpose, impact tensile test was carried out the load and the specimen size as close as possible to those used in computational model. Both computational and experimental results are found to be in good agreement in terms of damage size.

ABSTRAK

Bahan-bahan komposit semakin banyak digunakan dalam kejuruteraan automotif, pembangunan angkasa lepas, alat alat elektronik, dan industri pembinaan. Kertas kerja ini melebihkan kepada model pengkomputeran untuk menganalisi kelakuan bahan-bahan komposit setelah diasak dengan daya impak.Tujuan utama kod elemen finit komersial digunakan untuk membangunkan model pengkomputeran. Komposit diperkukuh dgn serat-kaca adalah bahan yang telah dipilih untuk menjadi bahan ujikaji. Model pengkomputeran telah dibina dengan finit elemen 2-D paksi-simetri. Bahan model elastik-plastik telah digandingkan ke dalam model elemen finit untuk mereflek respon bahan komposit di bawah beban impak dan ciri-ciri bahan komposit diperoleh dari laporan yang telah diumumkan. Dalam tujuan untuk mengira efek kadar tarikan tinggi,beban diletakkan pada nod-nod dan ditetapkan kedudukan pada nod-nod yang bersebelahan. Analisis tekanan statik selari telah dipertunjukkan untuk menganggar perubahan bentuk dan zon kerosakan.Untuk tujuan pembezaan, ujian impak tegangan telah dijalanka dengan beban dan saiz bahan ujian yang mempunyai saiz yang terdekat dengan saiz yang digunakan model pengkomputeran. Kedua-dua keputusan dari kaedah pengkomputeran dan eksperimen ditemui di dalam keadaan perjanjian yang baik dalam terma kawasan dan saiz kerosakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS

A	Area (in m^2)
ASTM	American Society of Testing and Materials
CSM	Chopped Strand Mat
DBTT	Ductile-Brittle Transition Temperature
E	Modulus of Elasticity (in Pa)
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Method
FRP	Fiber Reinforced Polymer
GRE	Glass Reinforced Epoxy
GRP	Glass Reinforced Polymer
IGES	Save format in Solidwork Software
L	Length (in meter)
m	Mass (in kg)
PDE	Partial Differential Equation
P_m	Equivalent Static Load (in N)
RTM	Resin Transfer Molding
T	Kinetic Energy
U	Strain Energy
v_0	Velocity (in m/s)
σ_m	Stress (in Pa)

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Composite materials (or composites for short) can be defined as engineered materials made from two or more constituent materials which contain significantly different physical or chemical properties and remain separate and distinct on a macroscopic level within the finished structure. There are two types of composite, the first one is short fiber reinforced polymer and the other one is continuous fiber reinforced polymer [2].

Glass fiber reinforced polymer or plastic is one of the example of composite material. Fiberglass is material made from extremely fine fibers of glass. The role of these fibers is as a reinforcement agent for polymer products. Fiber glass is widely used in electronic, marine and automotive industries [2].

With the increased application of glass fibre composite in dynamic situation , knowledge of impact strength of this material is becoming important. As such, considerable amount of research has devoted to study the strength of this composite under dynamic load using computational and experimental methods [1].

Among the computational method, finite element method (FEM) is a widely-used method due to its flexibility to model and analyze variety of engineering problems[4]. Some popular FE packages p to date are Algor Software, ANSYS, Dyna and many more.

Major advantage of FEM is we can reduce the cost of experimenting. Impact analysis is expensive whereas the material will be analyzed and it will be failed intentionally [3]. Another than that, the analysis is a time consuming process, by using FEA method we can save a lot of valuable time and reduced losses.

Based on the information and published journal found, the number of journal that related to the impact test of fiber glass is still low. The journals found are mostly research on other composite materials such as carbon fiber and so on. With this impact response test, it will give other researchers the new information on fiber glass characteristic.

1.2 PROBLEM STATEMENTS

Firstly, the study about fiber glass composite is one of enormous complexity. A single impact event can produce several different damage modes simultaneously. In glass fiber material the damages can hardly detect, so, it is important to identify the factor that contributes to the damages [5]. It would be very dangerous in some application such as automobiles and so on. Because of all these factors, impact response test will be carried out.

In addition, the other problem is to researchers cannot model easily the fiberglass in the FEA software [6, 7]. The value of the mechanical properties need to known unless the simulation cannot be done. It is important to get the correct result.

1.3 OBJECTIVES OF THE PROJECT

The project objectives are:

i. To develop computational model of response of fiber-glass composite under impact load using finite element method.

ii. To verify the computational model with impact experiment.

iii. To analyze the behavior of fiber-glass composite under various impact load using the above computational model.

1.4 SCOPE OF THE PROJECT

The scopes of this project are:

i. Analysis of fiber glass reinforced polymer subjected to impact using Finite element method (FEM) will be studied.

ii. Experimental result will be obtained from impact test in laboratory.

iii. FEM will be validated by experiment.

iv. Algor finite element code will be used to analyze the impact test virtually.

