IOP Conf. Series: Materials Science and Engineering **226** (2017) 012037 doi:10.1088/1757-899X/226/1/012037

Investigation on Suitability of Natural Fibre as Replacement Material for Table Tennis Blade

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Abstract. This paper presents an investigation of suitability natural fibre as replacement material for table tennis blade, due to low cost, lightweight and apparently environmentally. Nowadays, natural fibre are one of the materials often used in replaced the main material on manufacturing sector, such as automotive, and construction. The objective of this study is to investigate and evaluate the suitability natural fiber materials to replace wood as a structure on table tennis blade. The mechanical properties of the different natural fibre material were examined, and correlated with characteristic of table tennis blade. The natural fibre selected for the study are kenaf (Hibiscus Cannabinus), jute, hemp, sisal (Agave Sisalana) and ramie. A further comparison was made with the corresponding properties of each type of natural fiber using Quality Function Deployment (QFD) and Theory of Inventive Problem Solving (TRIZ). TRIZ has been used to determine the most appropriate solution in producing table tennis blade. The results showed the most appropriate solution in producing table tennis blade using natural fibre is kenaf natural fibre. The selected on suitability natural fibre used as main structure on table tennis blade are based on the characteristics need for good performance of table tennis blade, such as energy absorption, lightweight, strength and hardness. Therefore, it shows an opportunity for replacing existing materials with a higher strength, lower cost alternative that is environmentally friendly.

1. Introduction

In sport aspect, the equipment is essential component for players. In table tennis sport, table tennis blade play an important criterion, and provide the satisfaction of performance to each player. Based on literature, none study was made to replace the structure of table tennis blade with natural fibre. However, until now the current materials for blade manufacturing process are, such as wood essence and synthetic fibre, which is carbon fibre. As reported by Larcorbe, B. (2016), the materials are quite expensive compared to natural fibre, whereby it is proposed here and it also difficult to be manufactured. In addition, wood essence also hard to dry in an open environment for more than a year for a better quality of wood essence (1). An example of wood, such as Kiri, Balsa, Ayous, Hinoki, Koto and Limba (2). Therefore, as a new alternative for the current situation, this study aim to select the suitable material used based on natural fibre, to replace the existing material, without ignoring the initial characteristic of table tennis blade.

An initial structure of table tennis blade, consists of a layer of lightweight and low modulus of elasticity material. The combination structure with respect to the thickness of the blade. However, all geometry and blade size must follow the requirement and standard that have been prepared by International Table Tennis Federation (ITTF). The evaluation of blades, started with the blades were made by single piece of wood. After that, the blades have been produced from multiple layers of wood, and its glued, pressed together to form a plywood structure. Following that, the innovation of blades structure have been added with carbon fibre (as a one of the layer), in order to improve the durability and performance of the blade. But, from time to time, due to the demanding and technology

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increasing, the investigation on table tennis blade must going on, due to the affected by characteristic of rubber and ball. Each blade have usually been covered with a sheet of rubber, and always been made modification by manufacturer, indirectly will be affected on the performance of blade, and also same like ball size. Therefore, the structure of blade itself must always be revised by manufacturer to ensure the capability of blade at the certain level of satisfactory.

The worldwide availability of natural fibre, and known as agro-waste, were introduced as new material on polymer science and engineering research, and the search of sustainable technology (3). Natural fibre have a lower density (1.2-1.6 g/cm^3) than glass fibre (2.4 g/cm^3), which ensure the production of lighter equipment (4). Nowadays, conventional material based on polymers, are used extensively with natural fibre, such as sisal, hemp, kenaf and jute (5). As a result, the growing interest in the use of natural fibre with combination of polymer materials are producing the composite structure, which is polymer matrix composites (PMC). Composite materials are man-made materials which are manufactured to replace the conventional materials by overcome their disadvantages, and improving the material properties (6). The combination of fibre (reinforcement) and filler (resin) as composite materials, a means of extending the properties of the composites that meets the requirement of application, such as on sport, automotive and construction. Furthermore, previous research describes that (3-9), these types of composites have many advantages such as, low density, cheaper cost, availability and biodegradability compared to synthetic fibre. Lut Pill et.al (2016) mentioned that natural fibre are used to produce surfboard and bow archery, in field of sport equipment (10).

