# THE EFFECT OF STRAIN RATES ON THE FRACTURE BEHAVIOUR OF BIOCOMPOSITE

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## DECLARATION

I declare that this project report entitled "The Effect od Strain Rates on the Fracture Behaviour of Biocomposite" is the result of my own work except as cited in the references

Signature : ..........................................

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Date : 27 JUNE 2016

**APPROVAL**

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

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# DEDICATION

To my beloved mother and father

## ABSTRACT

In this study, impact performance of biocomposites fabricated from pineapple leaf fibre (PALF) and polylactic (PLA) subjected to quasi-static indentation and low velocity impact loading were presented. In terms of fabrication of the biocomposites, the pineapple leaf fibre was pre-treated with sodium hydroxide with the aim to improve adhesion between the fibres and the matrix and the composite laminates were fabricated using hot compression moulding technique. The quasi static indentation was run by using an Instron 5585 model Universal Testing Machine at crosshead displacement rate of 1 mm/min and 2 mm/min. Meanwhile for dynamic loading condition, an Instron Dynatup model 9250 HV dropweight impact was used to a low velocity impact test at impact velocities of 1 m/s, 1.5 /s, 2 m/s, 2.5 m/s, 3 m/s, and 3.5 m/s. The impact response due to different velocity were investigated and the experimental observations were reported. From the results obtained from quasi static indentation test, it was observed that the deformation of the fibre have significant influence due to the crosshead displacement rate on PLA/PALF composite material. The result show that the maximum peak load, and maximum stress of 1 mm/min is higher compared to 2 mm/min. The corresponding damage for all the specimens are barely visible and limited to the contact loading radius. Meanwhile for dynamic behavior on biocomposites, the maximum load and total energy absorbed increase linearly with an increase of velocity. 2.5m/s velocity has higher maximum load and total absorbed energy compared to other velocity. This was attributed to the fibre wettability, alignment and location of the indenter effect which creates the cross-over points which act as stress distributor.

# *ABSTRAK*

*Dalam kajian ini, prestasi kesan biocomposites daripada serat daun nanas (PALF) dan polylactic (PLA) tertakluk kepada lekukan kuasi-statik dan kesan beban halaju rendah dibentangkan. Dari segi penghasilan biokomposit, serat daun nanas telah pra-dirawat dengan natrium hidroksida dengan tujuan untuk meningkatkan lekatan antara gentian dan matriks dan bahan komposit lamina komposit telah direka menggunakan teknik pengacuan mampatan panas. Lekukan statik seakan telah dijalankan dengan menggunakan Instron 5585 model Universal Testing Machine pada kadar kecepatan 1 mm / min dan 2 mm / min. Sementara itu, bagi keadaan pembebanan dinamik, model Instron Dynatup 9250 HV jatuhan beban kesan telah digunakan untuk ujian kesan halaju rendah pada halaju kesan 1 m / s, 1.5 / s, 2 m / s, 2.5 m / s, 3 m / s, dan 3.5 m / s. Sambutan kesan disebabkan halaju yang berbeza telah disiasat dan pemerhatian eksperimen dilaporkan. Daripada keputusan yang diperolehi daripada ujian lekukan statik kuasi, ia telah diperhatikan bahawa ubah bentuk gentian mempunyai pengaruh yang besar disebabkan oleh kadar kecepatan pada bahan komposit PLA / PALF. Menunjukkan keputusan yang beban maksimum puncak, dan tekanan maksimum 1 mm / min adalah lebih tinggi berbanding dengan 2 mm / min. Kerosakan yang sama untuk semua spesimen adalah hampir tidak kelihatan dan terhad kepada jejari hubungan beban. Sementara itu, bagi tingkah laku dinamik pada biocomposites, beban maksimum dan jumlah tenaga diserap peningkatan segaris dengan peningkatan halaju. Halaju 2.5 m / s mempunyai beban maksimum yang lebih tinggi dan jumlah tenaga yang diserap berbanding halaju lain. Ini adalah disebabkan oleh gentian kebolehbasahan, penjajaran dan lokasi kesan indenter yang mewujudkan mata sebaran yang bertindak sebagai pengedar tekanan*

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Secondly, I would like to thank my course mates for giving me their support, patience and encouragement. Finally, I would like to thank my family for their support.

