UNIVERSITI PUTRA MALAYSIA

MALAYSIAN PINEAPPLE (YANKEE) LEAF FIBER COMPOSITES DAMAGE INVESTIGATION USING NON-DESTRUCTIVE TECHNIQUES

MUHAMMAD IMRAN BIN NAJEEB

FK 2022 84

MALAYSIAN PINEAPPLE (YANKEE) LEAF FIBER COMPOSITES DAMAGE INVESTIGATION USING NON-DESTRUCTIVE TECHNIQUES

By

MUHAMMAD IMRAN BIN NAJEEB

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

April 2022

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

MALAYSIAN PINEAPPLE (YANKEE) LEAF FIBER COMPOSITES DAMAGE INVESTIGATION USING NON-DESTRUCTIVE TECHNIQUES

By

MUHAMMAD IMRAN BIN NAJEEB

April 2022

Chair : **Prof. Ir. Ts. Mohamed Thariq Bin Haji Hameed Sultan, PhD, PEng, CEng, PTech**
Faculty : **Engineering**

In Malaysia, there are abundant agricultural wastes generated from 15,000 hectares of pineapple plantation. The current study focuses on fully utilising the pineapple leaf fiber (PALF) extracted from the Yankee variant sourced from a plantation in Telok Panglima Garang as a reinforcement material in composite, hence converting the agriculture waste into a potentially useful and sustainable resource. The physical, chemical, thermal, as well as mechanical properties of untreated and silane treated PALF were investigated in this study. Three types of composites, pineapple leaf fiber composite (P), pineapple leaf fiber/glass fiber composite (GPG), glass fiber composite (GGGG) were evaluated for low velocity impact (LVI) properties. Visual inspection, computed tomography (CT) scan, digital detector array (DDA) radiography and infrared (IR) thermography techniques were applied to detect the damage evolution of the impacted composites. The broad peaks at 1317.81 and 1100 cm-1 of the Attenuated Total Reflectance (ATR) analytical graph indicate silane compound bonding with PALF. In addition, there are no significant changes to the configuration of the silane's treated PALF due to its crystallinity. Treated PALF displays thermal stability improvement by 5.9%, with degradation occurring at the temperature of 360°C. The surface area of the treated PALF displays broader peaks, indicating greater surface roughness compared to untreated PALF. The tensile strength test on single fiber shows PALF display highest tensile strength when treated for three hours compared to one and five hours respectively. The untreated PALF composite (UT-PALFC) possess 7.1% higher storage modulus than treated PALF composite (T-PALFC), indicating untreated fiber attribute to high dynamic property in composite. Meanwhile, the thermomechanical analysis shows the sequence of linear coefficient of thermal expansion (CTE) of the treated and untreated fiber composites as follows: T-PALFC > Neat epoxy > UT-PALFC. On the other hand, the low impact analysis shows three varying impact energy ranges at 1-2J, 2-9J and 9-12J for P, GPG, GGGG respectively. The addition of glass fiber in GPG composites further delayed

damage initiation time and propagation throughout the sample by about 8.5% compared to GGGG composite as shown in LVI. Visual inspections as captured in photographic images show different damage modes in the presence of woven fiberglass mat in GPG compared to P. CT-scan images show significant cross-section cracks on impacted GPG and GGGG composites compared to P. Compared to IR thermography technique that only shows the general area of damage, the DDA radiography captures significant surface damages on impacted P, GPG and GGGG composites. For example, the DDA captures significant damage in GPG at 9J with an area of 84% less than IR thermography. However, CT-scan, DDA radiography and IR thermography failed to capture occurrence of surface delamination as observed in visual inspection. This shows that the NDT techniques used in this research need to be complimented with other tools for clearer interpretation of the extent impacted damage in composite. Overall, the newly developed hybrid GPG composite shows great potential in structural applications such as drone because of its favourable impact resistance properties.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN TERHADAP KEROSAKAN KOMPOSIT SERAT DAUN NANAS MALAYSIA (YANKEE) MENGGUNAKAN TEKNIK UJIAN TANPA MUSNAH

Oleh

MUHAMMAD IMRAN BIN NAJEEB

April 2022

Pengerusi : Prof. Ir. Ts. Mohamed Thariq Bin Haji Hameed Sultan, PhD, PEng, CEng, PTech
Fakulti : Kejuruteraan

Di Malaysia, terdapat lambakan sisa pertanian yang dihasilkan daripada 15,000 hektar ladang nanas. Penyelidikan ini tertumpu kepada penggunaan serat daun nanas (PALF) daripada variasi Yankee yang diperoleh dari sebuah ladang di Telok Panglima Garang, Selangor. PALF dijadikan sebagai bahan tetulang di dalam pembuatan komposit, dengan ini menjurus ke arah menukarkan sisa pertanian kepada sumber yang berguna dan mampan. Sifat fizikal, kimia, haba dan mekanikal PALF yang tidak dirawat dan yang dirawat dengan silane telah disiasat di dalam kajian ini. Kesan impak halaju rendah (LVI) terhadap tiga jenis komposit iaitu komposit serat daun nanas (P), komposit serat daun nanas/serat kaca (GPG), komposit serat kaca (GGGG) telah diuji. Kerosakan LVI terhadap pelbagai komposit tersebut telah dinilai menggunakan teknik-teknik visual, imbasan komputer tomografi (CT), radiografi pengesan jajaran digital (DDA) dan termografi infra merah (IR). Ikatan kimia antara silane dengan PALF di kesan pada puncak 1317.81 dan 1100 cm-1 di dalam graf analisis jumlah pemantulan terkurang (ATR). Di samping itu, tiada perubahan ketara terhadap konfigurasi PALF yang dirawat dengan silane disebabkan sifat kehablurannya. PALF yang dirawat memaparkan peningkatan kestabilan terma sebanyak 5.9%, dan degradasi berlaku pada suhu 360°C. Luas permukaan PALF yang dirawat terpapar dalam bentuk cerun yang lebih melandai, menunjukkan kewujudan permukaan yang lebih kasar berbanding PALF yang tidak dirawat. Ujian kekuatan tegangan terhadap serat tunggal menunjukkan PALF memaparkan kekuatan tegangan tertinggi apabila dirawat selama tiga jam berbanding dengan serat yang dirawat selama satu dan lima jam. Komposit PALF yang tidak dirawat (UT-PALFC) mempunyai modulus penyimpanan 7.1% lebih tinggi berbanding komposit PALF yang dirawat (T-PALFC), ini menunjukkan serat yang tidak dirawat menyumbang kepada kepada sifat dinamik yang tinggi di dalam komposit. Sementara itu, analisis termomekanikal menunjukkan jujukan pekali linear pengembangan terma (CTE) bagi komposit serat yang dirawat dan tidak

dirawat seperti berikut: T-PALFC > Epoksi > UT-PALFC. Analisa kesan impak halaju rendah terhadap tiga komposit tersebut dijalankan dengan menggunakan julat tenaga yang berbeza-beza iaitu 1-2J, 2-9J dan 9-12J untuk P, GPG, dan GGGG masing-masing. Penambahan serat kaca di dalam komposit GPG melambatkan lagi masa permulaan kerosakan dan penyebarannya ke seluruh sampel sebanyak kira-kira 8.5% berbanding dengan komposit GGGG seperti yang ditunjukkan di dalam analisis LVI. Pemeriksaan visual seperti yang dipapar dalam imej fotografi menunjukkan mod kerosakan yang berbeza dengan kewujudan kain serat kaca tenunan dalam GPG berbanding dengan P. Imej keratan rentas menggunakan imbasan CT menunjukkan kewujudan retakan yang lebih ketara di dalam komposit GPG dan GGGG berbanding dengan P. Berbanding dengan teknik termografi IR yang hanya menunjukkan kawasan kerosakan secara umum, alat radiografi DDA membuktikan kerosakan yang ketara pada permukaan komposit P, GPG dan GGGG selepas hentaman halaju rendah. Sebagai contoh, ujian DDA menunjukkan kerosakan yang ketara terhadap GPG pada 9J dengan keluasan kawasan kerosakan sebanyak 84% lebih rendah berbanding yang dikesan menggunakan teknik termografi IR. Walaubagaimanapun, imbasan CT, radiografi DDA dan termografi IR gagal mengesan ketidaksamaan pada permukaan seperti yang diperhatikan di dalam pemeriksaan visual. Ini menunjukkan bahawa teknik NDT yang digunakan di dalam penyelidikan ini perlu digandingkan dengan peralatan-peralatan lain untuk memberi tafsiran yang lebih jelas terhadap kerosakan yang berlaku kepada komposit yang terjejas. Secara keseluruhannya, komposit hibrid GPG yang baru dibangunkan menunjukkan potensi yang besar di dalam aplikasi struktur seperti dron memandangkan ianya menunjukkan daya ketahanan rintangan yang baik terhadap impak.