Design approach, which is Quality Function Deployment, QFD and Technique Theory of Inventive Problem Solving, TRIZ have been used in this study. QFD is a product development process used to achieve higher customer satisfaction (11) and decision model for the prioritization of design requirements (12). Quality Function Deployment was developed by Yoji Akao in Japan in 1966 and in 1978 the first book on the subject was published in Japanese and then later translated into English in 1994 (13). QFD designers, are performed in uncertain environments, and usually more than one goal must be taken into account. The approach are applied to formulate the relationships between customer requirements (CRs) and engineering design requirements (DRs). Another, approach was used in this study is TRIZ. TRIZ was developed to assist engineers in finding innovative solutions to technical problems in product development processes. Therefore, in this study TRIZ has been used to determine and obtain the most appropriate solution if any problem and improving the quality of table tennis blade based on the selection of natural fibre.

In relation to the brief literature overview, the main purposes of the work is to investigate the suitability of natural fibres used as replacement material for table tennis blade. The characteristic of table tennis blade are determined at the first stage, in order to select the suitable natural fibre characteristic, whereby it have significant effect on table tennis blade behaviour. Therefore, two method design approach are used, which is Quality Function Deployment, QFD and Technique Theory of Inventive Problem Solving, TRIZ. Both types of design approach have different contribution in this study, to ensure all element of design process are achieved, based on customer requirements (CRs) and engineering design requirements (DRs).

2. Methodology

In this study, the characteristic of initial table tennis blade was identified, in order to ensure the most important aspect that correlated and affected the capability and performance of table tennis blade. The affected element have been identified based on literature review, such as shape, weight, thickness, hardness and energy absorption. All element was studied, due to the contribution of performance among table tennis player, in term of speed, control and spin. A flow chart of the process in this study is shown in Fig. 1.

