

DESIGN AND MANUFACTURE OF RECURVE BOW  
RISER USING FUSED DEPOSITION MODELING (FDM)  
AND FIBER- REINFORCED COMPOSITE MATERIAL

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

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## **APPROVAL**

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory is as follow:

.....

(Project Supervisor)

## DECLARATION

I hereby, declared this report entitled “Design and Manufacture of Recurve Bow Riser Using Fused Deposition Modeling (FDM) And Fiber- Reinforced Composite Material” is the results of my own research except as cited in references.

Signature : .....

Author's Name : .....

Date : .....

## ABSTRAK

Projek ini adalah untuk merangka semula dan mengeluarkan riser busur memanah *recurve* menggunakan *Fused Deposition Modeling* (FDM) dengan meningkatkan kekuatan dan pemilihan bahan. Satu kaedah salutan prototaip yang menggunakan gentian karbon telah digunakan untuk meningkatkan kekuatan riser. Walau bagaimanapun, terdapat perubahan sedikit, iaitu disebabkan ketidaksuaian kaedah salutan untuk prototaip. Pembalut kaedah vakum telah digunakan untuk timbunan bahan komposit serat karbon ke dalam pelbagai lapisan berlainan set. Ini kemudiannya telah diuji menggunakan Universal Testing Machine (UTM) untuk menguji kekuatannya. Ia didapati bahawa lapisan komposit boleh menahan 0.1 KN beban. Oleh itu, mengukuhkan menggunakan bahan ini sesuai untuk menjadi terang, mudah untuk membentuk dan kuat.

## **ABSTRACT**

This project is done to redesign and manufacture the archery recurve bow riser using Fused Deposition Modelling (FDM) with improve in weight strength and material selection. A method of coating the prototype using carbon fibre was used to enhance the strength of the riser. However, there were slight changes, due to inappropriate method of coating to the prototype. Vacuum bagging method was used to stack the carbon fibre composite material into multiple layers, with different set of layers. This then was tested using Universal Testing Machine (UTM) to test the strength. It is found that the layer of composite can withstand 0.1 KN of load. Thus, reinforcing using the material is suitable for it is light, easy to shape and strong.

## **DEDICATION**

I dedicate this work to my family and many friends. A special feeling of gratitude to my loving parents whose words of encouragement and push for tenacity ring in my ears. I also dedicate this project to my many friends who have supported me throughout the process. I will always appreciate all of you who have commented, give opinions and suggestions in upon completing this project.

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Furthermore I would also like to acknowledge with much appreciation the crucial role of the staff of Faculty of Manufacturing Engineering, who gave the permission to use all required equipment and the necessary materials to complete the task related to my project. Special thanks go to my friends who gave suggestion regarding my project. Last but not least, I have to appreciate the guidance given by other supervisor as well as the panels especially in my project presentation that has improved my presentation skills thanks to their comment and advices.



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# CHAPTER 1

## INTRODUCTION

Archery is one of the most popular activities that has been known since Paleolithic, and has been popular ever since. It is also a type of sport and is played at Olympics. Not only known as a sport or for competition but also used as an activity such as hunting. In fact, the history of archery starts with hunting, whereby people from Paleolithic used archery to hunt for their living. Since then, archery had been developed through centuries to become as a sport.

The difference between previous archery and now is not much. The only difference is the shape, design and also the technology applied on the construction of the bow and arrow. The concept of playing is still the same, where by one need the arrow, bow and target to play archery. Not to forget a right technique to avoid injury that could occur. Revolution of bow and arrow has been developed from centuries. Figure 1.0 shows the pictures of bow from previous century and current one:



Figure 1.0 (a): Previous Century Bow



Figure 1.0 (b): Current Recurve Bow

Archery is a very simple sport and very easy to play with. It can train one to be more focus, plus can be act as a self-defense. There are 3 basic things needed to play archery, which are: bow, arrow and target bad. Despite these few things, skills and techniques are also needed.

There are many types of archery bow; one that is use for hunting, sport, and etc. Bow for hunting and sports have a different function and method to use. For the hunting bow the archer need to pull the string up to the side of the archer eyes. Figure1.0 (c) below shows how this is done:



Figure 1.0 (c): Hunting Bow

For the sport bow, archer needs to pull the string and anchor it under the chin, and to make sure the string touch the lips and the tip of the nose. Figure 1.0 (d) below shows how the archer shoot using this type of bow:



Figure 1.0 (d): Compound Bow

Despite the type of archery, the bow use in the sport branched into two types, which are; recurve bow and compound bow (Mary B, 2005). Recurve bow has several parts that can be dissembled and assembled to become a complete bow. This makes it portable and easy to carry around during tournament or etc. The parts consist of raiser, upper limb, lower limb and string. In the archery industry nowadays, the top company for bow production is Win&Win from Korea, and another one is Hoyt, from the America.

On the other hand, compound bow is much smaller than recurve bow. The most obvious difference from recurve bow is that, it has cam to operate the draw of string while shooting the arrow(Mary B., 2005)This basically operate using lever system.