ACKNOWLEDGEMENTS

Firstly, I hereby record heartfelt gratitude to my supervisor Prof. Ir. Ts. Dr. Mohamed Thariq Bin Haji Hameed Sultan for rendering continuous support and guidance throughout my studies. I would also like to express my immense appreciation to my Japanese supervisor Assoc. Prof. Yoshito Ando and fellow laboratory mates for their kind assistance and guidance during my Japan Student Services Organization (JASSO) internship program at Kyushu Institute of Technology in Japan from January 7, 2019 to March 31, 2019.

Thank you very much Dr. Siti Madiha Muhammad Amir who was my external supervisor, for your friendly supervision and dedication which motivate me to give my best efforts throughout the research work at Leading Edge Non Destructive Testing Technology Group (LENDT), Industrial Technology Division, Malaysian Nuclear Agency, Selangor.

I am deeply grateful to Dr. Ain Umaira Md Shah, Dr. Mohammad Jawaid, Dr. Ahmad Hamdan Ariffin, Dr. Adi Azriff Bin Basri, Prof. Ir. Ts. Dr. Abd. Rahim Bin Abu Talib, and among many others, who have assisted me directly or indirectly throughout my research project. Their guidance, knowledge-sharing and valuable feedback were of great assistance during compilation and preparation of this study. I am also grateful to the local community, especially the farmers in Telok Panglima Garang, Selangor for giving their full cooperation and assistance in supplying the pineapple leaf for the research. Finally, I would like to thank my beloved mother, father, brother, sister and aunts for their kind support throughout this journey.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Mohamed Thariq bin Haji Hameed Sultan, PhD, CEng, PEng, PTech
Professor, Ir. Ts.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Abd. Rahim bin Abu Talib, PhD
Professor, Ir. Ts.
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Adi Azriff bin Basri, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Mohammad Jawaid, PhD
Research Fellow
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF,PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 August 2022

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research and the writing of this thesis were done under our supervision;
- supervisory responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2015-2016) are adhered to.

Signature: ______________________________

Name of Chairman of Supervisory Committee: ______________________________

Signature: ______________________________

Name of Member of Supervisory Committee: ______________________________

Signature: ______________________________

Name of Member of Supervisory Committee: ______________________________

Signature: ______________________________

Name of Member of Supervisory Committee: ______________________________

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

UPM	Universiti Putra Malaysia
° C	Degree celsius
µg	Microgram
AC	Ananas Comosus
ASTM	ASTM American Society for Testing and Materials
At%	Atomic percentage
ATR	Attenuated Total Reflection
C	Carbon (chemical element)
CTE	Coefficient of thermal expansion
DDA	Digital Detector Array
DMA	Dynamic Mechanical Analysis
DTG	Derivative Thermogravimetry
EDX	Energy-dispersive X-ray
GGGG	Four layer woven glass fiber epoxy composite cure at room temperature
GPG	Two layer of woven glass fiber and 5wt% pineapple leaf fiber hybrid epoxy composite cure at room temperature
H	Hydrogen (chemical element)
IR	Infrared
J	Joule (unit of energy)
K	Potassium (chemical element)
m	Meter (unit of length)
mm	Milimeter
MPa	Megapascal
N	Nitrogen (chemical element)

NFPC	Natural fiber polymer composite
NDT	Non-Destructive Testing
O	Oxygen (chemical element)
P	10wt% pineapple leaf fiber epoxy composite cure at room temperature
Pa	Pascal (unit of pressure)
PALF	Pineapple leaf fiber
SEM	Scanning Electron Microscopy
TRIZ	Theory of Inventive Problem Solving
TG	Thermogravimetric
TGA	Thermogravimetric Analysis
T-PALFC	10wt% treated pineapple leaf fiber epoxy composite cure using hot press
UT-PALFC	10wt% pineapple leaf fiber epoxy composite cure using hot press
Wt%	Weightage percentage
XRD	X-Ray Diffractor

CHAPTER 1

INTRODUCTION

This chapter outlines the research background, the introduction of natural fiber and its composites, research problem statement, objectives, research questions and scopes of the study.

1.1 Background

Pineapple (*Ananas comosus (L.) Merr.)* an exotic plant of South American origin is currently a much treasured commercial crop in Malaysia. The Portuguese colonials introduced the pineapple plant to Malaya (now known as Malaysia) in the 16th century, and tapped into its commercial viability. Malaysia eventually became one of the main global exporters of pineapple fruit, and stands to be a leading player in the sector if it succeeds in tapping into the commercial viability of every part of the plant from its roots to shoots; hence reducing wastage and promoting sustainability. The height and width of a typical mature pineapple plant range between 1m - 2m. The main morphological structures of a pineapple plant include crown, fruit, leaf, aerial sucker and roots, as shown in Figure 1.1.

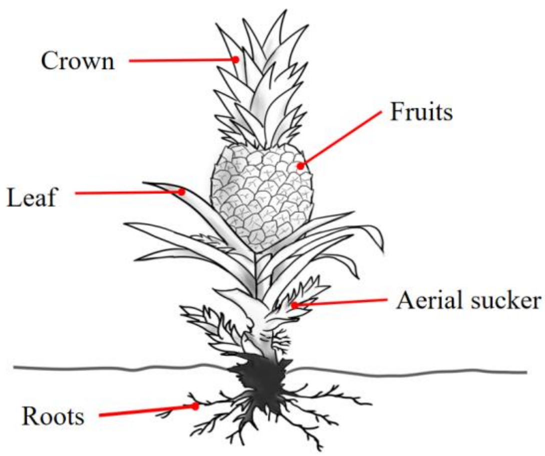

Figure 1.1: Pineapple plant morphological structure

Pineapple plantations are found in almost all the states in Malaysia, with Johor recording the largest total area (8639 hectares), followed by Sarawak (1780 hectares) and Pahang (1100 hectares) in the year 2018 (Lembaga Perindustrian Nanas Malaysia, 2018), as in Figure 1.2

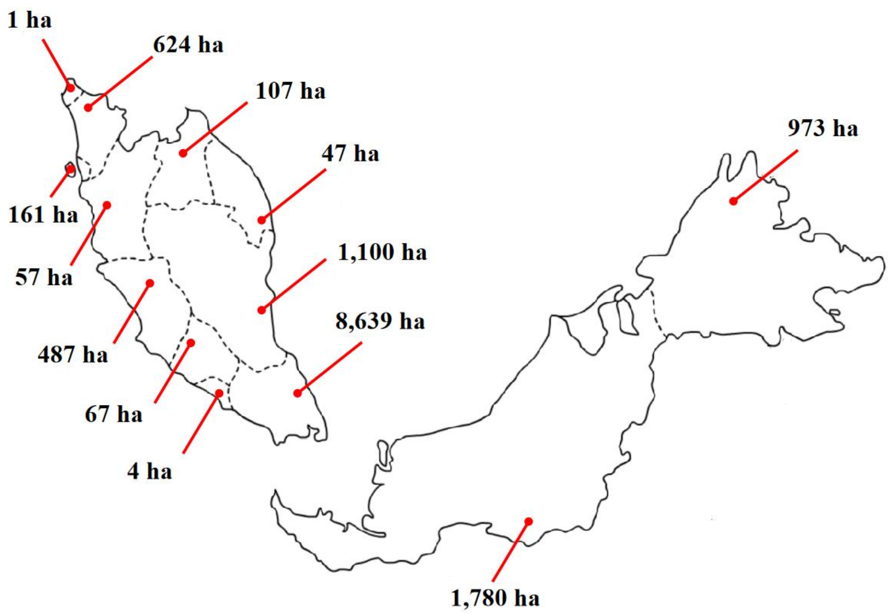

Figure 1.2: Pineapple plantation area across Malaysia

Data from the Jabatan Pertanian Malaysia plant varieties registry indicates at least 12 pineapple plants varieties are grown in Malaysia. Table 1.1 shows a list of commercially grown pineapple varieties (Lembaga Perindustrian Nanas Malaysia, 2021; Lembaga Perindustrian Nanas Malaysia - Negeri Kedah/Perlis, 2021). Among all the pineapple variants grown in Malaysia, the Yankee variant posses the longest leaf. The sweet-tasting fruit is aptly nicknamed “Sweet Selangor”, as this variant is widely grown in the state, including Telok Panglima Garang in the district of Kuala Langat. The light geen-coloured tapered shaped fruit of the Yankee variant bears between 100 and 120 diagonally positioned eye dots, and weighs between 1kg and 2.1kg each shown in Figure 1.3. This particular plant variant produces juicy and sweet-tasting fruits, hence attributing to its high demand in the local market.