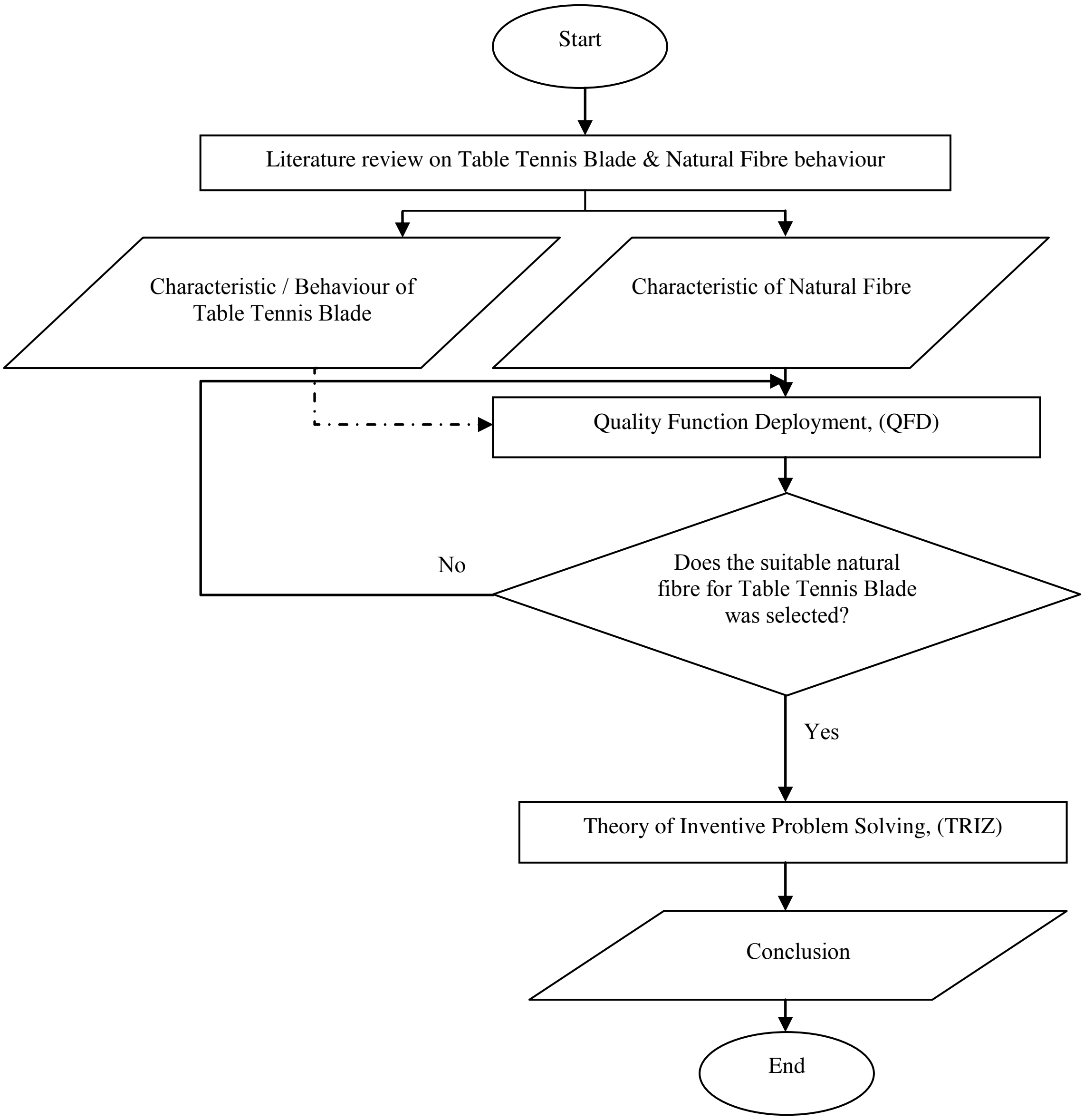

Figure 1: Flow Chart of the methodology

Following that, Quality Function Deployment, QFD is then used to find the most suitable characteristic that suitable used as table tennis blade structure based on several type of natural fibre, such as Kenaf, Jut, Hemp, Sisal and Ramie. All criterion must satisfy the customer requirement and correlate with engineering design requirements. This technique and design approach was selected, due to most appropriate method used in this study, which is based on criterion and characteristics. Fig. 2, shows the QFD table.