There are many design of the bow, mostly in the riser part that could affect the strength of the bow itself. Not only the design of the raiser, but material also plays an important role on the strength of the bow. Some of the common used material is carbon graphite, forged aluminum, royal cross carbon(Marry B.,2005).

### **1.1 Problem Statement**

Nowadays, there are many type of riser design for archery bow. Each of this riser has their own weight specifically, according to the type of design and material. This makes the archer has difficulty to handle the bow weight for a long time. In this project, a riser with low weight but has good performance will be manufactured.

### **1.2 Aims**

To design and manufacture a low- weight riser yet has good performance and strength.

### **1.3 Objective**

The objectives for this project are:

- a) To redesign and manufacture the riser prototype using FDM machine.
- b) To reinforced composite material to the prototype.
- c) To test and analyze the prototype

### **1.3 Scope**

The riser design is only for recurve type of bow which is used in sports. It also does not cover the other part of the bow such as the string and limb. The material use is only fiber- reinforced.

## **CHAPTER 2**

### **LITERATURE REVIEW**

Today riser design had been tremendously advanced and popular whereby they are so many improvements done by the famous archery bow manufacture company such as Win & Win and Hoyt. This result from improve research to enhance the performance of bow (Lieu,D.K, 2010). This study aims to improve the design of typical riser base on weight and strength. Thus, this chapter touches on five important key points that are riser design, riser weight, material use, process of manufacturing and coating of fibre layer.

#### **2.1 Riser Design**

In order to design a riser, the first thing to look up to is the aesthetic value to be parallel with the performance of the riser. One would not want a ‘good looking’ riser but least in performance. The dimension also plays an important role upon designing the riser. Because the size of the user is differ from another, thus the dimension is varied accordingly. There are three types of standard riser design namely deflex, inline, reflex -the pictures below, apparently is not recurve bow, but for compound bow.

##### **2.1.1 Deflex Riser**

Deflex risers have the limb pockets behind the arrow rest. This is the most forgiving design and will shoot better groups easier. However, it may not reach the distances needed for shooting long-distance target rounds.



Figure 2.11: Using Deflex Riser Design

### 2.1.2 Inline Riser

Inline risers have the limb pockets in line with the arrow rest. These bows are less forgiving, but have more speed, making it easier to reach the long distances easier. In general, this is a good compromise for a target bow.

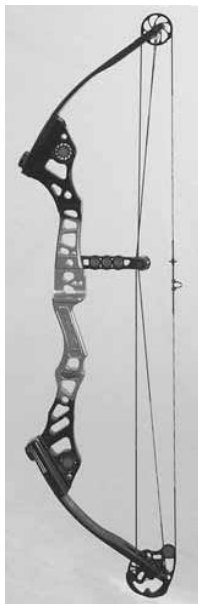


Figure 2.1.2: Using Inline Riser Design

### 2.1.3 Reflex Riser Design

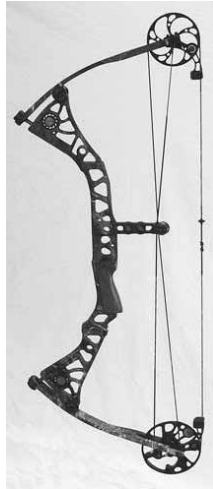


Figure 2.1.3: Using Reflex Riser Design

Reflex riser has the limb pockets in front the arrow rest. These have the most speed (and therefore, get the most distance), but can be more critical. Older reflex bows may be more critical than newer ones.

This three types of riser could influence the speed of arrow upon release. But the speed of arrow is not covered in this study.

There is previous riser design which focuses on movable arrow rest, which has been patented on 2011 that help on minimizing the rotational effect of an archer's forehand when drawing a bow string. From the patented study, it is said that there were many conventional arrow rest are connected to a bow riser with a bracket. The bracket can adjoin the arrow rest to one of many different types of bow risers, using mounting hole, with particular size and position according to an Archery Manufacturers and Merchant's Organization (AMO) specification(Miroslow A. 2011).

The bracket includes a moment arm that offsets the arrow rest from and thus not aligns with a longitudinal axis of the bow riser. From the study, this offset makes aiming at a target more difficult for an archer. From that, the patented riser was design to tackle this problem. Below are the related pictures from the

patent; Figure 2.1.3 (a) is the perspective view of a portion of the archery bow riser in a start position, according to one embodiment of the respective invention.

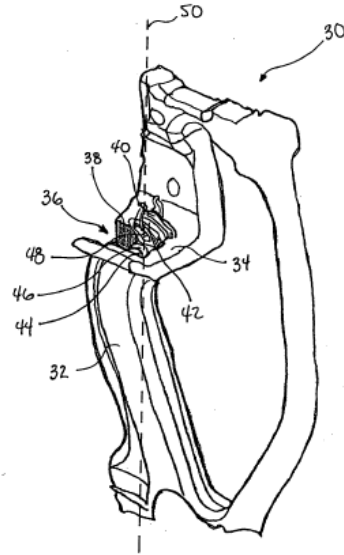


Figure 2.1.3 (a): Perspective View of Bow Riser

While as Figure 2.2 (b) below is the perspective view of a portion of the archery bow riser in a launch position;