The Malaysian authorities are supportive of the pineapple industry development, and have incorporated it as part of the national agenda as outlined in the 12th Malaysian Plan (RMK12). This sector can potentially grow to much greater heights if relevant parties, including researchers and industry players, tapped into the commercial viability of every part of the plant from roots to shoots.

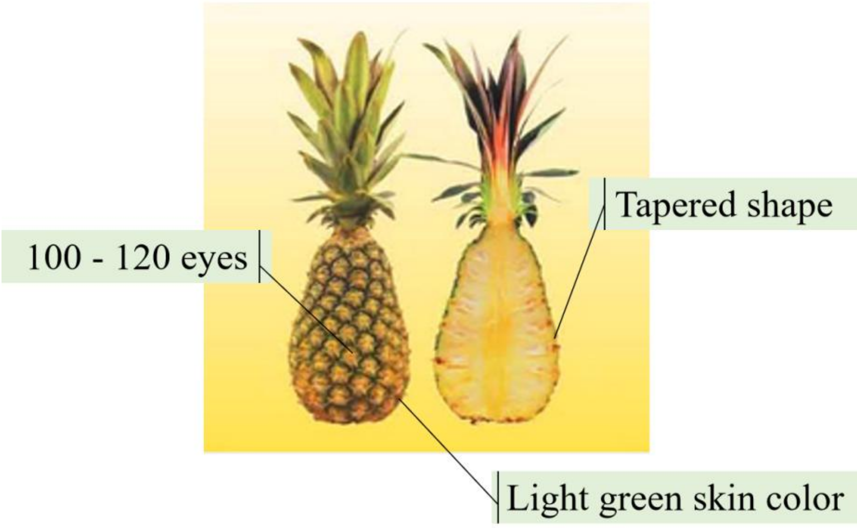

Figure 1.3: Yankee pineapple fruit (Lembaga Perindustrian Nanas Malaysia, 2018)

Table 1.1: Pineapple variety in market

Pineapple Variety	Registration code	Category
Moris	AC 1	Queen
Sarawak	AC 2	Cayenne
Gandul	AC 3	Spanish
Maspine	AC 4	Hybrid
Josapine	AC 5	Hybrid
Yankee	AC 6	Queen

Table 1.1: Continued

Pineapple Variety	Registration code	Category
Moris Gajah	AC 7	Queen
N36	AC 8	Hybrid
MD2	AC 9	Hybrid
View of Sunset	AC 10	-
Madu Kaca	AC 11	Cayenne
Keningau Diamond	AC 12	Cayenne

The harvesting season for pineapple plants can differ, depending on the variants. Generally, the harvesting period varies from 12 to 24 months. During harvesting, the pineapple stem is cut just below the fruit using gardening shears. The fruits are valued according to variant and size, while the rest of the plant parts are generally disposed of as waste. The leaf is rich in fiber compared to the other parts of the pineapple plant. The fibers can be extracted using various processes including manual scraping, retting or degumming, and application of mechanical instruments. In some cases, the combination of multiple methods are required to extract the fibers.

The application of fiber in the fabric production sector has long been established in the textile industry. In the Philippines, fabric made of woven pineapple leaf fibers are used to make traditional clothes as well as high-end fashionable attire (Richard, 2020). A United Kingdom-based company, uses pineapple leaf fiber as a base material for its leather products (Ananas Anam - About Us, n.d.). These examples proved the fact that pineapple fibers are in high demand in such high-end revenue-generating industries.

The interest in using plant fibers in composites for structural application has been growing in recent years. For example, automotive giant Ford Motor utilises rice husk, wheat straw, and many other renewable resources as reinforcement material for its car components (Austin, 2017). On average, the total weight of bio-based or renewable material content in Ford cars varies between 9–18 kilogrammes. Porsche had since 2019 been utilising natural fiber mix sourced primarily from renewable raw materials to make its 718 Cayman GT4 Clubsport MR’s double door and rear wing (Racing cars with body parts made from renewable raw materials, 2020; Bio-composites for cars, n.d).

Innovation in natural fiber-based composites is made possible due to the growing database of characterisation of natural fibers and their structural properties in polymers. Such data is useful for ongoing research and development in the search for fiber composites with desired characteristics and strength in primary and secondary structure applications.

1.2 Problem Statement

In Telok Panglima Garang, Selangor, the existing practice of burning and disposing of agricultural waste in pineapple plantations poses a serious environmental concern. Some farmers are unaware that they can swap the agriculture waste for cash if they can find the right stakeholders banking on commercially viable wastes. Disposing the fiber-rich pineapple leaves as agricultural wastes equals loss of additional earning for farmers.

Unfortunately the interest in extracting pineapple leaf fibers is generally lacking because of the tedious and inefficient extraction process using existing machines. Additional processes are required, as the fibers extracted from the leaves are irregular in size and are not fine enough. The entire process is time-consuming and labour-intensive, rendering it inefficient. Therefore, it is critical to make the necessary improvisation to the existing machine to enhance productivity.

The great potentials of pineapple leaf fibers in diverse applications ranging from craft to advanced material in the composite applications are well documented in literature. The utilisation of renewable resources in various applications is fast gaining traction globally, as the trend is shifting in favour of environment-friendly products, particularly agro-based products. The newly discovered fiber extracted from the Yankee variant pineapple leaf warrants the need to further analyse its physical, mechanical and thermal properties (Shah, 2018). Further investigations are critical because chemical compositions differ from one variant to another (Faruk et al. 2012).

Fibers in their natural form are known to exhibit poor interfacial bonding in a polymer matrix. Previous studies have shown that surface treatment of natural fiber is essential to enhance its bonding with the polymer matrix (Sahu & Gupta 2020). However, the effect of the surface treatment on the fiber and composite varied, depending on the type of chemical used and the characteristics of the fiber (Sood & Dwivedi 2018). Therefore it is vital to carry out investigations into the compatibility of the fiber post chemical treatment by carrying out tests to ascertain its chemical, mechanical and thermal properties.

Materials are vulnerable to impact in any applications, especially in composite applications. Impact damage can adversely affect the performance and compromise the reliability of composite materials. Therefore, it is critical to assess post impact properties of composites. Impact damage can occur either during in-service applications or handling during the manufacturing process. Most studies showed impact resistance of composites are further enhanced when plant fibers are hybridised with a synthetic fibers (Chapman & Dhakal, 2019; Sarasini et al., 2013).

Furthermore, it is difficult to detect composite damage in natural fiber because of its non-homogeneous nature. It is even more challenging to detect and analyse the damage where natural fibers are used as composite reinforcement. This is attributable to the inconsistent properties of natural fibers due to age, geographical location and climate conditions (Sahu & Gupta 2020). In-depth investigations using various non-destructive testing (NDT) applications are needed to ascertain compatibility of composites post impact.

Currently there is no available literature focusing on damage characterisation of composites subjected to low-velocity impact, indicating a gap found in this area of research. Hence, this research focuses on the characterisation of Malaysian pineapple (Yankee) leaf fiber composites and evaluating composite damages post low-velocity impact aimed at establishing compatibility of such composites in engineering applications, including in making light-weight drone structures.

1.3 Research Objectives

The main objective of this research work is to study the low-velocity impact properties of pineapple leaf fiber composites from the Yankee variant and to evaluate the damage of the impacted composites using non-destructive testing (NDT). To address the main objective, several specific objectives were conducted as follows:

i. To carry out pioneering evaluation into the properties of pineapple leaf fiber from Yankee variant.

ii. To investigate the effect of variable silane treatment hours on the physical, chemical, thermal and mechanical properties of pineapple leaf fiber.

iii. To determine the flexural, dynamic and thermo-mechanical properties of both silane-treated and untreated pineapple leaf fiber composites.

iv. To carry out a novel study on the damage propagation and properties of Yankee pineapple leaf fiber subjected to low velocity impact using NDT techniques.

1.4 Research Scope

The research scope in this study is listed as follows, stating the limitations and boundaries:

i. The design process approach in developing only the improvised machine blade through the Theory of Inventive Problem-solving (TRIZ) method and computational software of ANSYS Explicit Dynamics.

ii. The detailed machine blade design is not disclosed in the thesis because patent application is in progress at material time.

iii. The pineapple leaf fiber was sourced from the Yankee variant grown in Telok Panglima Garang, Selangor.

