UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND ANALYSIS FOR DEVELOPMENT OF BICYCLE HELMET MOULDING PROCESS

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

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DECLARATION

I hereby, declared this report entitled “PSM Title” is the results of my own research except as cited in references.

Signature :……..

Author’s Name :……..

Date :……..

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the Bachelor Degree of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

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(Project Supervisor)

ABSTRACT

Mould is a container that is used to gives shape to a product with various media. With the help of CAD/CAM technique available nowadays together with advance machining, the mould production time and cost of manufacturing can be reduced. Also, the limitation of the conventional moulding technique can be improvised. Open mould is one of the mould that is suitable for hand lay-up technique of moulding where rapid product development cycle can be developed. Hand lay-up technique is suitable for fabricating composites product which is the epoxy resin with kenaf fiber reinfored. Air pollution due to industrialisation is the biggest concerned nowadays. In order to achieved greener manufacturing practice, synthetic material used by manufacturer to produced a product is replaced by non- synthetic material such as epoxy resin with kenaf fiber reinforment. The use of material like ABS plastics going through injection moulding process will affect both operators and end users health and also environment. This project designed an open mould suitable for the hand lay-up moulding of kenaf fiber with epoxy resin adhesion. Furthermore, the propose of the project is to analysed the mould designed for its mechanical properties such as plasticity, hand lay- up problem and sharp edges effect upon the product. In order to get the most suitable mould for hand lay-up moulding, the mould is first being analyzed with ANSYS software analysis. From the Pugh concept selection method, open mould design was selected as it is satisfy all the criteria needed for the fabrication process. After the mould is validated where from the analysis shown that the design is strong and have safety factor of 0.71722. Thus, the fabrication process of outer shell of the helmet can be used with this mould repeatedly, the outermost bicycle helmet shell is fabricated using hand lay-up technique by concerning about curing time to achieved better result.

ABSTRAK

Acuan adalah bekas yang digunakan untuk memberi bentuk kepada produk daripada pelbagai media. Dengan bantuan teknik CAD/CAM yang terdapat pada masa kini dengan penggunaan pemesinan moden, masa pengeluaran acuan dan kos pembuatan dapat dikurangkan. Juga, had atau kesukaran teknik membentuk konvensional boleh ditambah baik. Acuan terbuka adalah acuan yang sesuai untuk teknik "*Hand lay-up"* acuan di mana perkembanyan kitaran produk boleh dihasilakn.Teknik "*Hand lay-up"*sesuai untuk menghasilkan produk komposit yang merupakan resin epoksi dengan gentian kenaf sebagai penguat. Pencemaran udara daripada aktiviti perindustrian adalah faktor yang membimbangkan pada masa kini. Usaha untuk mencapai amalan pembuatan yang lebih hijau, bahan sintetik yang digunakan oleh pengeluar untuk menghasilkan produk perlu digantikan dengan bahan bukan sintetik seperti resin epoksi dengan gentian kenaf sebagai penguat. Penggunaan bahan seperti plastik ABS yang melalui proses pengacuan suntikan akan memberi kesan kepada kesihatan kedua-dua pengendali dan pengguna dan juga alam sekitar. Projek ini mereka acuan terbuka yang sesuai untuk teknik "*hand lay-up"* bagi serat kenaf dengan epoxy resin sebagai adhesi. Tambahan pula, tujuan projek ini adalah untuk menganalisi acuan yang direka untuk sifat mekanikal acuan seperti keplastikan, masalah "hand lay-up" efek dan efek bucu tajam terhadap acuan. Dalam usaha untuk mendapatkan acuan yang paling sesuai untuk acuan teknik "*hand lay-up"*, rekaan acuan terlebih dahuli dianalisis dengan menggunakan analisis ANSYS. Selepas acuan disahkan dengan kaedah pemilihan konsep Pugh, reka bentuk acuan terbuka dipilih kerana ia memenuhi semua kriteria yang diperlukan untuk proses fabrikasi. Selepas acuan disahkan di mana dari analisis menunjukkan bahawa reka bentuk adalah kuat dan mempunyai faktor keselamatan 0.71722. Tempurung topi keledar

basikal dihasilkan menggunakan teknik "*hand lay-up"* dengan mengambil kira faktor masa pengawetan untuk mencapai keputusan yang terbaik.

