



**UNIVERSITI PUTRA MALAYSIA**

***MECHANICAL AND BALLISTIC PROPERTIES OF COMPRESSED COIR-  
EPOXY COMPOSITE***

**MUNAIM ALI BIN OMAR BAKI**

**FK 2015 48**



**MECHANICAL AND BALLISTIC PROPERTIES OF COMPRESSED COIR-  
EPOXY COMPOSITE**

**By**

**MUNAIM ALI BIN OMAR BAKI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in  
Fulfilment of the Requirements for the Degree of Master of Science**

**May 2015**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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May 2015

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As aerospace industry has expanded with implementation of new technology, there is a need to reduce cost and weight for new aerospace products with safety as primary concern. Another consideration is product which could reduce environment pollution which related to implementation of Kyoto protocol. Current preference of materials can be consider less aiding in preserving green environment. The effect is deteriorating the environment from the event of material processing and production. Thus, the concept of green technology for aerospace product suit the matters being considered. Currently, green technology for aerospace product is suitable to be introduced in composite. One of the advantage of composite is lightweight if compared with metal-based product. To further reduce the weight of composite, it could be achieved with the introduction of green technology. One of the solution is to use natural fibre as one of constituent of composite. With the weight variation of natural fibre, coir fibre is one of natural fibre which low in weight and has the potential to withstand impact event. The impact resistance characteristic is important issue to be investigate when composite is operating at high speed condition. Since the literature about coir composite is lacking, further investigation of its properties and behaviour is required to evaluate impact resistance characteristic. In this study, the compressed coir-epoxy composite was fabricated using combination of hand lay-up method and compression machine. Then, compression effect of compressed coir-epoxy composite is experimentally investigated and evaluated by its mechanical properties. The ballistic impact properties was also evaluated from velocity of projectiles and energy absorption. For mechanical properties of 25 wt% coir fibre, the tensile modulus of elasticity is 17.42 MPa and flexural modulus is 74.02 MPa. For ballistic impact properties, the ballistic limit value of 1 layer specimen is about 88.25 m/s.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sains

## **SIFAT MEKANIKAL DAN BALISTIK BAGI KOMPOSIT SERAT KELAPA-EPOKSI TERMAMPAT**

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Sejak industri aeroangkasa telah berkembang seiring dengan pelaksanaan teknologi baru, terdapat keperluan untuk mengurangkan kos dan berat bagi produk baru aeroangkasa dengan keselamatan sebagai keutamaan. Pertimbangan lain pula adalah produk yang boleh mengurangkan pencemaran alam sekitar yang berkaitan dengan pelaksanaan protokol Kyoto. Bahan yang menjadi pilihan utama buat masa ini boleh dipertimbangkan kurang membantu dalam memelihara kehijauan alam sekitar. Kesan ini bertambah buruk kepada alam sekitar kerana hasil daripada pemprosesan dan pengeluaran bahan tersebut. Oleh itu, konsep teknologi hijau bagi produk aeroangkasa sesuai dengan perkara-perkara yang sedang dipertimbangkan. Pada masa ini, teknologi hijau bagi produk aeroangkasa sesuai untuk diperkenalkan pada komposit. Salah satu kelebihan komposit adalah ringan jika dibandingkan dengan produk berasaskan logam. Untuk mengurangkan lagi berat komposit, ia boleh dicapai dengan pengenalan teknologi hijau. Salah satu penyelesaian adalah dengan menggunakan gentian semula jadi sebagai salah satu bahagian komposit. Dengan variasi berat gentian semula jadi, gentian sabut kelapa adalah salah satu daripada gentian semula jadi yang rendah dalam berat dan mempunyai potensi untuk merintang keadaan hentaman. Ciri rintangan kepada hentaman adalah isu penting untuk disiasat apabila komposit beroperasi pada keadaan kelajuan tinggi. Sejak kesusasteraan mengenai komposit gentian sabut kelapa adalah kurang, siasatan lanjut mengenai sifat dan kelakuan diperlukan bagi menilai karakteristik rintangan kepada hentaman. Dalam kajian ini, komposit gentian sabut kelapa-epoksi termampat telah dibuat menggunakan gabungan kaedah *hand lay-up* dan mesin mampatan. Kemudian, kesan mampatan oleh komposit gentian sabut kelapa-epoksi termampat disiasat secara uji kaji dan dinilai dari sifat mekanikal. Ciri-ciri hentaman balistik juga dinilai dari halaju peluncur dan penyerapan tenaga. Sifat mekanikal bagi 25% berat gentian sabut kelapa, modulus tegangan bagi keanjalan adalah 17.42 MPa dan modulus lenturan adalah 74.02 MPa. Bagi sifat hentaman balistik, nilai had balistik 1 lapisan spesimen adalah kira-kira 88.25 m/s.

