UNIVERSITI TEKNIKAL MALAYSIA MELAKA

RECYCLE ROVING FIBRE KIT FOR ROVING GLASS COMPOSITES

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this "RECYCLE ROVING FIBRE KIT FOR ROVING GLASS" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MUHAMMAD HAZIQ HAZMAN BIN ABD WAHID

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

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Date : 18 JANUARY 2022

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DEDICATION

Dedicated to

My beloved mother, Ruzaiha Binti Abd Aziz

My beloved father, Abd Wahid bin Mohd Yusof

My lovely sister, Nur Syazana and Nur Farzana Aida

My generous friends, Muhammad Fikri, Muhammad Ayyub, Muhammad Afiq and Shamsu Hazmirul

My apprentice, Ts. Mohd Fadli Bin Hassan

For giving me moral support, cooperation, encouragement and understandings.

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ABSTRACT

Composite materials have been the subject of study mainly synthetic fibers because of their high strength and light weight but non-bio-degradable nature. The waste of the machine pultrusion process in the composite industry has produced waste material in the form of roving, and usually this waste will be discarded, since there are no further studies that applied this waste to convert into application of glass fibre woven mats. Therefore, this study will explore the glass roving waste generated by pultrusion machine to the application of mat weaving patterns. This idea is for fibre waste that can used to make the something to be the product. In this research, the Recycle Roving Fibre Kit (RRF kit) is self-designed hand loom was produced to facilitate users to convert roving waste into glass mat plain weave patterns (RWR). Recycled mat samples (RWR) and commercial mat samples WR 600/(CWR) reinforced Epoxy and hardener using a hand -layup technique to produce test specimens for flexural, impact, density and water absorption testing based on ASTM standards. This study found that the 3 -plies RWR samples produced a maximum increase of 428.11% compared to the 3 -plies CWR in impact properties. Additionally, 1 ply RWR has a 74 % higher impact strength than 2 plies CWR, and 2 plies RWR has a 92 % higher impact strength than 3 plies CWR. Despite the RWR samples' excellent impact performance, its flexural properties were inferior to CWR. The density properties of the 3 -plies RWR were almost the same as the 3 -plies RWR sample with a slight difference of 0.5%. The best result for water absorption is 2 plies among the RWR samples, but its performance had an insignificant difference when compared to the 3 plies of CWR which were not more than 30%. It can be concluded, RWR can still be function similar to CWR while having better energy absorption result.

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ABSTRAK

Bahan komposit telah menjadi subjek kajian terutamanya gentian sintetik kerana kekuatannya yang tinggi dan ringan tetapi sifatnya tidak boleh terurai secara bio. Sisa proses pultrusion mesin dalam industri komposit telah menghasilkan bahan buangan dalam bentuk roving, dan biasanya sisa ini akan dibuang, kerana tiada kajian lanjut yang menggunakan sisa ini untuk ditukar kepada aplikasi gentian kaca anyaman tikar. Oleh itu, kajian ini akan meneroka sisa kaca roving yang dihasilkan oleh mesin pultrusion kepada aplikasi corak anyaman tikar. Idea ini adalah untuk sisa serat yang boleh digunakan untuk membuat sesuatu untuk menjadi produk. Dalam penyelidikan ini, Kit Kitar Semula Fiber Roving (RRF Kit) Semula adalah alat tenun tangan rekaan sendiri telah dihasilkan bagi memudahkan pengguna menukar sisa kaca roving kepada corak anyaman biasa tikar kaca (RWR). Sampel kitar semula (RWR) dan sampel tikar komersial WR 600/(CWR) diperkukuh Epoksi dan pengeras menggunakan teknik hand-layup untuk menghasilkan spesimen ujian bagi ujian lenturan, hentaman, ketumpatan dan penyerapan air berdasarkan piawaian ASTM. Kajian ini mendapati sampel RWR 3-lapisan mehasilkan peningkatan maksimum sebanyak 428.11% berbanding CWR 3-lapisan dalam sifat impak. Selain itu, RWR 1 lapis mempunyai kekuatan hentaman 74 % lebih tinggi daripada CWR 2 lapis, dan RWR 2 lapis mempunyai kekuatan hentaman 92 % lebih tinggi daripada CWR 3 lapis. Walaupun prestasi impak cemerlang sampel RWR, sifat lenturnya adalah lebih rendah daripada CWR. Sifat ketumpatan RWR 3-lapisan hampir sama dengan sampel RWR 3-lapis dengan sedikit perbezaan 0.5%. Keputusan terbaik untuk penyerapan air ialah 2 lapis antara sampel RWR, tetapi prestasinya mempunyai perbezaan yang tidak ketara jika dibandingkan dengan 3 lapis CWR yang tidak melebihi 30%. Dapat disimpulkan, RWR masih boleh berfungsi sama dengan CWR di samping mempunyai hasil penyerapan tenaga yang lebih baik.