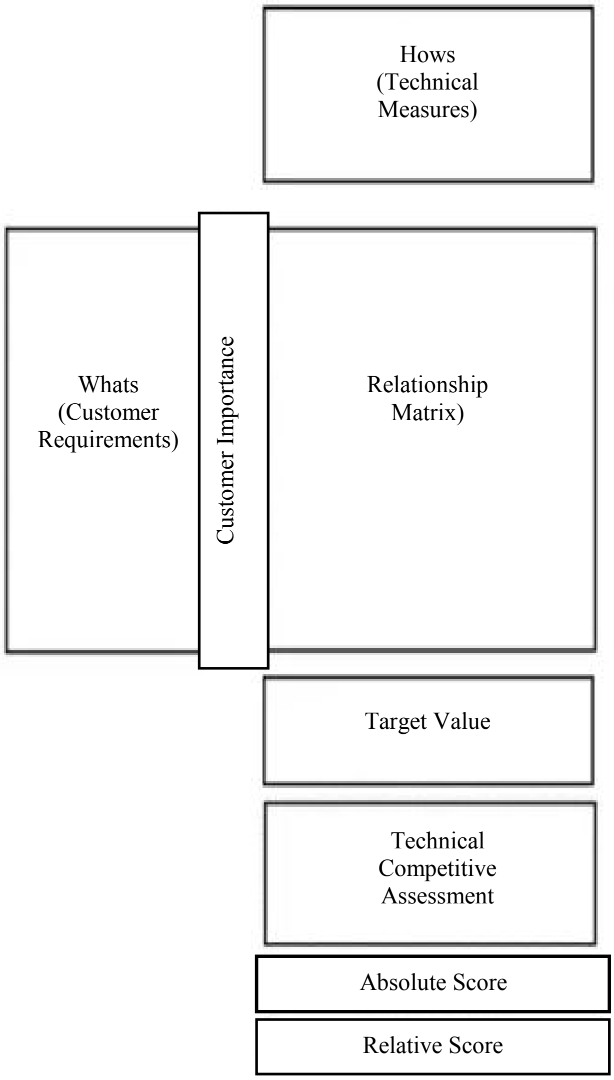

Figure 2: Component of QFD model

Finally, TRIZ was conducted based on selected material. Theory of Inventive Problem Solving was used to obtain the most appropriate solution for every problem and improve the quality of a product. In this case, the natural fiber that has been selected from QFD method, was considered as main material in the production of table tennis blade. Therefore, TRIZ was provided 40 possible solution and the solution will be select based on requirement that are need. As assumption, TRIZ will provided the better solution, to ensure the quality of table tennis blade made by natural fibre material.

3. Results and Discussion

As shown in Figure 3, based on literature research on very limited information, it shows the most characteristics that are need for each table tennis blade, such as spin, control, speed, shape and handle. All characteristic affecting the capability and durability of table tennis blade performance. Therefore, the selection process of material to be used as main material for table tennis blade, should be considered on capabilities of material itself, such as energy absorption, hardness and lightweight.

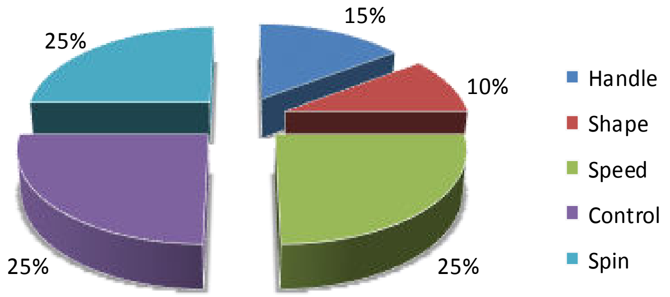

Figure 3: Type of characteristic for Table Tennis Blade

Correlated with above finding, in order to produce novel ideas for table tennis blade using natural fibre as main material, five (5) types of natural fibre were selected to be used on design approach using Quality Function Deployment (QFD) technique. In this study, only the relationships between customer requirements (CRs) and engineering design requirements (DRs) was considered. It should be noted that, the selection of natural fibre, based on comparison of an existing material used for table tennis blade , which is wood, in terms of characteristic. Only the approaching characteristic with wood was considered. Jute and hemp natural fibre were chosen, based on reported by Lut Pill et. al (2016), whereby that material was used in sport equipment (10). Therefore, as prediction it have potential to be used as table tennis blade. Kenaf, sisal and ramie, was selected due to the mechanical characteristic, which is strong, lightweight and others criterion that suitable used as replacement material on table tennis blade production (14). The properties of each natural fibre employed in this investigation are shown in Table 1.

Table 1 : Properties for each natural fibre. (15)

Natural Fiber	Density, (g/m^3)	Percentage of Elongation, (%)	Tensile Strength, (MPa)	Modulus Young, (GPa)
Kenaf	1.40	1.5	1000	53
Jut	1.30	1.5-1.8	393-773	26.5
Hemp	1.48	1.6	690	70
Sisal	1.50	2.0-2.5	511-635	9.4-22.0
Ramie	1.50	3.6-3.8	400-938	61.4-128

Table 2: Quality Function Deployment (QFD) Kenaf Natural Fibre

	Tensile Strength, Mpa	Hardness, N	Density, g/m3	Young Modulus, Mpa	Percentage of Elongation, mm	Flexibility	Costudy	Natural	Row No.	Weightage Row	Importance
Weight Table Tennis Blade	3		5			1		2	1	4	44
Size Table Tennis Blade			4		5	5			2	3	42
Speed table Tennis Blade	5		5	4		3			3	5	80
Control Table Tennis Blade			5	4		3			4	5	60
Spin While Hitting The Ball		5	4	4					5	5	65
Kenaf Natural Fibre	5	5	5	3	3	3	3	4	6	5	155
Safety						3	3	4	7	3	30
Column No.	1	2	3	4	5	6	7	8			
Colomn Weightage	4	5	5	4	3	3	2	2			
Importance	52	50	140	60	24	60	12	16			