1.5 SUMMARY

This chapter is generally about background, problem statement, objectives of the project and scope of the project in order to achieve the objectives as mentioned.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The main purpose if this literature review is to get information about the project reference books, magazines, journals, technical papers and web sites. In this chapter, the information gathered from a variety of sources will be discussed.

2.2 COMPOSITE MATERIAL

Composite materials or composites for short are engineered materials made from two or more constituent materials as shown in Figure 2.1. Each one of them has significantly different physical or chemical properties. The combination of the materials can remain separate and distinct on a macroscopic level within the finished structure. These materials are widely used in automotive industries, boat making industries and so on [6].

Figure 2.1: Glass Fiber Reinforced Polymer

2.3 THE METHOD OF PRODUCING FIBER GLASS REINFORCED POLYMER

Generally, the reinforcing and matrix materials are combined, compacted and processed to undergo a melding or a blending event. After the melding event, the part shape is essentially set, although it can deform under certain process conditions.

For a thermo set polymeric matrix material, the melding event is a curing reaction that is initiated by the application of additional heat or chemical reactivity such as organic peroxide. For a thermoplastic polymeric matrix material, the melding event is solidification from the melted state. For a metal matrix material such as titanium foil, the melding event is a fusing at high pressure and a temperature near the melt point. In process of producing fiber glass reinforced polymer, there is several most popular method used in the industries [8].

2.3.1 Open Molding

Open molding is a process using a rigid, one sided which shapes only one surface of the panel. While the opposite surface is determined by the amount of material placed upon the lower mold. Reinforcement materials can be placed manually by human or robotically. For the examples of reinforcement agent are continuous fiber forms fashioned into textile constructions and chopped fiber. The matrix is generally a resin, and can be applied with a pressure roller, a spray device or manually. This process is generally done at ambient temperature and atmospheric pressure. Two variations of open molding are Hand Lay-up and Spray-up[8].

2.3.2 Vacuum Bag Molding

This process using a two-sided mold set that shapes both surfaces of the panel. On the lower side is a rigid mold and on the upper side is a flexible membrane or vacuum bag. The flexible membrane can be a reusable silicone material or an extruded polymer film [7]. Then, vacuum is applied to the mold cavity. This process can be performed at either ambient or elevated temperature with ambient atmospheric pressure acting upon the vacuum bag. Most economical way is using a venturi vacuum and air compressor or a vacuum pump.

2.3.3 Pressure Bag Molding

This process is related to vacuum bag molding in exactly the same way as it sounds. A solid female mold is used along with a flexible male mold. The reinforcement is place inside the female mold with just enough resin to allow the fabric to stick in place. A measured amount of resin is then liberally brushed indiscriminately into the mold and the mold is then clamped to a machine that contains the male flexible mold [8].

The flexible male membrane is then inflated with heated compressed air or possibly steam. The female mold can also be heated. Excess resin is forced out along with trapped air. Cycle times for a helmet bag molding machine vary from 20 to 45 minutes, but the finished shells require no further curing if the molds are heated.

2.3.4 Autoclave Molding

A process using a two-sided mold set that forms both surfaces of the panel. On the lower side is a rigid mold and on the upper side is a flexible membrane made from silicone or an extruded polymer film such as nylon. Reinforcement materials can be placed manually or robotically. They include continuous fiber forms fashioned into textile constructions. Most often, they are pre-impregnated with the resin in the form of prepreg fabrics or unidirectional tapes. In some instances, a resin film is placed upon the lower mold and dry reinforcement is placed above. The upper mold is installed and vacuum is applied to the mold cavity. The assembly is placed into an autoclave pressure vessel. This process is generally performed at both elevated pressure and elevated temperature. The use of elevated pressure facilitates a high fiber volume fraction and low void content for maximum structural efficiency.

2.3.5 Resin transfer molding (RTM)

A process using a two-sided mold set that forms both surfaces of the panel. The lower side is a rigid mold. The upper side can be a rigid or flexible mold. Flexible molds can be made from composite materials, silicone or extruded polymer films such as nylon. The two sides fit together to produce a mold cavity. The distinguishing feature of resin transfer molding is that the reinforcement materials are placed into this cavity and the mold set is closed prior to the introduction of matrix material.

Resin transfer molding includes numerous varieties which differ in the mechanics of how the resin is introduced to the reinforcement in the mold cavity. These variations include everything from vacuum infusion (see also resin infusion) to vacuum assisted resin transfer molding. This process can be performed at either ambient or elevated temperature.

2.4 The Definition of Fiber Glass

Fiberglass also called fiberglass and glass fiber is material made from extremely fine fibers of glass. It is used as a reinforcing agent for many polymer products. The resulting composite material, properly known as fiber-reinforced polymer (FRP) or glass-reinforced plastic (GRP), is called "fiberglass" in popular usage in the industries. Figure 2.2 shows an example of continuous fiber glass.