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LIST OF SYMBOLS AND ABBREVIATIONS

CWR	-	Comercial Woven Roving
RWR	-	Recycle Woven Roving
D,d	-	Diameter
FRP	-	Fiber Reinforced Polymer
EU	-	European Union's
RRF	-	Recycle Roving Fibre kit
ASTM	-	American Society for Testing and Materials
MMCs	-	Metal Matrix Composites
CMCs	-	Ceramic Matrix Composites
PS	-	Polystyrene
PP	-	Polypropylene
PC	-	Polycarbonate
PEI	-	Polyetherimide
RTM	-	Resin Transfer Moulding
RFI	-	Resin Film Infusion
Polyvinyl chloride	-	PVC
Polyester-ether ketone	-	PEEK
Acrylonitrile-butadiene-styrene	-	ABS
Polyvinyl chloride	-	PVC

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CHAPTER 1

INTRODUCTION

This chapter will elaborate and explain about the background, introduction to pultrusion process, waste generated, and methods of handling composite waste. This research is an idea consisting of basic theories about past research, books, journals and online resources. Therefore, information and problems were collected to identify the improvements needed for this research.

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1.1 Background

The pultrusion process in the manufacturing industry is plain glass (GF), carbon (CF), or aramid (AF) reinforcing fibres are pulled through a thermoset resin bath for impregnation (typically a polyester, vinyl ester, or epoxy resin), and then permitted to enter a heated forming die, where it attains the shape of the die cavity and cures. Finally, outside the die, a continuous pulling mechanism pulls the already solidified composite part (GFRP, CFRP, or AFRP profile), which is subsequently trimmed to the necessary length by a cut-off saw (Meira et al., 2014).

Pultrusion manufacturing has progressed dramatically over the last 60 years, from its conception and early phases in the early 1950s to its present status as a well-established and efficient industrialized process (Lindahl et al., 2014). In reality, even when thermoplastic-based material is included, production wastes such as (glass roving's) (Yazdanbakhsh and Bank, 2014), non-conformance, and end-of-life items are often landfilled in the pultrusion sector, and in general in the composite materials business, due to their weak recycling capacity. Until now, companies have been quickly utilizing these materials without enough knowledge on how to dispose of them.

Incineration, thermal and/or chemical recycling technologies, and mechanical recycling procedures are currently available procedures that can be utilized to extract some value from thermoset FRP waste products. Because of the high calorific power of FRP materials, incineration is the most preferred method for recovering energy from the heat produced during the combustion process. Incinerator facilities, on the other hand, charge more for incinerating FRP wastes because the high calorific content and hazardous fumes overwhelm the system, limiting their ability to treat as much domestic waste. In addition, the air pollution caused by the combustion of FRP scrap must be considered (Conroy et al., 2006).

Various studies have been conducted in recent decades to estimate market requirements for new composites as well as the quantity of accumulating wastes in order to minimize the unavoidable negative repercussions. With an annual growth rate of 6.6 percent, the market for fibre-reinforced composites (FRC) in the market will reach $12 billion by 2020 (Naqvi et al., 2018). As a result, the pultrusion industry will give its fair part to this scenario. Due to increases of production, there will be more production waste generated and, in the near future, more end-of-life items.

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As a result, collaborating with other organizations to valorize by-products and production wastes, as well as encouraging recycling and repurposing of recyclates into new added-value goods, are crucial and necessary measures toward improving the sector's eco-efficiency. Furthermore, landfill and disposal will no longer be viable options due to more stringent EU waste management regulation, which includes higher landfill costs and capacity limitations (Pickering, 2006). FRP scrap materials will be set aside for recycling and reuse; as a result, FRP makers and suppliers must solve this issue if they do not want to lose market share to metal and other more readily recycled materials (Conroy et al., 2006).

Therefore, the current composite waste management system is insufficient to meet the problem of waste from composite manufacturing, particularly the waste addressed in this study, which is raw material waste from the pultrusion machine process (glass roving). This had decided to come out an idea to overcome the problem by creating a modelling Recycle roving fiber kit. The main material used to make this kit uses tools that are readily available, easy to make and do not require high costs. This kit is a small -scale and early stage model that uses basic weaving operations to weave waste into recycling mats so that this study can be a reference for researchers to create large -scale machines in the future because there are no previous studies examining fibre roving waste from the process of pultrusion machines converted to woven mats. In this study the weaving patterns of commercial mats such as plain, satin and twill are studied based on past studies to find out the type of weave that produces the best mechanical and physical properties. The best type of pattern based on past studies will be used to apply roving glass waste on the RRF kit to make a recycling mat. Then, this recycled mat pattern will be compared to the same pattern on commercial mats. This idea is for fibre waste that can used to make the something to be the product that can save costs and can overcome the problem of waste from the pultrusion process (glass roving) which can lead to global composite waste pollution reduction.

1.2 Problem Statement

Due to limited recycling capabilities, manufacturing wastes such as glass roving, inappropriate products, and end-of-life are often disposed of in the pultrusion sector, and in general in the composite materials industry (Meira et al., 2014). Various studies have been carried out in recent decades to anticipate market requirements for new composites as well as the volume of accumulated waste in order to reduce the unavoidable negative consequences. The market for fibre-reinforced composites (FRC) is expected to reach $ 12 billion by 2020, with an annual growth rate of 6.6 percent (Naqvi et al., 2018). As a result, the pultrusion sector will play a significant role in this scenario. Increased production will result in more production waste and, in the not-too-distant future, more end-of-life products and this can result in pollution to the environment because fiberglass is a synthetic material and its non -biodegradable.