DEDICATION

To my beloved mother Mrs Sharifah binti Salleh and my beloved father Mr Mohd Zulkarnain bin Hassan

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	- Acrylonitrile- Butadiene- Styrene
A&E	- Accident and Emergency
CNC	-Computer Numerical Control
FDM	- Fused Deposition Modelling
GFRP	- glass-fibre reinforced plastic
HL	- Hand Lay-Up
LSR	- Liquid Silicon Rubber
PMCs	- Preformed Moulding Compounds
PP	- Polypropylene
POM	- Polyoxmethylene
SLA	- Stereolithography
SLS	- Selective laser sintering
STL	- Standard Template Library
UCS	- Ultimate Compressive Strength
UTS	- Ultimate Tensile Strength
VI	-Vacuum Infusion
VIP	- Vacuum Infusion Process

CHAPTER 1
INTRODUCTION

1.0 Background

Moulding process is crucial in manufacturing process in giving the desired shape of a work piece. A process of shaping liquid or pliable raw material using a rigid frame is known as mould or matrix with hollowed- out block ("What Is Moulding?" 2014). What defers mould from casting though both are the process shaping a specimen or product is that mould is a common term used for shaping plastics while casting is a common term used for metal shaping (Groover, 2007). They are several categories of moulding process according to Groove (2007). First is particulate process which involves the use metal powders and ceramics whereby these materials involves in the technique of pressing and sintering. Second is deformation process where the raw material is being shaped by the application of forces that exceed the material's yield strength. Third is metal removal process. The operation in this process involves in removing the excess of the raw material from the starting work piece and formed it into desired shape. Lastly is surface processing where the operations of cleaning, surface treatment, coating and thin film deposition process take place.

According to Steel (2012), helmet can be define as a hard hat that is used to protect the head. The legislation upon helmet's wearing among cyclist has been enacted across almost all of the country in the world. Take the United States for example, the government has requires the cyclist to wear helmets since 1987 to the 22 states and 201 localities and ordinance including the District of Columbia ("Bicycle Helmet Law", Jan 2017). This law is enacted due to the increment of injuries amongst cyclist. Over 900 bicyclists were killed and about 494 000

emergency department visits due to bicycle injuries in 2013 according to Centre for Disease Control and Prevention (2016). There are three basic types of bicycle helmet. First is recreational helmets second is rode bike helmet and third is mountain bike helmet. These helmets usually use the in-mould type of construction where the outer shell and inner shell are fused without using any glue. This type of moulding results in light-yet-strong design.

1.1 **Problem Statement**

Acrylonitrile- Butadiene- Styrene (ABS) is a thermoplastic material that has been used widely in manufacturing world. Despite the versatility of this material in manufacturing world, there are drawbacks that lead to severe environmental defect. The environment is endangered by the melting process where hazardous gasses were emitted during injection moulding process. The melting plastic used for injection moulding also may be hazardous to the operator where there might be potentials of getting skin burns from contact with the heated barrel or from splattering hot plastic and gases or vapours (United States Department of Labour). The concern of the non-biodegradable material also is one of the major contributors to environmental hazard (Carr, 2016). Furthermore, photochemical oxidation contain in the plastic depleting the ozone layer (Elduque *et al.*, 2015).The alternatives way available nowadays still using plastic based as material for the outer shell of the bicycle's helmet. Mould of the outer shell of the bicycle is usually made out of metal which is complex and costly to fabricate. Also, the humidity effect during the processing phase where the humidity enters the system while the plastic is being made there will be uneven surface appearance of the moulded part and worst it is unusable ("Plastic Materials", n.d).

According to (Olofsson, Bunketorp and Andersson, 2015), until 2009 there are 3578 in average annually children below 18 years of age were severely injured in road traffic crashes. Most of the cases that visit the accident and emergency (A&E) are not a helmet wearer and people who are not concern about the benefits of wearing the helmet that meet the specification. The helmets that are mostly bought

by especially the recreational cyclist are only based on the appearance. The awareness on the benefits of wearing a good helmet amongst cyclist especially the recreational cyclist is still low. The education about how the good design and material of the outer most shell of the bicycle helmet is still at its bottommost level. Severe head injuries may leads to death without proper protection to prevent the occurrence.