1.5 Thesis Organisation

This thesis is divided into five chapters, detailing research of pineapple leaf fiber composite using Malaysian Yankee variant pineapple plant.

i. Chapter 1 outlines the research background, introduction of natural fiber and composites, research problem statement, objectives, questions and scopes.

ii. Chapter 2 focuses on literature review on fiber extractor machines, TRIZ methodology, and finite element analysis. This chapter also presents previous studies on the properties of natural fibers and pineapple leaf fiber composite; and summary of non-destructive evaluation techniques applied on composites ii.to assess post impact characteristics.

iii. Chapter 3 details the entire process applied in this research work.

iv. Chapter 4 presents critical discussions based on research findings in the current study.

v. Chapter 5 presents specific conclusions drawn for each objective, summary of the overall findings, and suggestions for improvement in future research.

REFERENCES

A kind of full-automatic pineapple leaf fiber extractor. N.d. Retreived from https://patents.google.com/patent/CN207210580U/en?oq=CN201720921937U+20170728

Acharya, A., Gahlaut, U., Sharma, K., Sharma, S. K., Vishwakarma, P. N., & Phanden, R. K. (2020). Crashworthiness Analysis of a Thin-Walled Structure in the Frontal Part of Automotive Chassis. International Journal of Vehicle Structures & Systems, 12(5).

Amir, S.M., M.T. Sultan, M. Jawaid, A.H. Ariffin, S. Mohd, K.A. Salleh, M.R. Ishak, and A.U.M. Shah. (2019). "Nondestructive testing method for Kevlar and natural fiber and their hybrid composites." In Durability and Life Prediction in Biocomposites, Fibre-Reinforced Composites and Hybrid Composites, 367-388.

An apparatus for extraction of leaf fibre. N.d. Retrieved 5 October 2021 from https://patentscope.wipo.int/search/en/detail.jsf?docId=MY203060004

Ananas Anam - About Us (n.d.). Retrieved 25 October 2021 from https://www.ananas-anam.com/about-us/

Andleeb, Z., Malik, S., Khawaja, H., Antonsen, S., Hassan, T., Hussain, G., & Moatamedi, M. (2021). Strain Wave Analysis in Carbon-Fiber-Reinforced Composites subjected to Drop Weight Impact Test using ANSYS®. The International Journal of Multiphysics, 15(3): 275-290.

Andre, W. (2021). FIBER WORLD: Sustainable Alternative Plant Fibers for Textiles. Retrieved 24 October 2021 from https://www.textileworld.com/textile-world/features/2021/04/fiber- world-sustainable-alternative-plant-fibers-for-textiles/

Anidha, S., N. Latha, M. Muthukkumar. (2020). "Effect of polyaramid reinforced with sisal epoxy composites: Tensile, impact, flexural and morphological properties." Journal of Materials Research and Technology, 9:7947-54.

Ansys Explicit Dynamics. N.d. Retreived 6 October 2021 from https://www.ansys.com/services/training-center/structures/ansys-explicit-dynamics

Ansys Mechanical Finite Element Analysis (FEA) Software for Structural Engineering. N.d. Retreived 6 October 2021 from https://www.ansys.com/products/structures/ansys-mechanical

Araújo, J. R., Waldman, W. R., and De Paoli, M. A. (2008). "Thermal properties of high density polyethylene composites with natural fibres: Coupling agent effect." Polymer Degradation and stability, 93(10):1770-1775.

Arhamnamazi, S. A., Bani Mostafa Arab, N., Refahi Oskouei, A., & Aymerich, F. (2019). Accuracy assessment of ultrasonic C-scan and X-ray radiography methods for impact damage detection in glass fiber reinforced polyester composites. Journal of Applied and Computational Mechanics, 5(2): 258-268.

Arroba, C. H., Núñez, D. F., Peña, F. A., Ruiz, E. G., Cabrera, S. P., & Ureña, M. E. (2019). Simulating Metamodel for Urban Bus Seats Design. In IOP Conference Series: Materials Science and Engineering, 507(1): 012027.

Asim, M., Jawaid, M., Abdan, K., & Ishak, M. R. (2016). Effect of alkali and silane treatments on mechanical and fibre-matrix bond strength of kenaf and pineapple leaf fibres. Journal of Bionic Engineering, 13(3): 426-435.

Asim, M., M. Jawaid, K. Abdan, and M. R. Ishak. (2018). The effect of silane treated fibre loading on mechanical properties of pineapple leaf/kenaf fibre filler phenolic composites. Journal of Polymers and the Environment, 26(4):1520–27.

Asim, M., Paridah, M. T., Jawaid, M., Nasir, M., & Saba, N. (2018, June). Physical and flammability properties of kenaf and pineapple leaf fibre hybrid composites. In IOP Conference Series: Materials Science and Engineering, 368(1): 012018.

Askadskii, A.A., A.I. Barabanova, E.S. Afanasev, N.D. Kagramanov, N.E. Mysova, N.S. Ikonnikov, E.P. Kharitonova, B.V. Lokshin, A.R. Khokhlov, and O.E. Philippova. (2020). "Revealing defects hampering the formation of epoxy networks with extremely high thermal properties: Theory and experiments." Polymer Testing.

Austin, W. (2017).Natural Fibers May Hold the Key to Lightweighting. Retrieved 25 October 2021 from https://www.assemblymag.com/articles/94029-natural-fibers-may-hold-the-key-to-lightweighting

Bakri, M. K. B., and Jayamani, E. (2016). "Comparative study of functional groups in natural fibers: Fourier transform infrared analysis (FTIR)." Futuristic Trends Eng, Sci, Humanities, Technol FTESHT-16, 167.

Barouni, A. K., & Dhakal, H. N. (2019). Damage investigation and assessment due to low-velocity impact on flax/glass hybrid composite plates. Composite Structures, 226: 111224.

Bensadoun, F., Depuydt, D., Baets, J., Verpoest, I., & Van Vuure, A. W. (2017). Low velocity impact properties of flax composites. Composite Structures, 176: 933-944.

Bilba, K., M. A. Arsene, and A. Ouensanga. (2007). Study of banana and coconut fibers: Botanical composition, thermal degradation and textural observations. Bioresource Technology, 98 (1):58–68.

Bio-composites for cars. N.d. Retrieved 5 October 2021 from https://cordis.europa.eu/article/id/124411-biocomposites-for-cars

Boccardi, S., Carlomagno, G. M., Meola, C., Russo, P., & Simeoli, G. (2018). The contribution of infrared thermography in the characterization of jute based composites. Composite Structures, 190: 119-126.

Cakmak, I. (2005). "The role of potassium in alleviating detrimental effects of abiotic stresses in plants." Journal of Plant Nutrition and Soil Science, 168(4):521-530

Campana, C., Leger, R., Sonnier, R., Ferry, L., & Ienny, P. (2018). Effect of post curing temperature on mechanical properties of a flax fiber reinforced epoxy composite. Composites Part A: Applied Science and Manufacturing, 107: 171-179.

Cavalcanti, D. K. K., Banea, M. D., Neto, J. S. S., Lima, R. A. A., Da Silva, L. F. M., & Carbas, R. J. C. (2019). Mechanical characterization of intralaminar natural fibre-reinforced hybrid composites. Composites Part B: Engineering, 175: 107149.

Chapman, M. & Dhakal, H.N. (2019) Effects of hybridisation on the low velocity falling weight impact and flexural properties of flax-carbon/epoxy hybrid composites. Fibers 7: 95.

Chee, S. S., Jawaid, M., Sultan, M. T. H., Alothman, O. Y., & Abdullah, L. C. (2019). Thermomechanical and dynamic mechanical properties of bamboo/woven kenaf mat reinforced epoxy hybrid composites. Composites Part B: Engineering, 163: 165-174.

Chew, E., Liu, J. L., Tay, T. E., Tran, L. Q. N., & Tan, V. B. C. (2021). Improving the mechanical properties of natural fibre reinforced laminates composites through Biomimicry. Composite Structures, 258: 113208.

Chin, S. C., Tong, F. S., Doh, S. I., Gimbun, J., Ong, H. R., & Serigar, J. P. (2018). Strengthening Performance of PALF-Epoxy Composite Plate on Reinforced Concrete Beams. In IOP Conference Series: Materials Science and Engineering, 318(1): 012026.

