

DEVELOPMENT OF HYBRID  
NATURAL/SYNTHETIC FIBER REINFORCED  
POLYMER COMPOSITE OF RECURVE BOW  
RISER FOR MALAYSIAN JUNIOR ATHLETES

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## SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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## **STUDENT'S DECLARATION**

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ATHLETES

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## ABSTRAK

Penggunaan gentian asli dan sisa produk telah menjadi satu keperluan untuk pembangunan lestari dalam pelbagai industri. Penggunaan gentian asli dalam industri berorientasikan sukan semakin meningkat pada tahun kebelakangan ini. Busur lentik (*recurve bow*) merupakan satu-satunya jenis busur yang digunakan dalam acara memanah di Sukan Olimpik. Justeru ianya penting untuk merekabentuk pemegang busur lentik bagi penggunaan pemanah junior di Malaysia. Kajian ini bertujuan untuk menganalisis pemegang busur lentik untuk pemanah junior Malaysia dengan menggunakan gentian asli sebagai bahan alternatif. Kajian ini dibahagikan kepada tiga fasa iaitu fasa penyediaan dan persiapan, fasa eksperimen, dan fasa analisis dan pengesahan. Dalam fasa penyediaan dan persiapan, campuran gentian semula jadi seperti serat kenaf dan daun nanas dituang bersama bahan pelekat iaitu *epoxy* ke dalam acuan dengan menggunakan kaedah manual (*hand lay up*). Setelah itu, komposit tersebut dikeringkan secara semulajadi pada suhu bilik selama 24 jam. Setiap campuran komposit di bahagikan kepada tujuh spesimen mengikut piawai ASTM D3039 dan ASTM D790 untuk ujian tegangan dan ujian lenturan. Gentian asli daun nanas dan gentian asli kenaf telah dipelbagaikan komposisi dengan 5 wt.% dan 10 wt.%, telah dihibridkan dengan 95 wt.% dan 90 wt.% gentian asli karbon dan gentian kaca (95 CF/5 PALF, 95 CF/5 K, 90 CF/10 PALF, 90 CF/10 K, 95 GF/5 PALF, 95 GF/5 K, 90 GF/10 PALF and 90 GF/10 K). Kandungan keseluruhan gentian adalah ditetapkan sebanyak 40 wt.%. Hibrid bahan gentian semula jadi terbaik telah dipilih berdasarkan dari hasil dapatan ujian tegangan dan lenturan. Dalam fasa analisis dan pengesahan, analisis struktur statik pemegang busur lentik telah dijalankan pada pemegang busur lentik. Analisis beban semasa tarikan penuh dilakukan setelah panjang tarikan tali busur diperolehi. Hasil dari fasa penyediaan menunjukkan bahawa penggunaan komposit serat daun nanas dan serat kenaf boleh digunakan dalam fasa eksperimen. Hasil dapatan menunjukkan bahawa sifat-sifat bahan komposisi yang terbaik adalah 95 CF/5 PALF. Ini disebabkan ia mencapai kekuatan tegangan yang tinggi, kekuatan lenturan dan ketumpatan yang rendah. Komposisi ini kemudian digunakan dalam analisis unsur terhingga. Dalam analisis unsur terhingga, anjakan maksimum pemegang busur lentik dengan 95 CF/5 PALF menunjukkan 98 % pengurangan anjakan maksimum pemegang busur lentik dengan kajian terdahulu. Kesimpulan dari hasil dapatan, 95 CF/5 PALF sesuai digunakan pada pemegang busur lentik alternatif. Ini kerana ia dapat mengekalkan daya yang dikenakan oleh pemanah junior Malaysia apabila mereka membidik papan sasaran pada keadaan tarikan penuh. Di samping itu, komposisi 95 CF/5 PALF ini berada didalam julat kekuatan mekanikal yang sama dengan aloi aluminium. Rekabentuk alternatif pemegang busur lentik yang dibangunkan boleh menjadi sangat bermanfaat untuk pemanah junior dan jurulatih semasa latihan memanah.