1.2 Objectives

1. To design and fabricate moulding for bicycle helmet outermost shell
2. To analyse the mould design using computerize analysis
3. To fabricate the outermost shell of the bicycle helmet

1.3 Scope of Project

In order to achieve the objectives, several scopes have been determined:

1. Designing the moulding for bicycle helmet outermost shell by using Solidwork.
2. Analysing the mould using Ansys software analysis.
3. Fabricating the mould of the bicycle helmet using liquid silicone rubber.
4. Fabricating the outermost shell using hand lay-up with epoxy-resin and kenaf fibre as the reinforcement.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Moulding is a very important component used to shape the product designed. The design for a product will need the aid of the computerized drawing software for higher precision and in-depth analysis on the mould designed to assure the defect that might occur during the product fabrication. Technique of fabrication should consider types of material that is being manufactured and the suitability of the chosen technique for the material to adapt with. Hand lay-up technique is a traditional technique in fabricating composite; however it is the most suitable technique that can be implied in making the outer shell of the helmet that is going to be reinforced with natural fiber.

2.1 Basics of Moulding

Mould is basically a container used to pour a liquid or a substance into (Steel, 2012). A mould should have a passage where a material can be transferred into it from the press. Also, the design of a mould should provide a method that allows the material to be hardened and a method of ejection to remove the formed part from the mould. While moulding is usually used for plastic manufacturing, there are several types of moulding process that being used in industry according to their application and product requirement. In manufacturing composites there are many methods that can be used. Figure 2.1 shows methods of manufacturing composites like epoxy resin with Kenaf fiber as reinforcement.

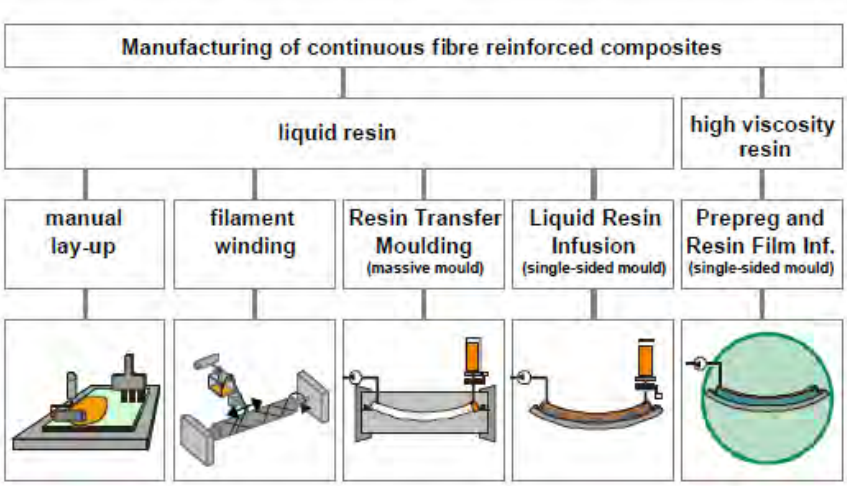

Figure 2.1 : Composite Manufacturing Technologies (Kleineberg, Herbeck and Schöppinger, 2004)

2.1.1 Injection Moulding

Injection mouldings are the most popular moulding process that is being used in all plastics forming industry nowadays. There are three types of plastics that are frequently being used in the injection moulding process. They are Acrylonitrile Butadiene Styrene (ABS), polypropylene (PP) and polyoxmethylene (POM). ABS is known with its good impact resistance and toughness, good surface finish and it is light in weight. There is over 1 to 37 million tons per year of global production that used this type of polymer (Lithner, 2011). However, there are many drawbacks despite the goods that this polymer provides. The most worrying issues upon the used of the ABS polymer is the environmental hazard that is effected by the melting process of the polymer in order to make it able to form into desired shapes by the manufacturers. Polypropylene is one of the most versatile plastic that can across the multifunctional task that is discovered by an Italian scientist in the mid of 1950s ("What is Polypropylene Plastics, 2014). It has a high melting point, does not react with water, detergent acids or bases which make it stiff and it is durable where it can withstand daily wear and tear. The limitations of polypropylene are it is highly flammable and is susceptible to UV degradation.