Classification of fibers and their general properties. N.d. Retreived 6 October 2021 from https://nptel.ac.in/courses/116/102/116102026/

d'Almeida, J. R. M., Aquino, R. C. M. P., and Monteiro, S. N. (2006). "Tensile mechanical properties, morphological aspects and chemical characterization of piassava (Attalea funifera) fibers." Composites Part A: Applied Science and Manufacturing, 37(9):1473-1479.

Da Silva, R. H., Kaminski, P. C., & Armellini, F. (2020). Improving new product development innovation effectiveness by using problem solving tools during the conceptual development phase: Integrating Design Thinking and TRIZ. Creativity and Innovation Management, 29(4): 685-700.

Das, S. K., & Pani, B. B. (2021) Explicit Dynamic Analysis and Design Optimization of Sheet Metal Forming. International Journal of Innovative Science and Research Technology, 6(4): 557-582.

de Vasconcellos, D. S., Sarasini, F., Touchard, F., Chocinski-Arnault, L., Pucci, M., Santulli, C., ... & Sorrentino, L. (2014). Influence of low velocity impact on fatigue behaviour of woven hemp fibre reinforced epoxy composites. Composites Part B: Engineering, 66: 46-57.

Devnani, G. L., & Sinha, S. (2019). Extraction, characterization and thermal degradation kinetics with activation energy of untreated and alkali treated Saccharum spontaneum (Kans grass) fiber. Composites Part B: Engineering, 166: 436-445.

Dhakal, H. N., Skrifvars, M., Adekunle, K., & Zhang, Z. Y. (2014). Falling weight impact response of jute/methacrylated soybean oil bio-composites under low velocity impact loading. Composites science and technology, 92: 134-141.

Dhakal, H. N., Zhang, Z. Y., Richardson, M. O. W., & Errajhi, O. A. Z. (2007). The low velocity impact response of non-woven hemp fibre reinforced unsaturated polyester composites. Composite Structures, 81(4): 559-567.

Eksiler, K., Andou, Y., and Shirai, Y. 2018. "Simple Manufacture of Surface- Modified Nanolignocellulose Fiber via Vapor-Phase-Assisted Surface Polymerization." ACS Omega, 3(4):4545-4550.

Eksiler, K., Andou, Y., Yilmaz, F., Shirai, Y., Ariffin, H., and Hassan, M. A. (2017)."Dynamically controlled fibrillation under combination of ionic liquid with mechanical grinding." Journal of Applied Polymer Science, 134(7).

Engelmann, G., and J. Ganster. (2016). "Lignin Reinforcement in Thermosets Composites." Lignin in Polymer Composite, 119-151.

Fadzullah, S. S. M., Ramli, S. N. N., Mustafa, Z., Razali, A. S., Sivakumar, D., & Ismail, I. (2020). Low velocity impact behaviour of pineapple leaf fibre reinforced polylactic acid biocomposites. Journal of Advanced Manufacturing Technology, 14(1).

Fan, M., Dai, D., and Huang, B. (2012). "Fourier transform infrared spectroscopy for natural fibres." In Fourier transform-materials analysis.

Fareez, I. M., N. A. Ibrahim, W. M. H. Wan Yaacob, N. A. Mamat Razali, A. H. Jasni, and F. Abdul Aziz. (2018). Characteristics of cellulose extracted from josapine pineapple leaf fibre after alkali treatment followed by extensive bleaching. Cellulose, 25(8): 4407–21.

Faruk, O., Bledzki, A. K., Fink,H. P., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. Progress in Polymer Science, 37(11):1552–96.

Faruk, O., Bledzki, A. K., Fink, H. P., and Sain, M. (2012). "Biocomposites reinforced with natural fibers: 2000–2010." Progress in polymer science, 37(11):1552-1596.

Frequently Asked Questions: Patents Basics. N.d. Retreived 6 October 2021 from https://www.wipo.int/patents/en/faq_patents.html

Fu, H., Dun, M., Wang, H., Wang, W., & Wang, Q. (2021). Rheological behavior, internal stress and structural changes of ultra-high-filled wood-flour/high-density polyethylene composite in shear flow field. Journal of Materials Research and Technology, 14:1191-1202

Gebino, G., & Muhammed, N. (2018). Extraction and characterization of Ethiopian pineapple leaf fiber. Current Trends in Fashion Technology & Textile Engineering, 4(4): 77-83.

George, J., S.S. Bhagawan, and S. Thomas. (1996). “Thermogravimetric and dynamic mechanical thermal analysis of pineapple fibre reinforced polyethylene composites.” Journal of Thermal Analysis, 47:1121–1140.

Gheith, M.H., M.A. Aziz, W. Ghori, N. Saba, M. Asim, M. Jawaid, and O.Y. Alothman. (2019). “Flexural, thermal and dynamic mechanical properties of date palm fibres reinforced epoxy composites.” Journal of Materials Research and Technology, 8:853-60.

Glória, G. O., Teles, M. C. A., Lopes, F. P. D., Vieira, C. M. F., Margem, F. M., de Almeida Gomes, M., & Monteiro, S. N. (2017). Tensile strength of polyester composites reinforced with PALF. Journal of Materials Research and Technology 6(4): 401-405.

Gupta, M. K., & Srivastava, R. K. (2016). Properties of sisal fibre reinforced epoxy composite. Indian Journal of Fibre & Textile Research, 41: 235–241.

Habibi, M., Selmi, S., Laperrière, L., Mahi, H., & Kelouwani, S. (2019). Experimental investigation on the response of unidirectional flax fiber composites to low-velocity impact with after-impact tensile and compressive strength measurement. Composites Part B: Engineering 171: 246-253.

Hassan, M. 2012. The Low Velocity Impact Response of Sandwich Structures, PhD Thesis, University of Liverpool.

Heriyanto, Farshid, P., & Veena S. (2019). Effect of different waste filler and silane coupling agent on the mechanical properties of powder-resin composite. Journal of Cleaner Production, 224:940-956.

Hoque, M.B., M.S. Hossain, A.M. Nahid, S. Bari, and R.A. Khan. (2018). "Fabrication and Characterization of Pineapple Fiber-Reinforced Polypropylene Based Composites." In Nano Hybrids and Composites, 21:31–42.

Hospodarova, V., Singovszka, E., & Stevulova, N. (2018). Characterization of cellulosic fibers by FTIR spectroscopy for their further implementation to building materials. American journal of analytical chemistry, 9(6): 303-310.

How Publications Affect Patentability, n.d. Retrieved on 24 October 2021 from https://www.utoledo.edu/research/TechTransfer/Publish_and_Perish.html

Huber, T., Bickerton, S., Müssig, J., Pang, S., & Staiger, M. P. (2013). Flexural and impact properties of all-cellulose composite laminates. Composites Science and Technology, 88: 92-98.

Huda, M. S., L. T. Drzal, A. K. Mohanty, and M. Misra. (2008). Effect of chemical modifications of the pineapple leaf fiber surfaces on the interfacial and mechanical properties of laminated biocomposites. Composite Interfaces, 15(2–3): 169–91.

Ismail, A. E., & Hassan, M. A. (2014). Low velocity impact on woven kenaf fiber reinforced composites. In Applied Mechanics and Materials, 629: 503–506.

Ismail, M. F., Sultan, M. T., Hamdan, A., Shah, A. U., & Jawaid, M. (2019). Low velocity impact behaviour and post-impact characteristics of kenaf/glass hybrid composites with various weight ratios. Journal of Materials Research and Technology, 8(3): 2662-2673.

Issa A.A., Luyt A.S.(2019). Kinetics of alkoxysilanes and organoalkoxysilanes polymerization: a review. Polymers 11(3):537

Jaafar, J., Siregar, J. P., Piah, M. B. M., Cionita, T., Adnan, S., & Rihayat, T. (2018). Influence of selected treatment on tensile properties of short pineapple leaf fiber reinforced tapioca resin biopolymer composites. Journal of Polymers and the Environment, 26(11): 4271-4281.

Jiahao, F., Gongchang, R., Yuexin, Y., & Yadong, S. (2021). Research and application of TRIZ theory in the field of service robots. In Journal of Physics: Conference Series, 1948(1): 012108.

Johar, N., I. Ahmad, and A. Dufresne. (2012). Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. Industrial Crops and Products, 37 (1): 93–99.

John, M. J., Francis, B., Varughese, K. T., & Thomas, S. (2008). Effect of chemical modification on properties of hybrid fiber biocomposites. Composites Part A: Applied Science and Manufacturing, 39(2): 352-363.