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| | |
|---|---|
| PALF | Pineapple leaf fibre |
| PLA | Poly lactic acid |
| SEM | Scanning Electron Machine |

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# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

Over the last few decades, there is a widespread uses of composites as a substitute to conventional materials such as metal or steel in numerous applications, from structural and non-structural applications. In particular, polymer matrix composites have been the new material of choice for many reasons, i.e. lightweight, high performance and cost effectiveness (Kafi, Magniez & Fox, 2011). Composite can be classified into two distinct level. For first level, it is made of matrix constituent and can be divided into organic-matrix composite, metal-matrix composite and ceramic-matrix composite. Meanwhile, for second level which can be known as reinforcement consist of woven reinforcement, particulate reinforcement, and continuous fibre laminated composites. Fibres act as reinforcement because it will provide strength and stiffness in composite materials (Paul A. Fowler et. al)

However, there is a growing concern about the long term effect of using such synthetic materials, particularly in terms of the environmental aspect. These include the release of carbon footprint, sustainability of the non-renewable petroleum-based polymer materials as well as industrial and domestic waste as a result of high consumptions of the materials.

Therefore, there is a need to come out with more environmental-friendly material as a substitute to the synthetic petroleum-based polymer composites. One of the initiatives taken has been in developing the 'biocomposites" or natural fibre reinforced composites. In doing so, the industry can overcome disposal issue and promote recycling of the composite material (T. Gurunathan et. al 2015). Thus, a large amount of research has been dedicated to the use of natural fibre as substitute materials for synthetic fibres such as glass and carbon fibres. Furthermore, such materials also features advantageous characteristics such low cost, reliable strength and durability when handled and processed effectively. Natural fibres can be categorized into vegetables, animals, and mineral fibres. There are many type of natural fibre used in industry, such as bast fibre, leaf fibre, seed fibre, core fibreglass fibre, and all other types (wood and root).

Nowadays, there is vast applications of natural fibres-reinforced biocomposites in various industries such as automobiles, aerospace, packaging and building industries, where high load carrying capacity not required (Zini E, Scandola M., 2011). Since natural fibres has characteristic of high moisture absorption and highly anisotropic nature (Jawaid M, Abdul Khalil HPS, 2011), it has to be incorporated with thermoplastic (PHA and PLA) and thermosets (polyester, epoxy and phenol formaldehyde). Before that, fibres must undergoes surface modification techniques by chemical treatment to alter the hydroxyl (-OH) group and carbonyl (C=O) group so that it changes the polarity of fibres and the matrix (Huda MS, Drzal LT, Mohanty AK, Misra M. 2008).

## 1.2 PROBLEM STATEMENT

This research project aims to study the strain rate effects of the mechanical behaviour of bio-composite. The focus is to study the effect of different speed on the mechanical properties (i.e. quasi-static flexural compression and drop weight impact) of the biocomposites, which consists of a series of experimental work to characterize the material. To-date, very limited amount of research has been reported on the strain rate effects in the mechanical properties of the biocomposites. The important to the study of effect strain rates is that it can be used to replace metallic component of automotive applications. Since biocomposites has low weight and cheaper compared to metallic component, it will save the cost of production. Therefore, this research will focus on different test speed and loading rates of the biocomposites when subjected to (i) quasi-static testing such as compression test and (ii) dynamic loading via drop weight impact testing in the low-velocity range (less than 10 m/s).

## 1.3 OBJECTIVES

i) Fabrication of biocomposites using different fibre loading and pre-treatment process

ii) Mechanical characterization of the biocomposites with different strain rates via quasi-static and dynamic testing.

## 1.4 SCOPES

The scopes of the project are listed below:

i) Selection of materials and chemicals for the composite

ii) Fabrication of polylactic acid (PLA plain) and composite (short and long fibre).

iii) Mechanical properties of biocomposites in compression and drop weight impact test.

## 1.5 PLANNING AND EXECUTION

This project consists of various research activities. Table 1.0 and 1.1 gives the planning and execution of this research project for semester 1 (PSM1) and semester 2 (PSM2) respectively. The project began in week 1 and will be end on week 15. Basically, the project started with selection of the project title, followed by literature review of the project, design of experiment and conducting preliminary experimental work on the biocomposites including pre-treatment of the pineapple leaf fibre (PALF), fabrication of the biocomposites and preliminary testing on the samples including quasi static indentation test and low velocity impact test. Following this, the final year project report I and II (PSM I and II) is prepared. Finally, in week 15, the PSM II report will be submitted and an oral presentation will be presented at the end of the semester.