2.1.2 Vacuum Infusion Moulding

UGent (2012) mention that there were many techniques to produce fiber that widely used nowadays. One of the techniques is Vacuum Infusion Process (VIP). This technique uses that vacuum pressure to drive resin into a cover. This procedure requires some assortment of supplies and materials. This technique had a few improvements implemented over traditional vacuum bagged parts. Thus, it provides much more advantages over the traditional method.

One of the advantages is this technique offers a better fiber-to-resin ratio than traditional vacuum bagging where it gives 1% in average of voids content (Swaylock's Surfboard Design Forum, 2011). A typical hand lay-up usually results in excess of 100% fabric weight by resin. Although vacuum bagging could reduce this number significantly, the technique was considered as not ideal as it could lead to additional problems. Vacuum pressure remove a significant part of the resin, yet the amount removed still relies on a few factors such as reinforcement, resin, time factors, and others. Meanwhile, Vacuum infusion uses an alternate approach, in that a vacuum is drawn while the materials are still dry. After that, the resin is infused using vacuum pressure. Preferably, the vacuum line will eventually sucked out excess resin that is presented. Thus, just the base measure of resin is presented. This will help to lowers weight, increases strength, and maximizes the properties of fiber and resin. Besides that, this also gives less wasted resin produced during the procedure, and of course reduces waste of money. Reinforcing fibres are more oriented in any direction at specific and targeted locations.

Another advantage of this technique is unlimited set-up time (St, no date). In average, resins have a pot-life of about 30 minutes. Different type of resins offers different work times. For instance 2000 Epoxy offer work times of up to 2 hours. However, vacuum infusion offers unlimited set-up time. This is because the vacuum is applied while reinforcements are still dry. After the sack is connected, holes can still be sought out. On the off chance that something is legitimately placed, simply discharge vacuum and rearrange it.

There were no time limitations until it is concluded that the time has come to infuse the resin. Before that minute, any changes can be made repeatedly. The last benefit provides by vacuum infusion is it gives much cleaner process which is very preferable for bicycle helmet making that held indoor. There are no brushes or rollers used during the process that could result in splashing or spattering. Furthermore, there are less resins fumes to contend with. Because the only fumes radiate from the resin reservoir, they are to some degree containable. Vacuum infusion process gives a cleaner, more secure, and friendlier workplace, however it is still critical to work in a very much ventilated region and wear a respirator and other proper security gear.

Finish with the advantages, next is the process of resin infusion. The apparatus and equipment was set as we can see from the Figure 2.2. The arrangement of material in vacuum infusion process is illustrated in Figure 2.3.

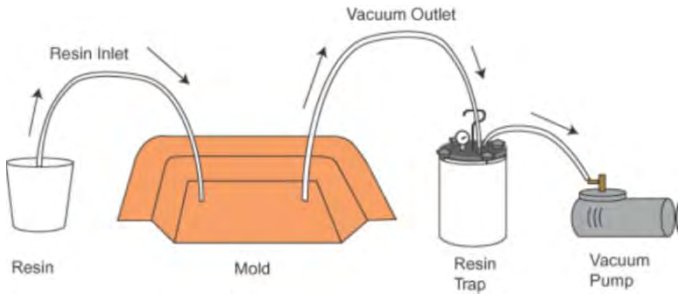

Figure 2.2**:** Sequence of vacuum infusion process(UGent, 2012)

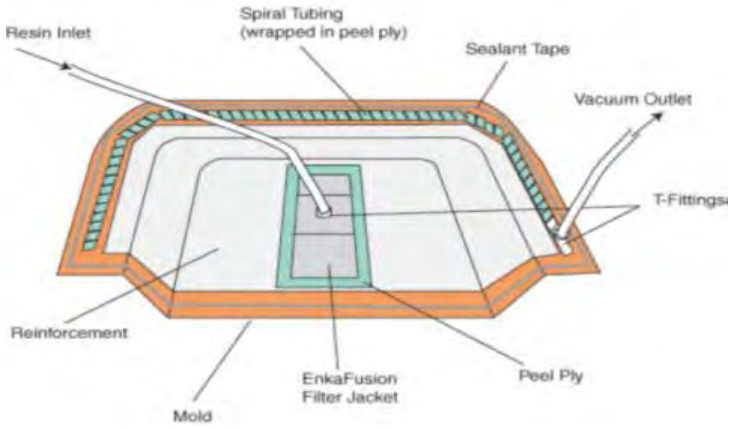

Figure 2.3**:** Arrangement of Materials (UGent, 2012)