Kommula, V. P., Reddy, K. O., Shukla, M., Marwala, T., Reddy, E. S., & Rajulu, A. V. (2016). Extraction, modification, and characterization of natural ligno-cellulosic fiber strands from napier grass. International Journal of Polymer Analysis and Characterization 21(1): 18-28.

Kutz, M. (Ed.).: Mechanical engineers' handbook, volume 1: Materials and engineering mechanics. 4th edn. John Wiley & Sons, United State of America (2015).

Laksana, P. Y. K., Setyanto, R. H., & Herdiman, L. (2021). Redesign walker for children with diplegic cerebral palsy using TRIZ method. Jurnal Sistem dan Manajemen Industri, 5(1): 8-14.

Lascano, D., Balart, R., Garcia-Sanoguera, D., Agüero, A., Boronat, T., & Montanes, N. (2021). Manufacturing and Characterization of Hybrid Composites with Basalt and Flax Fabrics and a Partially Bio-based Epoxy Resin. Fibers and Polymers, 22(3):751-763.

Leão, M.A., Aquino, E.M.F., Tinô, S.R.L. & Fontes, R.S. (2011). Licuri fibers: alternative reinforcement to polymeric composites. Journal of reinforced plastics and composites, 30(6):516-523.

Lembaga Perindustrian Nanas Malaysia (2018). Keluasan dan Pengeluaran Nanas Malaysia. Retrieved 25 October 2021 from https://www.data.gov.my/data/ms_MY/dataset/keluasan-dan-pengeluaran-nanas-malaysia-2013-2016

Lembaga Perindustrian Nanas Malaysia (2021). Retrieved 25 October 2021 from https://www.mpib.gov.my/kultivar/

Lembaga Perindustrian Nanas Malaysia-Negeri Kedah/Perlis (2021). Retrieved 25 October 2021 from https://www.facebook.com/Lembaga-Perindustrian-Nanas-Malaysia-Negeri-KedahPerlis-1042700022455442/?hc_ref=ARRIqyk3-plHrs5rrpcbvcr4SBU6i__N39YhqiDTx6VGMDe2lxoVXKOGVlQVoHaSWPU&ref=nf_target&__tn__=kCH-R

Léonard, F., Stein, J., Soutis, C., & Withers, P. J. (2017). The quantification of impact damage distribution in composite laminates by analysis of X-ray computed tomograms. Composites Science and Technology, 152: 139-148.

Li, Y., Ming, A. B., Mao, H., Jin, G. F., Yang, Z. W., Zhang, W., & Wu, S. Q. (2019). Detection and characterization of mechanical impact damage within multi-layer carbon fiber reinforced polymer (CFRP) laminate using passive thermography. IEEE Access 7: 27689-27698.

Li, Z., Khennane, A., Hazell, P. J., & Brown, A. D. (2017). Impact behaviour of pultruded GFRP composites under low-velocity impact loading. Composite Structures, 168, 360-371.

Lin, Y. S., & Chen, M. (2021). Implementing TRIZ with Supply Chain Management in New Product Development for Small and Medium Enterprises. Processes, 9(4): 614.

Lu, N., Swan Jr, R. H., & Ferguson, I. (2012). Composition, structure, and mechanical properties of hemp fiber reinforced composite with recycled high-density polyethylene matrix. Journal of Composite Materials, 46(16): 1915-1924.

Lu, T., Chen, X., Wang, H., Zhang, L., & Zhou, Y. (2020). Comparison of low-velocity impact damage in thermoplastic and thermoset composites by non-destructive three-dimensional X-ray microscope. Polymer Testing, 91: 106730.

Luz, F. S. D., Monteiro, S. N., & Tommasini, F. J. (2018). Evaluation of dynamic mechanical properties of PALF and coir fiber reinforcing epoxy composites. Materials Research, 21.

Majid, D. L., Jamal, Q. M., & Manan, N. H. (2018). Low-velocity impact performance of glass fiber, kenaf fiber, and hybrid glass/kenaf fiber reinforced epoxy composite laminates. BioResources, 13(4): 8839-852.

Manimaran, P., P. Senthamaraikannan, M. R. Sanjay, M. K. Marichelvam, and M. Jawaid. (2018). Study on characterization of furcraea foetida new natural fiber as composite reinforcement for lightweight applications. Carbohydrate Polymers, 181:650–58.

Matsubara, M., Teramoto, S., Nagatani, A., Kawamura, S., Tsujiuchi, N., Ito, A., ... & Furuta, S. (2021). Effect of Fiber Orientation on Nonlinear Damping and Internal Microdeformation in Short-Fiber-Reinforced Natural Rubber. Experimental Techniques, 45(1): 37-47.

Md Shah, A. U., Hameed Sultan, M. T., & Safri, S. N. A. (2020). Experimental evaluation of low velocity impact properties and damage progression on bamboo/glass hybrid composites subjected to different impact energy levels. Polymers 12(6): 1288.

Meola, C., Boccardi, S., & Carlomagno, G. M. (2019). The Contribution of Infrared Thermography in the Characterization of Glass/Epoxy Laminates through Remote Sensing of Thermal-Stress Coupled Effects. In Multidisciplinary Digital Publishing Institute Proceedings, 15(1): 21.

Militello, C., Bongiorno, F., Epasto, G., & Zuccarello, B. (2020). Low-velocity impact behaviour of green epoxy biocomposite laminates reinforced by sisal fibers. Composite Structures 253: 112744.

Mishra, S., Mohanty, A. K., Drzal, L. T., Misra, M., and Hinrichsen, G. (2004). "A review on pineapple leaf fibers, sisal fibers and their biocomposites." Macromolecular Materials and Engineering, 289(11):955-974.

Mobarakian, M., M. Safarabadi, and M. Farahani. (2020). “Developing a thermomechanical and thermochemical model for investigating the cooling rate effects on the distortion of unsymmetrical viscoelastic polymeric composite laminates.” Polymer Testing, 87:106503.

Mohamed, A. R., S. M. Sapuan, M. Shahjahan, and A. Khalina. (2009). Characterization of pineapple leaf fibers from selected Malaysian cultivars. Journal of Food, Agriculture & Environment, 7 (1):235–40.

Mohamed, S.A., E.S. Zainudin, S.M. Sapuan, M.D. Azaman, and A.M. Arifin. (2020). “Energy behavior assessment of rice husk fibres reinforced polymer composite.” Journal of Materials Research and Technology, 9:383-93.

Mostafa, N.H., Z.N. Ismarrubie, S.M. Sapuan, and M.T.H Sultan. (2016). “The influence of equi-biaxially fabric prestressing on the flexural performance of woven E-glass/polyester-reinforced composites.” Journal of Composite Materials, 50:3385-93.

Munirah, M., A. R. Rahmat, and A. Hassan. (2007). Characterization and treatments of pineapple leaf fiber thermoplastic composite for construction application, Universiti Teknologi Malaysia.

Nadirah, W. W., Jawaid, M., Al Masri, A. A., Khalil, H. A., Suhaily, S. S., and Mohamed, A. R. (2012). "Cell wall morphology, chemical and thermal analysis of cultivated pineapple leaf fibres for industrial applications." Journal of Polymers and the Environment, 20(2):404-411.

Nadirah, W. W., Jawaid, M., Al Masri, A. A., Khalil, H. A., Suhaily, S. S., & Mohamed, A. R. (2012). Cell wall morphology, chemical and thermal analysis of cultivated pineapple leaf fibres for industrial applications. Journal of Polymers and the Environment, 20(2): 404-411.

Nagarajan, T. T., Babu, A. S., Palanivelu, K., & Nayak, S. K. (2016). Mechanical and Thermal Properties of PALF Reinforced Epoxy Composites. In Macromolecular Symposia, 361(1): 57-63.

Narendiranath, B. T., Singh, A. P., Reddy, N. S., & Murpani, D. (2021). Simulation of Ballistic Impact on Different Composite Samples of Bullet Proof Vest. In IOP Conference Series: Materials Science and Engineering 1123(1): 012030.

Nazari, L., Sarathy, S., Santoro, D., Ho, D., Ray, M. B., & Xu, C. C. (2018). Recent advances in energy recovery from wastewater sludge. Direct thermochemical liquefaction for energy applications, 67-100.

Noergaard Petersen, H., Almdal, K., Kusano, Y., & Broendsted, P. (2013). Preliminary characterization of glass fiber sizing.

Nurazzi, N.M., A. Khalina, S.M. Sapuan, R.A. Ilyas, S.A Rafiqah, and Z.M Hanafee. (2020). “Thermal properties of treated sugar palm yarn/glass fiber reinforced unsaturated polyester hybrid composites.” Journal of Materials Research and Technology, 9:1606-18.