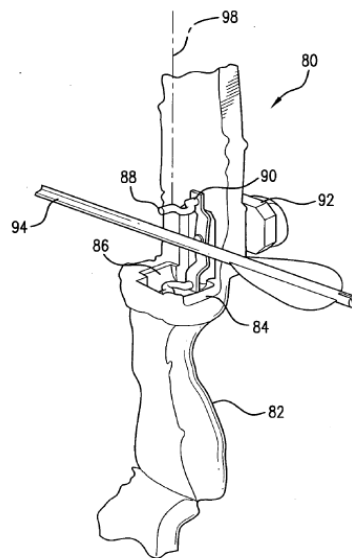


Figure 2.1.3 (b): Bow riser in Launch Position

The patent basically focuses on the ergonomic of the riser upon release. Which has stated previously; the author claims that from the current archery riser design, it creates difficulties for archers to aim the target. Unfortunately, this is not covered in this study as the design suit for compound bow only. Recurve bow is simpler and does not have any offset to make it hard to aiming the target. Thus this design is not suitable to be applied in the project.

## **2.2 Bow's Weight**

Anybody who ever shoot an arrow before, definitely would know how heavy the bow is. The weight of the limb, riser, stabilizer, sight stabilizer, the weight and other accessories make the bow heavier. This statement however, is differing from every type of archery bow. The hunting bow for example, seldom needs additional accessories because, this will make the archer difficult to bring along the equipment. Differ from sports bow, the archers definitely need accessories to enhance their bow performance, in terms of stability, reduce vibration and etc. (Wise, Larry; n.d).

The efficiency of a bow will increase when the weight of the moving parts of the bow is lighter. The moving parts are the limbs and the string (Lieu, D. K, 2010). This statement shows that riser weight will not affect the efficiency of the bow either making it heavier or lighter. But in current market, the riser has been made lighter from time to time, in order to fulfill customer specification. Some might not want to bring heavy equipment during tournament or go for hunting.

## **2.3 Material Use**

Previously many materials had been used to produce riser such as, wood, aluminum, carbon and etc. Choosing material to fabricate riser is important because, different material has different mechanical properties such as strength, weight, and stiffness. These three is the main properties designer look for upon fabricating the riser.

The material use must pose high strength in order to stand the vibration after the shoot. The mechanism of arrow basically; when the archer draw the arrow, a lot of kinetic energy is stored in the limb and string. Upon releasing, the kinetic energy is then transferred to the riser and this will produce vibration (Lieu, D. K, 2010).

The continuous vibration will affect the riser in time and could possibly undergo crack. Thus, there are many riser made from material that has high stiffness and strength in order to last long. There is a design of multiple layer of material used in this area, that is using two to three materials to produce a limb. Figure below is the cross section of modern Olympic recurve bow limb;



Figure 2.3: Layer of Material

The material is usually fiber glass or epoxy matrix in order to produce strength and stiffness with low weight (Lieu, D. K, 2010).

Glass fiber reinforced plastic (GFRP) composites are widely used in sports equipment due to their multi potential properties, such as high strength to weight ratio, high specific stiffness, high damping, high fracture toughness, good dimensional stability and excellent corrosion resistance (Ramesh, B.; Ajay Balaji,D; 2013). The appearance of new materials such as carbon fiber composites, which are both lighter and stronger than previous material have improved the performance of Olympic recurve bows over the past two decades.

Typically the riser is fabricated from metal such as aluminum or magnesium or from composite materials that generally lack any appreciable amount of. Upon drawing the bow string back on a bow having riser fabricated from material that substantially

inelastic and limbs that are more flexible; producing an undesirable stresses into the bow. Technically speaking, the stress is produced in the joints between riser and the limbs. If left unnoticed, these stresses may compromise the structural integrity of the bow (Pilpel, E 2013).

Moreover, Pilpel also mention that in bows and crossbows that have risers fabricated from substantially inelastic material, the opportunity for stress- related cracking to develop as result of repeated use increases. Apart from that, climate changes also a key to the deterioration of the microstructure of the material of the riser, which later will reduce the useful life of the bow. Furthermore, this deterioration of microstructure too, can lead to visible defects in the riser which in turn can affect the overall appearance of the bow. The problem is explained by Pilpel; climate changes such as high temperature that results in increases creep or degradation of the composite matrix or the adhesive used, and variation in humidity.

Pilpel then patented an archery bow, mainly riser which it's general objective is to provide an archery bow having components fabricated from a material that overcomes the problems stated below.

## **2.4 Manufacturing Process**

There are many processes used to fabricate riser, be it conventional machining or non-conventional machining. Not only that, previous process also used die casting (arundown.org.uk). But mostly, the popular company such as Hoyt and Win&Win Archery use machining due to good surface finish and less time consume.

For this study, FDM machine is use to fabricate the prototype. This one also will help in testing the strength of the material. An intake manifold were fabricate using FDM to develop a new design which has result in reduce of weight, improved charge distribution to compare with traditionally- manufactured aluminum counterpart. The use of FDM in order to optimize a certain design is useful as one could replicate the original object without destroying it upon undergoing a test ( Ryan, I 2009).