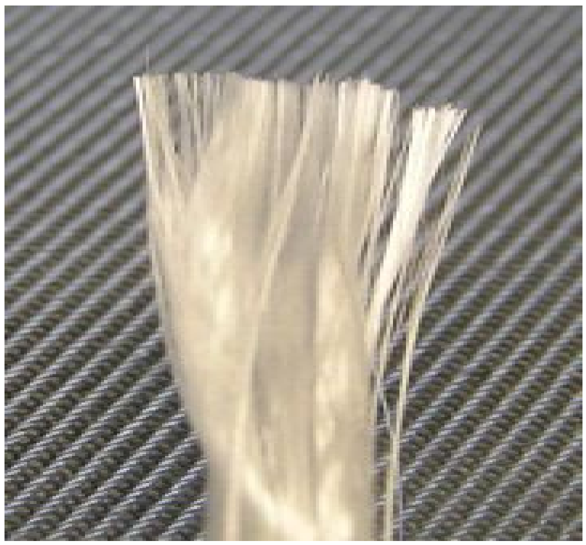

Figure 2.2: Continuous fiber glass

Glassmakers throughout history have experimented with glass fibers, but mass manufacture of fiberglass was only made possible with the advent of finer machine-tooling. In 1893, Edward Drummond Libbey exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers. What is commonly known as "fiberglass" today, however, was invented in 1938 by Russell Games Slayter of Owens-Corning as a material to be used as insulation. It is marketed under the trade name Fiberglas, ® which has become a generalized trademark.

2.4.1 Properties of Fiber Glass

Glass fibers are useful because of their high ratio of surface area to weight [1] However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity of 0.05 W/m-K.

Glass strengths are usually tested and reported for "virgin" fibers: those which have just been manufactured. The freshest, thinnest fibers are the strongest because the thinner fibers are more ductile. The more the surface is scratched, the less the resulting tenacity.[3] Because glass has an amorphous structure, its properties are the same along the fiber and across the fiber.[2] Humidity is an important factor in the tensile strength. Moisture is easily adsorbed, and can worsen microscopic cracks and surface defects, and lessen tenacity.

In contrast to carbon fiber, glass can undergo more elongation before it breaks.[2] The viscosity of the molten glass is very important for manufacturing success. During drawing (pulling of the glass to reduce fiber circumference) the viscosity should be relatively low. If it is too high the fiber will break during drawing, however if it is too low the glass will form droplets rather than drawing out into fiber.

2.5 GLASS REINFORCED PLASTIC (GRP)

Glass-reinforced plastic (GRP) is a composite material or fiber-reinforced plastic made of a plastic reinforced by fine fibers made of glass. For the example of graphite-reinforced plastic, the composite material is commonly referred to by the name of its reinforcing fibers (fiberglass). The plastic is thermosetting, most often polyester or vinylester, but other plastics, like epoxy (GRE), are also used. The glass is mostly in the form of chopped strand mat (CSM), but woven fabrics are also used.

As with many other composite materials (such as reinforced concrete), the two materials act together, each overcoming the deficits of the other. Whereas the plastic resins are strong in compressive loading and relatively weak in tensile strength, the glass fibers are very strong in tension but have no strength against compression. By combining the two materials together, GRP becomes a material that resists well both compressive and tensile forces. The two materials may be used uniformly or the glass may be specifically placed in those portions of the structure that will experience tensile loads.

2.6 APPLICATIONS OF GLASS POLYMER

GRP was developed in the UK during the Second World War as a replacement for the molded plywood used in aircraft radomes (GRP being transparent to microwaves). Its first main civilian application was for building of boats, where it gained acceptance in the 1950s. Its use has broadened to the automotive and sport equipment sectors, although its use there is being taken over by carbon fiber which weighs less per given volume and is stronger both by volume and by weight. GRP uses also include hot tubs, pipes for drinking water and sewers.

Advanced manufacturing techniques such as pre-pregs and fiber rovings extend the applications and the tensile strength possible with fiber-reinforced plastics.

GRP is also used in the telecommunications industry for shrouding the visual appearance of antennas, due to its RF permeability and low signal attenuation properties. It may also be used to shroud the visual appearance of other equipment where no signal permeability is required, such as equipment cabinets and steel support structures, due to the ease with which it can be molded, manufactured and painted to custom designs, to blend in with existing structures or brickwork. Other uses include sheet form made electrical insulators and other structural components commonly found in the power industries.

Glass reinforced plastics are also used in the house building market for the production of roofing laminate, door surrounds, over-door canopies, window canopies & dormers, chimneys, coping systems, heads with keystones and cills. The use of GRP for these applications provides for a much faster installation and due to the reduced weight manual handling issues are reduced. With the advent of high volume manufacturing processes it is possible to construct GRP brick effect panels which can be used in the construction of composite housing.

These panels can be constructed with the appropriate insulation which reduces heat loss. The fiber glasses are also widely used in piping such as underground as well as above. For example, the firewater systems, cooling water systems, drinking water systems and waste water systems or sewage systems.

2.7 IMPACT TESTS

Impact Analysis is a technique that helps researchers to think through the full impacts of a proposed change. As such, it is an essential part of the evaluation process for major decisions. It is very reliable to predict the damages that could occur [5].

Furthermore, it gives the ability to spot problems before, so that companies can develop contingency plans to avoid these issues smoothly. This can help the researchers to make the difference between well-controlled and seemingly-effortless project management. However there are of types for impact test.