Ornaghi, H.L., H.S.P. da Silva, A.J. Zattera, and S.C. Amico. (2011). “Hybridization effect on the mechanical and dynamic mechanical properties of curaua composites.” Materials Science and Engineering, 528:7285–7289.

Oushabi, A., Sair, S., Hassani, F. O., Abboud, Y., Tanane, O., & El Bouari, A. (2017). The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF–Polyurethane composite. South African Journal of Chemical Engineering, 23: 116-123.

Panyasart, K., Chaiyut, N., Amornsakchai, T., & Santawitee, O. (2014). Effect of surface treatment on the properties of pineapple leaf fibers reinforced polyamide 6 composites. Energy procedia 56: 406-413.

Patel, A., O. Kravchenko, and I. Manas-Zloczower. (2018). “Effect of curing rate on the microstructure and macroscopic properties of epoxy fiberglass composites.” Polymers (Basel), 10.

Pietrikova, A., T. Lenger, O. Fricova, L. Popovic, L. Livovsky. (2020). “Properties of glass/epoxy sandwich structure for electronic boards.” Microelectronics Internationals, 37:139-146.

Pineapple leaf fiber packing device. N.d. Retrieved 5 October 2021 from https://worldwide.espacenet.com/publicationDetails/biblio?CC=CN&NR=103477797A&KC=A&FT=D&ND=3&date=20140101&DB=EPODOC&locale=en_EP

Pineapple leaf fiber splitting machine. N.d. Retrieved 5 October 2021 from https://worldwide.espacenet.com/publicationDetails/claims?CC=CN&NR=204325585U&KC=U&FT=D&ND=3&date=20150513&DB=EPODOC&locale=en_EP

Pineapple leaf fiber stripping device with function of intelligently feeding according to amount of input material. N.d. Retrieved 5 October 2021 from https://worldwide.espacenet.com/publicationDetails/biblio?CC=CN&NR=107099852A&KC=A&FT=D&ND=3&date=20170829&DB=&locale=en_EP

Pineapple leaf harvesting and fiber extracting combined harvester. N.d. Retrieved 5 October 2021 from https://patents.google.com/patent/CN103477797A/en

Poletto, M., Ornaghi, H., and Zattera, A. (2014). "Native cellulose: structure, characterization and thermal properties." Materials, 7(9):6105-6119.

Racing cars with body parts made from renewable raw materials. 2020. Retrieved 5 October 2021 from https://newsroom.porsche.com/en/2020/motorsports/porsche-718-cayman-gt4-clubsport-mr-natural-fibre-composite-body-kit-22439.html

Rahman, W. A. W. A., Adenan, N., Ali, R. R., & Sulaiman, H. (2009). Effect of silane crosslinker on the thermal properties of rice straw/HDPE biocomposite. Journal of Applied Sciences, 9(17): 3041-3047.

Rajak, D. K., Pagar, D. D., Menezes, P. L., & Linul, E. (2019). Fiber-reinforced polymer composites: Manufacturing, properties, and applications. Polymers, 11(10): 1667.

Ramírez-Rios, L. Y., Camargo-Wilson, C., Olguín-Tiznado, J. E., López-Barreras, J. A., Inzunza-González, E., & García-Alcaraz, J. L. (2021). Design of a Modular Plantar Orthosis System through the Application of TRIZ Methodology Tools. Applied Sciences, 11(5): 2051.

Ramli, S. N. R., Fadzullah, S. H. S. M., & Mustafa, Z. (2017). The Effect Of Alkaline Treatment And Fiber Length On Pineapple Leaf Fiber Reinforced Poly Lactic Acid Biocomposites. Jurnal Teknologi, 79(5-2): 111-115

Raposo, M., Ferreira, Q., & Ribeiro, P. A. (2007). A guide for atomic force microscopy analysis of soft-condensed matter. Modern research and educational topics in microscopy, 1: 758-769.

Rashid, B., Z. Leman, M. Jawaid, M.J. Ghazali, and M.R Ishak. (2017). “Dynamic mechanical analysis of treated and untreated sugar palm fibre-based phenolic composites.” BioResources 12:3448–3462.

Ratna, D. (2012). Thermal properties of thermosets. Thermosets, 62–91.

Ravandi, M., Teo, W. S., Tran, L. Q. N., Yong, M. S., & Tay, T. E. (2017). Low velocity impact performance of stitched flax/epoxy composite laminates. Composites Part B: Engineering, 117: 89-100.

Reddy, M. V. K., Lakshmi, R. V. S., Pragathi, Y., Devaraj, P., & Naresh, N. (2021). Evaluation of mechanical properties: Influence of glass fiber on banana fiber reinforced with epoxy composite. Materials Today: Proceedings, 37: 1305-1312.

Richard, C. (2020). Pina Weaving, Making Clothes From Pineapples. Retrieved 25 October 2021 from https://www.travel-tramp.com/pina-weaving-philippines-making-clothes-from-pineapples/

Rihayat, T., Suryani, S., Fauzi, T., Agusnar, H., Wirjosentono, B., Alam, P. N., & Sami, M. (2018). Mechanical properties evaluation of single and hybrid composites polyester reinforced bamboo, PALF and coir fiber. In IOP Conference Series: Materials Science and Engineering, 334(1): 012081.

Saba, N., M. Jawaid, O.Y. Alothman, and Z. Almutairi. (2019). "Evaluation of dynamic properties of nano oil palm empty fruit bunch filler/epoxy composites." Journal of Materials Research and Technology, 8:1470-5.

Saba, N., M. Jawaid, K. R. Hakeem, M. T. Paridah, A. Khalina, and O. Y. Alothman. (2015). Potential of bioenergy production from industrial kenaf (Hibiscus cannabinus L.) based on Malaysian perspective. Renewable and Sustainable Energy Reviews, 42: 446–59.

Saeedifar, M., Saleh, M. N., El-Dessouky, H. M., De Freitas, S. T., & Zarouchas, D. (2020). Damage assessment of NCF, 2D and 3D woven composites under compression after multiple-impact using acoustic emission. Composites Part A: Applied Science and Manufacturing ,132: 105833.

Sahu, P., & Gupta, M. (2020). A review on the properties of natural fibres and its bio-composites: Effect of alkali treatment. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, 234(1): 198–217.

Salman, S.D., Z. Leman, M.T.H. Sultan. M.R. Ishak, and F. Cardona. (2015). "Kenaf/synthetic and Kevlar®/cellulosic fiber-reinforced hybrid composites: A review." BioResources, 10:8580-603.

Santos, E. B. C., Barros, J. J. P., de Moura, D. A., Moreno, C. G., de Carvalho Fim, F., & da Silva, L. B. (2019). Rheological and thermal behavior of PHB/piassava fiber residue-based green composites modified with warm water. Journal of Materials Research and Technology, 8(1): 531-540.

Sarah, S., Rahman, W. A. W. A., Majid, R. A., Yahya, W. J., Adrus, N., Hasannuddin, A. K., & Low, J. H. (2018). Optimization of Pineapple Leaf Fibre Extraction Methods and Their Biodegradabilities for Soil Cover Application. Journal of Polymers and the Environment, 26(1): 319-329.

Sarasini, F., Tirillò, J., D'Altilia, S., Valente, T., Santulli, C., Touchard, F., ... & Gaudenzi, P. (2016). Damage tolerance of carbon/flax hybrid composites subjected to low velocity impact. Composites Part B: Engineering 91: 144-153.

Sarasini, F., Tirillò, J.; Valente, M.; Valent, T.; Cioffi, S.; Iannace, S.; Sorrentino, L. (2013) Effect of basalt fiber hybridization on the impact behavior under low impact velocity of glass/basalt woven fabric/epoxy resin composites. Composite Part A Applied Science Manufacturing, 47: 109–123.

Satyanarayana, K. G., Sukumaran, K., Mukherjee, P. S., and Pillai, S. G. K. (1986). "Materials science of some lignocellulosic fibers." Metallography, 19(4):389-400.

Scarponi, C., Sarasini, F., Tirillo, J., Lampani, L., Valente, T., & Gaudenzi, P. (2016). Low-velocity impact behaviour of hemp fibre reinforced bio-based epoxy laminates. Composites Part B: Engineering, 91: 162-168.

Seghini, M. C., Tirillò, J., Bracciale, M. P., Touchard, F., Chocinski-Arnault, L., Zuorro, A., ... & Sarasini, F. (2020). Surface Modification of Flax Yarns by Enzymatic Treatment and Their Interfacial Adhesion with Thermoset Matrices. Applied Sciences, 10(8): 2910.