## ABSTRACT

The utilisation of natural fiber and the waste product has become necessary in order to develop sustainability in various industries. The usage of natural fibers in the sport-oriented industries has increased in the recent years. As the recurve bow is the only type of bow that is used in the Olympic Games, it is crucial to design a recurve bow for the use of Malaysian junior archers. This study aims to analyse a recurve bow riser for the Malaysian junior athletes uses hybrid natural fiber as an alternative material. This study is divided into three phases: the set-up and preparation phase, experiment phase and analysis and validation phase. In the set-up and preparation phase, a mixture of natural fiber such as kenaf fiber and pineapple leaf fiber and epoxy was poured into the mold and left to dry at room temperature for 24 hours. The pineapple leaf fiber and kenaf fiber content were varied between 5 wt.% until 20 wt.%. This mixture was prepared using hand lay-up technique. Nine samples were cut according to ASTM D3039 and ASTM D790 for tensile and flexural testing respectively. The experiments of the tensile and flexural test were also conducted on the various compositions of hybrid materials in the experiment execution phase. The pineapple leaf fiber and kenaf fiber were varied between 5 wt.% and 10 wt.%, were respectively hybridised with 95 wt.% and 90 wt.% carbon fiber and glass fiber (95 CF/5 PALF, 95 CF/5 K, 90 CF/10 PALF, 90 CF/10 K, 95 GF/5 PALF, 95 GF/5 K, 90 GF/10 PALF and 90 GF/10 K) with the overall fiber content fixed to 40 wt.%. The best hybrid natural fiber composite material was selected after the mechanical properties assessment was conducted. In the analysis and validation phase, the static structural analysis of the riser was executed on the alternative design of the recurve bow riser. The analysis on the recurve riser has been conducted after the result of draw length was obtained. The finding from the pre-experiment suggests that both pineapple leaf fiber and kenaf fiber 5 wt.% and 10 wt.% could be used in the experiment phase. Results from the study showed that the material property of the best composition is 95 CF/5 PALF because it achieved the highest tensile strength, flexural strength and lower density. The composition was then used in the finite element analysis. In the finite element analysis, the maximum displacement of the alternative design of the recurve riser with 95 CF/5 PALF composite showed 98 % reduction in deformation compared to a previous established study. It can be concluded that the alternative design of the recurve riser is suitable for the alternative material. It can sustain the force applied by the Malaysian junior athletes when they aim at the target board at a full drawn bow position. In addition, the 95 CF/5 PALF composite meets the requirement of the mechanical properties, which is in the same range as aluminum alloy. Therefore, the hybrid composition can be used as a new alternative material to make a recurve riser. The developed recurve riser can be very beneficial for both athletes and coaches during training.

## TABLE OF CONTENT

<b>DECLARATION</b>	
<b>TITLE PAGE</b>	
<b>ACKNOWLEDGEMENTS</b>	<b>ii</b>
<b>ABSTRAK</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>iv</b>
<b>TABLE OF CONTENT</b>	<b>v</b>
<b>LIST OF TABLES</b>	<b>viii</b>
<b>LIST OF FIGURES</b>	<b>ix</b>
<b>LIST OF SYMBOLS</b>	<b>xi</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xii</b>
<b>CHAPTER 1 INTRODUCTION</b>	<b>1</b>
1.1 Introduction	1
1.2 Significance of Study	3
1.3 Problem Statements	4
1.4 Objectives of the Study	5
1.5 Scopes of the Study	5
1.6 Structure of the Thesis	6
<b>CHAPTER 2 LITERATURE REVIEW</b>	<b>8</b>
2.1 Introduction	8
2.2 Natural Fiber Composites	9
2.2.1 Natural Fiber Reinforced Polymer	11



2.2.2	Natural Fiber in Hybrid Composite	14
2.3	Alkali Treatment of Natural Fiber	16
2.4	Carbon Fiber Reinforced Polymer	17
2.5	Glass Fiber Reinforced Polymer	18
2.6	Finite Element Analysis	18
2.7	Recurve Bow Materials	20
2.8	Recurve Bow Mechanism	20
2.9	Application of Natural Fiber in Sports	22
2.10	Summary	23
<b>CHAPTER 3 METHODOLOGY</b>		<b>25</b>
3.1	Introduction	25
3.2	Preparation and Fabrication of Natural Fiber Composite	27
3.3	Hybrid Composites Sample Preparation	30
3.4	Mechanical Properties Testing	32
3.5	Thermal Analysis	34
3.6	Scanning Electron Microscopy	34
3.7	Measurement of Draw Length	35
3.8	Digital Modelling	36
3.9	Load Analysis during Full Drawn Condition	38
3.10	Finite Element Analysis of a Recurve Riser	41
3.11	Summary	42
<b>CHAPTER 4 RESULTS AND DISCUSSION</b>		<b>43</b>
4.1	Introduction	43
4.2	Mechanical Properties of Natural Fiber Reinforced Epoxy	43