This problem is further augmented by owing to stricter EU waste management regulations, which include increasing landfill fees and capacity constraints, dumping and disposal will no longer be feasible solutions (Pickering, 2006). FRP production waste materials will be set aside for recycling and reuse; as a result, if FRP manufacturers and suppliers do not want to lose market share to metal and other more easily recycled materials, they must address this issue (Conroy et al., 2006).

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Besides that, the problem found is before starting the pultrusion machine the first step of the procedure is set up glass roving through the resin reservoir area, die and finally puller will pull of glass roving. The result of this setup is a roving fiber glass that is wasted 25 meters in each cycle to produce a product according to the shape of the die. This waste glass roving will usually not be used and cannot be recycled because Pultrusion process is a continuous process and produce continuous product. Waste from the pultrusion process of this machine will result in an increase in waste in the composite industry which increases the cost because the glass roving waste cannot be recycled.

The most common is incineration, which allows some energy to be recovered from the heat produced during the combustion process due to the high calorific power of FRP materials; however, incinerator facilities charge more for incinerating FRP wastes because both the high calorific content and toxic emissions tend to overload the system, limiting how much domestic waste they can process, which can result the air pollution (Conroy et al., 2006). Pyrolysis is the most common thermal process, which involves heating scrap material in an inert atmosphere to recover the polymer material as oil. Because this type of atmosphere prevents combustion, the air pollution effects are less harmful than incineration (Pimenta and Pinho, 2011).

Due to the difficulties faced, the aim of this study is to develop a model kit that can help reduce composite waste, with a focus on glass roving fibre recycling from the pultrusion process. The purpose of producing the Recycle Roving Fiber Kit is to reduce fiber waste for the pultrusion process in the composite industry and can even introduce other alternatives in recycling glass roving waste with user -friendly without involving the use of a lot of cost, energy and environmental pollution to produce recycled products compared to recycling methods such as incineration, thermo and/or chemical recycling.

1.3 Research Objective

The main objectives of this project:

a) To fabricate Recycle Roving Fibre kit (RRF).

b) To produce fiber mats from roving fibre glass waste resulting from the pultrusion process using Recycle Roving Fibre kit (RRF).

c) To study the comparison of mechanical and physical properties between recycle mat and commercial mat.

1.4 Scope of Research

In order to achieve the objectives this research is focusing on the following scopes:

a) To designed a Recycle Roving Fibre kit that has a user-friendly design using SolidWorks software.

b) To fabricate self-designed handloom (RRF) which has an overall dimension of 1000 mm x 540 mm x 191 mm (L x W x H).

c) The fabricated Recycle Roving Fibre kit will be produced using low cost materials.

d) To produce a recycle mat using Recycle Roving Fibre kit.

e) To laminate the recycle woven mat and comercial mat using hand lay-up technique.

f) Tests will be conducted in accordance with ASTM standards to compare the mechanical and physical properties between woven recycled mats and woven commercial mats using impact, flexural, density and water absorbtion tests.

g) The results obtained from the tests are analyzed by comparing their properties and discussed to make a conclusion.

1.5 Rational of Research

In the rationale for this research, there are various important measures to examine, such as:

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a) In the composites industry, mostly the roving waste generated by the machine pultrusion process being disposed of through landfill, instead it can be reused by converting it to another product such as in the form of a woven mat.

b) Recycle Roving Fibre Kit is another new alternative to overcome the problem of recycling waste to reduce roving fiber waste for pultrusion process in the composite industry by introducing user -friendly recycle roving fiber kit without involving much cost, energy and environmental pollution.

c) Produce and generated advanced research based on experiments and technical research by converting pultrusion process material waste into reusable materials.

d) To be studied comprehensively so that this study serves as a reference point for future analysis by making this model to researchers to develop large-scale machines.

1.6 Thesis arrangement

The major purpose of this research is to investigate the waste problem from pultrusion machines by converting the waste into a fibre mat that can be reused and reduced in cost utilising the Recycle Roving Fiber kit (RRF). Chapter 1 is primarily concerned with the study's introduction, which comprises the background, problem statement, objectives, scopes, research rationale, a synopsis of the methodology, and the thesis arrangement. For Chapter 2, Analysis of literature relevant to previous studies including introduction of loom and composites whereas containing reinforcement types, synthetic fibres, fibre forms and roving, composite laminated, applying a review of mat weaving patterns from synthetic fibres is also included. Otherwise, the description of the physical and mechanical testing is included. Followed by Chapter 3 as the methodology used in this research to explain proper process flow and methodology is used to produce RRF kits and recycling mats of different weaving patterns using roving waste. These methods include preparation of raw materials, manufacture of products and testing with standard tests namely impact test, flexural test and density test and water absorption. Data from of the experimental results are gathered and analysed in Chapter 4 for data analysis. The results of several types of testing would be analysed and discussed.