## ACKNOWLEDGEMENTS

### **Bismillahirrahmanirrahim,**

Alhamdulillah. Thanks to Allah SWT, the Almighty and Compassionate, blessings to our beloved prophet Muhammad S.A.W. and his followers. There is no deity except Him, the exalted in Might, the Wise. With His Might, permitted by Him an opportunity to complete this thesis.

First of all, I would like to express my deepest thanks to members of the team, Assoc. Prof. Dr. Azmin Shakrine Bin Mohd. Rafie who had guided and supported me in many ways, Assoc. Prof. Dr. Rizal Bin Zahari who offered the opportunity to venture further into the academic world. Without their aid and knowledge the thesis would have never accomplished.

Deepest thanks and appreciation to Supervisory Committee, technicians, staff, fellow students, authors, editors and others for their cooperation, encouragement, constructive suggestion and full support for the report completion, from the beginning till the end. Not to forget, thanks to all my family, friends, seniors and everyone, that contributed by supporting my work. It takes more than a person commitment and cooperation to make the best for my thesis. Thank You!

I certify that a Thesis Examination Committee has met on 29 May 2015 to conduct the final examination of Munaim Ali Bin Omar Baki on his thesis entitled “Mechanical and Ballistic Properties of Compressed Coir-Epoxy Composite” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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## LIST OF ABBREVIATIONS

GFRP  
CFRP  
NFC  
CSM

glass fibre-reinforced plastic  
carbon fibre-reinforced plastic  
natural fibre composite  
chopped strand mat



# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Aerospace industry has progressively expanded with implementation of new technology such as composite. Current composite technology greatly reduce the weight of parts. With less weight, the aircraft flight duration, range and performance will increase. At the early stage of composite introduction to aircraft, there are several feedbacks from the experts regarding safety of aircraft during operation. In addition, aerospace and aviation are highly regulated industry which focuses on safety. As for now, using composite in aircraft is acceptable and approved by the regulatory body. To progress further in the industry, researchers are looking if there is possibility to reduce the composite weight without impairing the safety. The weight reduction of composite could be achieved by altering the type of reinforcement. With rising awareness of environment condition, there is a need to create product which is environmental friendly. Current preferred materials in composite manufacturing such as glass fibre and carbon fibre contributes to pollution which could disrupt the progress of Kyoto protocol 2013-2020 (Monteiro et al., 2008). One of the efforts which may support the cause is to use natural fibre for making composite.

Natural fibres were always the subject of interest when there is a motivation to go green. Current green technology concept for composite is to combine natural fibre and polymeric resin. There is growing trend in the research society with respect to studies on natural fibre composite (NFC) whether at macroscopic and microscopic level. The point of studies may vary from wide application especially in engineering but as current progress of composite material is concerned, natural fibre to act as reliable reinforcement material is still in development process. From the literatures, it seems that green technology concept could be fit with composite. But, aerospace product which based on NFC will need to be investigated due to lack of literature. Before creating new product out of natural fibre, the properties of material must be considered. Comparing the physical and mechanical properties of natural fibre and commercial fibre, the coir fibre is among natural fibre that shows low density characteristic which is  $1.20 \text{ g/cm}^3$  (Beckwith, 2008). Details of the comparison of natural fibre and commercial fibre listed in Appendix A, Table A.1. Coir fibre is able to satisfy the required characteristic of composite material which further reduced in weight and environmental friendly.