4.3	Thermal Analysis of Natural Fiber Composites	48
4.3.1	Thermogravimetric Analysis	49
4.3.2	Differential Scanning Calorimetry	52
4.4	Mechanical Properties of Hybrid Natural Fiber Composites	54
4.5	Modelling of Recurve Bow Riser	57
4.6	Load Analysis of Recurve Bow Riser	59
4.7	Finite Element Analysis of Recurve Bow Riser	60
4.8	Cost of the Recurve Bow Riser	65
4.9	Specification of the Alternative Recurve Riser	66
4.10	Summary	66
<b>CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS</b>		<b>68</b>
5.1	Conclusions	68
5.2	Contribution to the Society	69
5.3	Recommendations	69
<b>REFERENCES</b>		<b>71</b>
<b>APPENDIX A PRICE OF THE EXISTING RECURVE BOW RISER</b>		<b>83</b>
<b>APPENDIX B RULES</b>		<b>84</b>
<b>APPENDIX C1 DIMENSIONS OF RECURVE BOW RISERS</b>		<b>87</b>
<b>APPENDIX C2 DIMENSIONS OF RECURVE BOW RISERS</b>		<b>88</b>
<b>APPENDIX D ELECTRICITY TARIFF</b>		<b>89</b>
<b>APPENDIX E PUBLICATIONS</b>		<b>90</b>

## LIST OF TABLES

Table 2.1	The mechanical and physical properties of thermosetting polymers	12
Table 3.1	The designation of untreated natural fiber reinforced epoxy composites	27
Table 3.2	The designation of treated natural fiber reinforced epoxy composites	30
Table 3.3	The designation of hybrid glass/natural fiber reinforced epoxy composites	31
Table 3.4	Designation of hybrid carbon/natural fiber reinforced epoxy composites	32
Table 3.5	Arm span data of Malaysian junior citizens.	36
Table 4.1	Results of TGA on treated and untreated PALF and kenaf fiber composite	51
Table 4.2	The forces $F_{BP}$ , $F_{AS}$ and $F_{BS}$ obtained from three different sizes of the draw length, $L_A$	59
Table 4.3	Material properties used in FEA	60
Table 4.4	Cost for the alternative recurve riser	65
Table 4.5	Specification of currently used recurve riser and alternative recurve riser	66

## LIST OF FIGURES

Figure 1.1	Components can be found in the recurve bow	2
Figure 2.1	The highlighted issues	8
Figure 2.2	Taxonomy of composite materials	10
Figure 2.3	The number of articles produced according to the types of natural fiber from the year 2010-2017	13
Figure 2.4	The configurations of hybrid materials (a) stacked layer by layer (b) yarn by yarn and (c) fiber by fiber	14
Figure 2.5	Parts of recurve bow	21
Figure 2.6	Various applications of natural fiber in sporting goods (a) Kayak, (b) skateboard, (c) surfboard and (d) bicycle frame	23
Figure 3.1	Flow chart for development of a recurve bow riser using hybrid natural fiber composite for Malaysian junior athletes	26
Figure 3.2	Hand lay-up method	28
Figure 3.3	Preparation of natural fiber composites (a) Mixing process of epoxy and hardener with mixing ratio 2:1 (b) covering the bottom of glass mold with plastic sheet and (c) covering the natural fiber composite with plastic sheet	29
Figure 3.4	Geometry of the tensile test a) top view of a specimen and b) side view of the specimen	33
Figure 3.5	Geometry of the flexural test a) top view of a specimen and b) side view of the specimen	33
Figure 3.6	Working principles during SEM	35
Figure 3.7	Schematic diagram for arm span measurement	36
Figure 3.8	3-D scanning conducted on the existing recurve riser	37
Figure 3.9	Riser after sprayed by the SKD-S2 developer	37
Figure 3.10	Sketch of an athlete drawing a bow with the external forces involved	38
Figure 3.11	Free body diagram of the external forces at the limb pocket involved during the drawn bow	39
Figure 3.12	Force-draw curve	40
Figure 3.13	Load condition on a recurve riser	41
Figure 4.1	Tensile strength and tensile modulus of untreated PALF and kenaf composites	44
Figure 4.2	Tensile strength and tensile modulus treated fiber of PALF and kenaf fiber composites	45
Figure 4.3	Comparison of adhesion bonding between (a) untreated kenaf fiber composite and (b) kenaf treated fiber composite by using SEM	46