Senthamaraikannan, P., M. R. Sanjay, K. S. Bhat, N. H. Padmaraj, and M. Jawaid. (2019). Characterization of natural cellulosic fiber from bark of albizia amara. Journal Of Natural Fibers, 16 (8):1124-1131.

Senthamaraikannan, P., Sanjay, M. R., Bhat, K. S., Padmaraj, N. H., and Jawaid, M. (2018). "Characterization of natural cellulosic fiber from bark of Albizia amara." Journal of Natural Fibers, 1-8.

Senthilkumar, K., Saba, N., Chandrasekar, M., Jawaid, M., Rajini, N., Alothman, O. Y., & Siengchin, S. (2019). Evaluation of mechanical and free vibration properties of the pineapple leaf fibre reinforced polyester composites. Construction and Building Materials 195: 423-431.

.

Shah, A.U.M. 2018., Low velocity impact sandwich structure bamboo for aerospace applications. PhD Thesis, Universiti Putra Malaysia

Sharaf, H. K., Ishak, M. R., Sapuan, S. M., & Yidris, N. (2020). Conceptual design of the cross-arm for the application in the transmission towers by using TRIZ–morphological chart–ANP methods. Journal of Materials Research and Technology, 9(4): 9182-9188.

Shenoy Heckadka, S., Pai Ballambat, R., Kini Manjeshwar, V., Kumar, M., Hegde, P., & Kamath, A. (2020). Influence of stack sequence on the mechanical characteristics of hybrid composites analyzed using cone beam computed tomography and scanning electron microscopy. Polymer Composites, 41(12): 5059-5071.

Shesan, O. J., Stephen, A. C., Chioma, A. G., Neerish, R., & Rotimi, S. E. (2019). Fiber-matrix relationship for composites preparation. Renewable and Sustainable Composites, 1-30.

Silva, W., Lopes, R., Zscherpel, U., Meinel, D., & Ewert, U. (2021). X-ray imaging techniques for inspection of composite pipelines. Micron 145: 103033.

Singh, T., B. Gangil, A. Patnaik, S. Kumar, A. Rishiraj, and G. Fekete. (2018). “Physico-mechanical, thermal and dynamic mechanical behaviour of natural-synthetic fiber reinforced vinylester based homogenous and functionally graded composites.” Materials Research Express, 6:25704.

Sood, M., & Dwivedi, G. (2018). Effect of fiber treatment on flexural properties of natural fiber reinforced composites: A review. Egyptian journal of petroleum, 27(4): 775-783.

Spiridon, I., and Popa, V. I. (2008). "Hemicelluloses: major sources, properties and applications." In Monomers, polymers and composites from renewable resources, 289-304.

Sreekala, M. S., Kumaran, M. G., & Thomas, S. (1997). Oil palm fibers: Morphology, chemical composition, surface modification, and mechanical properties. Journal of Applied polymer science, 66(5): 821-835.

Sughanthy, S.A., M.N Ansari, and A. Atiqah. (2020). “Dynamic mechanical analysis of polyethylene terephthalate/hydroxyapatite biocomposites for tissue engineering applications.” Journal of Materials Research and Technology 9:2350-2356.

Sun, R., Fang, J. M., Goodwin, A., Lawther, J. M., and Bolton, A. J. (1998). "Fractionation and characterization of polysaccharides from abaca fibre." Carbohydrate Polymers 37(4):351-359.

Sy, B. L., Fawaz, Z., & Bougherara, H. (2018). Damage evolution in unidirectional and cross-ply flax/epoxy laminates subjected to low velocity impact loading. Composites Part A: Applied Science and Manufacturing, 112: 452-467.

TA instruments. Quantifying Polymer Crosslinking Density Using Rheology and DMA . Retrieved 23 December 2021 from https://www.tainstruments.com/pdf/literature/RH102.pdf

Tan, D. W. H., Ng, P. K., & Noor, E. E. M. (2021). A TRIZ-driven conceptualisation of finger grip enhancer designs for the elderly. F1000Research 10(392): 392.

Tanpichai, S., Witayakran, S., & Boonmahitthisud, A. (2019). Study on structural and thermal properties of cellulose microfibers isolated from pineapple leaves using steam explosion. Journal of Environmental Chemical Engineering, 7(1): 102836.

Tao, Y., Liu, M., Han, W., & Li, P. (2021). Waste office paper filled polylactic acid composite filaments for 3D printing. Composites Part B: Engineering, 221:108998.

Thomas, M. G., Abraham, E., Jyotishkumar, P., Maria, H. J., Pothen, L. A., & Thomas, S. (2015). Nanocelluloses from jute fibers and their nanocomposites with natural rubber: Preparation and characterization. International journal of biological macromolecules, 81: 768-777.

Ullah, H., Silberschmidt, V. 2018. Mechanical Behaviour And Computed Tomography Damage Analysis Of Fabric-Reinforced Composites Under Bending. In Proceedings of the 18th Conference on Composite Materials.

Vasilchenko-Malishev, G. (2016). Design and construction of the 28 m tall self-supporting glass lift enclosure. Glass Structures & Engineering, 1(1): 233-246.

Vieille, B., Pujols-Gonzalez, J. D., Bouvet, C., Breteau, T., & Gautrelet, C. (2020). Influence of impact velocity on impact behaviour of hybrid woven-fibers reinforced PEEK thermoplastic laminates. Composites Part C: Open Access, 2: 100029.

Vinod, A., Sanjay, M. R., Siengchin, S., & Fischer, S. (2021). Fully bio-based agro-waste soy stem fiber reinforced bio-epoxy composites for lightweight structural applications: influence of surface modification techniques. Construction and Building Materials, 303:124509

Vivek, S., Kanthavel, K., Torris, A., & Kavimani, V. (2020). Effect of bio-filler on hybrid sisal-Banana-Kenaf-flax based epoxy composites: a statistical correlation on flexural strength. Journal of Bionic Engineering, 17(6): 1263-1271.

Wu, J., Xu, C., Qi, B., & Hernandez, F. C. R. (2018). Detection of impact damage on PVA-ECC beam using infrared thermography. Applied Sciences, 8(5): 839.

Xiong, D., Wang, D., Liu, X., Peng, S., Huang, J., & Li, Y. (2016). Leaf density explains variation in leaf mass per area in rice between cultivars and nitrogen treatments. Annals of Botany, 117(6): 963-971.

Yang, H., Yan, R., Chen, H., Lee, D. H., and Zheng, C. (2007). "Characteristics of hemicellulose, cellulose and lignin pyrolysis." Fuel, 86(12-13):1781-1788.

Yang, Z., Feng, X., Xu, M., & Rodrigue, D. (2020). Properties of poplar fiber/PLA composites: Comparison on the effect of maleic anhydride and KH550 modification of poplar fiber. Polymers, 12(3):729.

Yusof, Y., Yahya, S. A., & Adam, A. (2014). A New Approach for Palf Productions and Spinning System: The Role of Surface Treatments. Journal of Advanced Agricultural Technologies 1(2).

Zelca, Z., Kukle, S., and Kajaks, J. (2017). "LLDPE and Natural Fiber Composites Characterization using AFM." In IOP Conference Series: Materials Science and Engineering, 251(1):012086.

Zhang, C., Rao, Y., Li, Z., & Li, W. (2018a). Low-velocity impact behavior of interlayer/intralayer hybrid composites based on carbon and glass non-crimp fabric. Materials, 11(12): 2472.

Zhang, K., Wang, F., Liang, W., Wang, Z., Duan, Z., & Yang, B. (2018b). Thermal and mechanical properties of bamboo fiber reinforced epoxy composites. Polymers, 10(6):608.

Zhang, P. F., Zhou, W., Yin, H. F., & Shang, Y. J. (2019). Progressive damage analysis of three-dimensional braided composites under flexural load by micro-CT and acoustic emission. Composite Structures, 226: 111196.

Zhou, H., Li, C., Zhang, L., Crawford, B., Milani, A. S., & Ko, F. K. (2018). Micro-XCT analysis of damage mechanisms in 3D circular braided composite tubes under transverse impact. Composites Science and Technology, 155: 91-99.

Zin, M. H., Abdan, K., Mazlan, N., Zainudin, E. S., & Liew, K. E. (2018). The effects of alkali treatment on the mechanical and chemical properties of pineapple leaf fibres (PALF) and adhesion to epoxy resin. In IOP Conference Series: Materials Science and Engineering, 368(1): 012035.