2.1.3 Mechanical properties and production quality of hand-layup and vacuum infusion materials

Over the decades, there were many typical techniques of fabricating glass-fiber reinforced plastic (GFRP) structure including wet hand lay-up (HL), vacuum infusion (VI), filament winding and resin transfer moulding (Sharma and Wetzel, 2010). Primary concern for larger the structures is the fabrication cost. In order to maintain the demanding design specifications huge investment were needed. Besides that, mechanical properties and performances of the composite structures are highly influenced by composite manufacturing processes (Kim et al., 2010; Ramulu et al., 2004). However, hybrid GFRP composites, which formed by applying the HL technique to construct the exterior layup against the mould, followed by a VI process on the interior once the HL processed layers are cured was introduced recently (Kim et al., 2010). This hybrid composite gives many advantageous for both composite structural performance and ease of manufacturing. Besides that, it also provides a good resistance to wave impact or local shock loads while provides high strength and stiffness due to its high fiber fraction volume (Belingardi et al., 2008; Kim et al., 2010). The procedure of the process hybrid GFRP material design and fabrication was start with placing the glass fiber manually inside mold. Next, matrix material was spread evenly over the fiber layers. The next processes are the VI process. Glass fibers were placed into, or on top of, a mould and covered with a thick plastic bag material. In order to spread the resin throughout the fiber evenly vacuum was used. Besides spreading the fiber, vacuum help to reduce voids and material discontinuities by evacuating air bubbles. For better impact or shock resistance, two sets along with two [M/90/0] chopped mat layers were fabricated using hand lay-up technique. Then, the vacuum infusion process was used to add additional [M/90/0] sets into the existing hand lay-up processed portion (Sang-Young Kim et al., 2014).

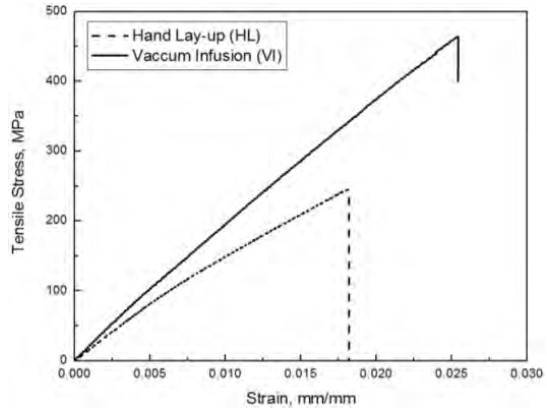

Figure 2.4: Tensile stress-strain curve (Sang-Young Kim et al., 2014)

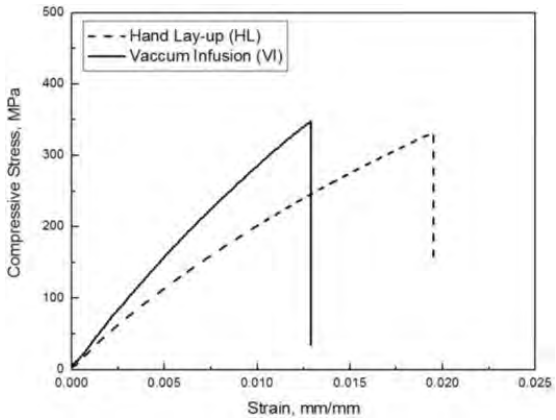

Figure 2.5: Compress stress-strain curve (Sang-Young Kim et al., 2014)

Table 2.1: Average mechanical properties in tension (Kim *et al.*, 2014)

	Hand Lay-up			Vacuum Infusion		
	Batch 1	Batch 2	Batch 3	Batch 1	Batch 2	Batch 3
Ultimate	249.8	299.5	282.3	433.0	430.9	420.2
Modulus(*GPa*)	13.8	13.5	13.0	17.7	18.8	16.7
Strain at break(%)	1.85	2.39	2.30	2.39	2.30	2.54