Figure 4.4	Flexural strength and a flexural modulus of untreated PALF and kenaf fiber composites	47
Figure 4.5	Flexural strength and a flexural modulus of treated fiber of PALF and kenaf composites	48
Figure 4.6	TGA curves of PALF composites	49
Figure 4.7	TGA curves of kenaf fiber composites	50
Figure 4.8	Heat flow of natural fiber composites reinforced epoxy obtained from DSC analysis	52
Figure 4.9	Glass transition temperature, $T_g$ of PALF and kenaf fiber composites	53
Figure 4.10	Tensile strength and tensile modulus of hybrid PALF/carbon fiber and hybrid kenaf/carbon fiber composites	54
Figure 4.11	Tensile strength and tensile modulus of hybrid PALF/glass fiber and hybrid kenaf/glass fiber composites	55
Figure 4.12	Flexural strength and a flexural modulus of hybrid PALF/carbon fiber composites and kenaf/carbon fiber composites	56
Figure 4.13	Flexural strength and a flexural modulus of hybrid PALF/glass fiber composites and hybrid kenaf/glass fiber composites	56
Figure 4.14	Scanned image of the currently used recurve riser	57
Figure 4.15	Alternative design of recurve riser	58
Figure 4.16	Total deformation of the existing recurve riser with aluminum alloy	60
Figure 4.17	Total deformation of existing recurve riser with 95 CF/5 PALF hybrid material	61
Figure 4.18	Directional deformation (a) X-axis (b) Y-axis and (c) Z-axis of existing recurve riser with 95 CF/5 PALF hybrid material	62
Figure 4.19	Total deformation of an alternative design of recurve riser with 95 CF/5 PALF hybrid material	63
Figure 4.20	Directional deformation (a) X-axis (b) Y-axis and (c) Z-axis of the alternative recurve riser with 95 CF/5 PALF hybrid material	64

## LIST OF SYMBOLS

RM	Ringgit Malaysia
MPa	Megapascal
GPa	Gigapascal
g	gram
cm <sup>3</sup>	Cubic centimeter
mm	millimeter
%	percentage
°C	Celcius
wt.%	Weight percentage
$u_{FE}$	Finite element solution
$\Phi_i$	Data of interest
$u_{EX}$	Exact solution
$M_f$	Mass fiber
$M_c$	Mass composite
$V_m$	Volume matrix
$V_f$	Volume fiber
$\rho_f$	Density fiber
$\rho_m$	Density matrix
$F_A$	Draw weight
$F_H$	Force that holds the drawn bow
$F_S$	String force
$L_A$	Draw length
$L_M$	Length of the riser
$L_W$	Length of the limbs
N	Newton

## LIST OF ABBREVIATIONS

USA	United States of America
FEA	Finite Element Analysis
TGA	Thermogravimetric analysis
DSC	Differential Scanning calorimetric
NFC	Natural Fiber Composite
HDPE	High density Polyethylene
NaOH	Sodium hydroxide
PALF	Pineapple leaf fiber
CFRP	Carbon fiber reinforced polymer
GFRP	Glass fiber reinforced polymer
DOF	Degree of freedom
ASTM	American Society of the International Association for Testing and Materials
100 GFRE	100 % glass fiber reinforced epoxy with overall fiber contents 40 % wt
95 GF/5 PALF	95 % glass fiber and 5 % PALF reinforced epoxy with overall fiber contents 40 % wt
95 GF/5 K	95% glass fiber and 5% kenaf reinforced epoxy with overall fiber contents 40 % wt
90 GF/10 PALF	90 % glass fiber and 10 % PALF reinforced epoxy with overall fiber contents 40 % wt
100 CFRE	100 % carbon fiber reinforced epoxy with overall fiber contents 40 % wt
95 CF/5 PALF	95 % carbon fiber and 5 % PALF reinforced epoxy with overall fiber contents 40% wt
95 CF/5 K	95 % carbon fiber and 5 % kenaf reinforced epoxy with overall fiber contents 40% wt
90 CF/10 PALF	90 % carbon fiber and 10 % PALF reinforced epoxy with overall fiber contents 40 % wt
SEM	Scanning electron microscopy
SE	Secondary electrons
BSE	Backscattered electron
3-D CAD	Three-dimensional computer aided design
WA	World Archery Federation
T <sub>g</sub>	Glass transition temperature
TNB	Tenaga Nasional Berhad

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