Table 1.1: Gantt chart for final year project 1.

| Weeks / Research activities | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Literature review | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Design of experiment | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | |
| Fabrication treated | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Characterization / testing | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | |
| Physical-density of composite | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | |
| Mechanical testing | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | |
| Data analysis | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | |
| Report writing | | | | | | | | | | | | | | ■ | ■ |

Table 1.2: Gantt chart for final year project 1.

| Weeks / Research activities | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design of experiment | | | | | | | | | | | | | | | |
| Fabrication treated | | | | | | | | | | | | | | | |
| PLA (plain) | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | |
| Composites (long fiber) | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | |
| Characterization testing | | | | | | | | | | ■ | ■ | ■ | | | |
| Mechanical testing | | | | | | | | | | ■ | ■ | ■ | | | |
| Data analysis | | | | | | | | | | | | | ■ | ■ | |
| Report writing | | | | | | | | | | | | | ■ | ■ | |
| Report submission | | | | | | | | | | | | | | | ■ |
| PSM seminar 2 | | | | | | | | | | | | | | | ■ |

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

This chapter will cover about the composite materials, polymer matrix composites, what is biocomposites and the fracture behaviour of biocomposites.

## 2.2 COMPOSITE MATERIALS

A composite is material that is made up of two or more different materials or elements. It needs to combine with other element which contain a continuous matrix to ensure an array form is stronger and stiffer reinforcement constituent (Daniel B. Miracle & Steven L. Donaldson, 2003). The combination of this element in term of strength to resistance to heat is much better than the elements alone (Martin Alberto Masuelli, 2013). Basically, composite is made up of matrix or binder which hold the fibres in place. The combination of fibre or fragments of the other materials can produce reinforcement. For an example for composite material was fiberglass. The matrix for fiberglass is plastic and the reinforcement is glass which in form of fine thread and often woven into sort of cloth.

As a matter of fact composite is light as well as strong is the reason why it is widely used in any industry. It also can be molded into any complex shape at quite low cost and has good durability due to long life span of composite structure. Hence, it require low maintenance. Composite can be divided into type of fibre or matrix used. If it based on fibre, it can be classified as continuous (long) fibre reinforced composite and short fibre reinforced composite. On the other hand for matrix, it can be classified into three groups; metal matrix composites, ceramic matrix composites, and polymer matrix composites respectively.

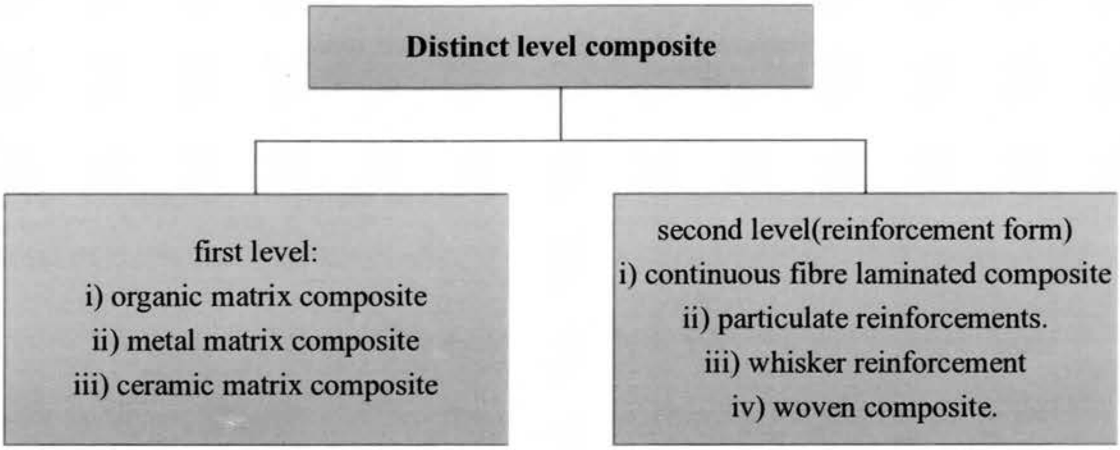


Figure 2.1: Distinct level composite. (Miracle & Donaldson, 2003)