Despite of natural fibre characteristic especially coir fibre which naturally low in weight and cost, there is a need to ensure that it is at least in line with safety requirement. Since aircraft is operating at high speed condition, the parts were exposed to impact event from many debris. Safety of parts could be determine from investigation of its impact resistance characteristic. Current studies of NFC shows that coir composite possessed decent impact resistance characteristic from low velocity impact test. As for high velocity impact test for coir composite, some researchers suggested that coir has the potential as an impact-worthy constituent in advanced aerospace material (Affandi et al., 2011). But, literature on high velocity impact test is very few and need to be further

investigated. Investigation of coir composite with random orientation will reveal its characteristic and significantly contributes to knowledge of NFC development. The expected achievement at the end of this study is to acknowledge the performance of coir composite to withstand high velocity impact and to act as a reliable composite material for advanced aerospace material.

## **1.2 Problem statement**

Current aerospace product such as panels were based on metal and high performance composite. Further improvement of aerospace product could be achieved with introduction of new composite. NFC could be the product which able to improve current aerospace composite. To create new product, testing of chosen material is important so that the properties and behaviour can be understand. Aerospace product which based on NFC will need to be tested and investigated due to lack of literature.

Coir composite is one of NFC that caught the attention of many researchers. Currently, knowledge and literature of coir composite is still very few. Another important matter is regarding coir fibre availability which highly abundant. The matter arise at certain region where consumption of coconut is high and it lead to problem of disposing the waste. Some of the waste was processed into mattress form. The idea of composite is one of the way to use coir fibre.

Since aerospace and aviation are highly regulated industry, safety has always be the top priority. The safety evaluation of NFC can be achieved by investigating its impact worthiness at high velocity region. From previous studies, it is suggested that coir composite has the potential to be impact-worthy constituent in advanced aerospace material. Ensuring good understanding of impact resistance is critical and decisive at design stage if coir composite to be implement during operation. In this study, coir composite will be evaluated by studying its mechanical and ballistic impact properties. Then, the findings in this study will increase the knowledge of coir composite and NFC.

## **1.3 Objectives of the study**

The specific objectives of this study are:

1. To determine the mechanical properties and ballistic impact properties of compressed coir-epoxy composite.
2. To investigate the potential of compressed coir-epoxy composite to withstand impact at high velocity.

#### **1.4 Scope of the study**

The analysis focuses on the matured brown coir fibre mat to act as reinforcement in composite which is physically like a panel after fabrication and its performance after sizing in accordance to material testing requirement. The procedure for determining mechanical properties including the geometry of specimen is according to ASTM D3039M-08 and ASTM D790-02. For determining ballistic impact properties, the specimen geometry selection of coir composite is 100mm (W) × 100m (L) which based on National Institute of Justice (NIJ). The average thickness 1 layer of specimens is about 3 mm. The ballistic impact tests are restricted to normal impact which excludes oblique impact. The projectiles used are blunt-nosed type. During the impact test, a rigid square steel frame with a circular type clamp holds the coir composite to the anvil. Damage or failure mode is complete penetration. Shock waves or stress waves occurred during impact of the projectile onto coir composite is neglected.

#### **1.5 Thesis layout**

This thesis contains five chapters. Chapter 1 presents the natural fibre composite issue and introduce one of the low weight natural fibre which is coir as potential constituent in aerospace composite material. This chapter also covers problem statement, objectives and limitations. Chapter 2 illustrates development of natural fibre composite, fabrication method, joining of composite, ballistic impact, evaluation of coir and ballistic test from other composite material. Chapter 3 describes theories, materials and experimental test. Chapter 4 discusses the result from mechanical test and ballistic impact test. Lastly, chapter 5 state the conclusion and recommendations for future works.

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