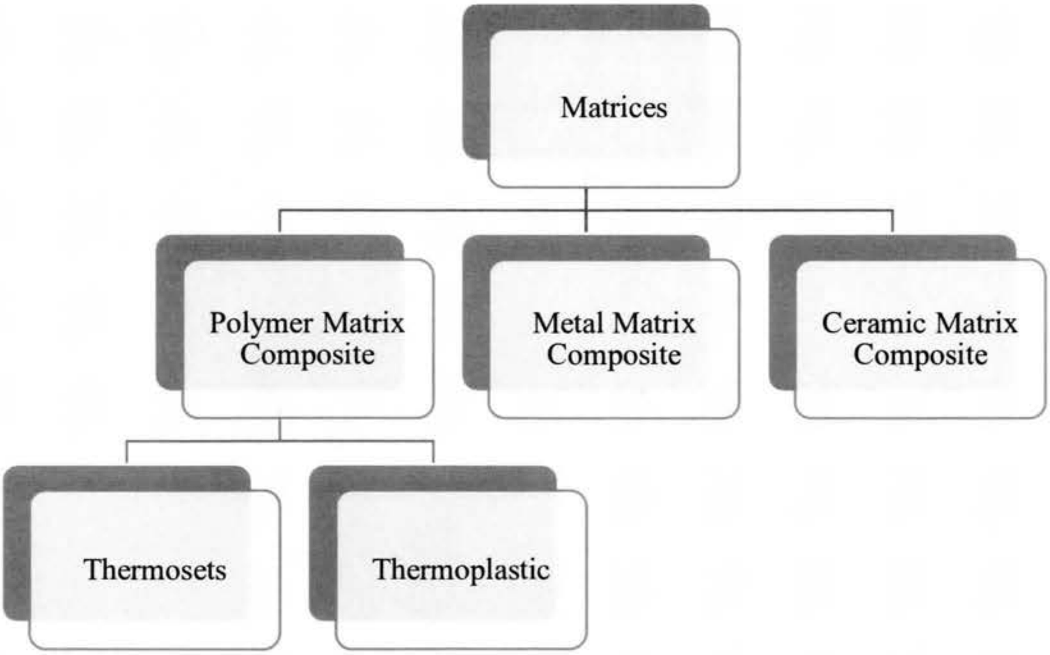


Figure 2.2: Classification of composite material respect to the matrix constituent (Jones,1998).

## 2.3 POLYMER MATRIX COMPOSITES

Polymer matrix composites (PMCs) are comprised of a variety of short or continuous fibres bound together by an organic polymer matrix. The reinforcement of PMC can provide high strength and stiffness. The matrix phases of PMC can be classified into thermoset and thermoplastic. Thermoset is consist of polypropylene (PP), polyethylene (PE), polystyrene (PS), and polyvinyl chloride (PVC). On the other hand, thermoplastic is consist of epoxy resin, polyester, phenol formaldehyde, and vinyl ester (Phillips, 1989)

Basically, the viscosity of thermoset resin is low. But due to these resins undergo chemical reaction called curing process that crosslink the polymer chains and thus connect the entire matrix together in a three-dimensional network. Due to the fact that, it tend to have high dimensional stability, high temperature resistance, and good resistance to solvent (Masuelli, 2013).

Thermoplastic resin or can be known as engineering plastic is undergo reversible process by simply reheating it and the resin can be formed any desirable shape. Eventhough it have high temperature strength, it more resistant to cracking and impact damage (Masuelli, 2013).

Table 2.1: Comparison of general characteristics of thermosets and thermoplastics matrices. (Phillips,1989)

| Resin type | Process temperature | Process time | Use temperature | Solvent resistance | Toughness |
|---|---|---|---|---|---|
| Thermoset | Low | High | High | High | Low |
| Toughened thermoset<br>Lightly crosslinked thermoplastic | ↑ | ↓ | ↓ | ↓ | ↑ |
| Thermoplastic | High | Low | Low | Low | High |

## 2.4 BIOCOMPOSITES

Biocomposites is a composite material formed by a matrix (resin) and a reinforcement of natural fibres. It is the combination of PALF with bio based matrices and can be referred as natural fibres reinforced composites. There are two type of matrix phase, which are renewable and non-renewable. For matrices renewable, the sources come from the vegetables oils and starch. Alternatively, for recycled thermoplastics such as polyethylene, polypropylene, polystyrene, and polyvinyl chloride or virgin thermosets such as unsaturated polyesters, phenol formaldehyde, isocyanates and epoxies. In terms on reinforcements, it is plant fibres which consist of flax, hemp, cotton, bamboo, jutes and others (Fowler,Hughes, & Elias, 2006).