Table 3: Quality Function Deployment (QFD) Jute Natural Fibre

	Tensile Strength, Mpa	Hardness, N	Density, g/m3	Young Modulus, Mpa	Percentage of Elongation, mm	Flexibility	Costudy	Natural	Row No.	Weightage Row	Importance
Weight Table Tennis Blade	3		5			1		2	1	4	44
Size Table Tennis Blade			4		5	5			2	3	42
Speed table Tennis Blade	5		5	4		3			3	5	80
Control Table Tennis Blade			5	4		3			4	5	60
Spin While Hitting The Ball		5	4	4					5	5	65
Jute Natural Fibre	3	3	3	2	4	3	3	4	6	5	125
Safety						3	3	4	7	3	30
Column No.	1	2	3	4	5	6	7	8			
Colomn Weightage	4	5	5	4	3	3	2	2			
Importance	44	40	130	56	27	60	12	16			

Table 4: Quality Function Deployment (QFD) Hemp Natural Fibre

	Tensile Strength, Mpa	Hardness, N	Density, g/m3	Young Modulus, Mpa	Percentage of Elongation, mm	Flexibility	Costudy	Natural	Row No.	Weightage Row	Importance
Weight Table Tennis Blade	3		5			1		2	1	4	44
Size Table Tennis Blade			4		5	5			2	3	42
Speed table Tennis Blade	5		5	4		3			3	5	80
Control Table Tennis Blade			5	4		3			4	5	60
Spin While Hitting The Ball		5	4	4					5	5	65
Hemp Natural Fibre	4	4	4	4	3	3	3	4	6	5	145
Safety						3	3	4	7	3	30
Column No.	1	2	3	4	5	6	7	8			
Colomn Weightage	4	5	5	4	3	3	2	2			
Importance	48	45	135	64	24	60	12	16			

Table 5: Quality Function Deployment (QFD) Sisal Natural Fibre

	Tensile Strength, Mpa	Hardness, N	Density, g/m3	Young Modulus, Mpa	Percentage of Elongation, mm	Flexibility	Costudy	Natural	Row No.	Weightage Row	Importance
Weight Table Tennis Blade	3		5			1		2	1	4	44
Size Table Tennis Blade			4		5	5			2	3	42
Speed table Tennis Blade	5		5	4		3			3	5	80
Control Table Tennis Blade			5	4		3			4	5	60
Spin While Hitting The Ball		5	4	4					5	5	65
Sisal Natural Fibre	3	4	5	2	4	3	3	4	6	5	140
Safety						3	3	4	7	3	30
Column No.	1	2	3	4	5	6	7	8			
Colomn Weightage	4	5	5	4	3	3	2	2			
Importance	44	45	140	56	27	60	12	16			

Table 6: Quality Function Deployment (QFD) Ramie Natural Fibre

	Tensile Strength, Mpa	Hardness, N	Density, g/m3	Young Modulus, Mpa	Percentage of Elongation, mm	Flexibility	Costudy	Natural	Row No.	Weightage Row	Importance
Weight Table Tennis Blade	3		5			1		2	1	4	44
Size Table Tennis Blade			4		5	5			2	3	42
Speed table Tennis Blade	5		5	4		3			3	5	80
Control Table Tennis Blade			5	4		3			4	5	60
Spin While Hitting The Ball		5	4	4					5	5	65
Ramie Natural Fibre	3	3	5	4	5	3	3	4	6	5	150
Safety						3	3	4	7	3	30
Column No.	1	2	3	4	5	6	7	8			
Colomn Weightage	4	5	5	4	3	3	2	2			
Importance	44	40	140	64	30	60	12	16			

Generally, all table shows the scale from one (1) until five (5). The scale represent as a weightage for the customers' needs and technical requirements in the study. The value of weightage given based on the priority of characteristic needs, in order to develop table tennis blade. Figure 4 is a representation of importance criterion need to consider and it shows kenaf natural fibre have high importance value compared with hemp, ramie, sisal and jute as conducted using QFD approach. As mentioned by H.M. Akil et. al. (2011), kenaf as potential as reinforcing material, because of its superior toughness, high tensile strength and high aspect ratio compared to other fibre (natural fibre) (3).

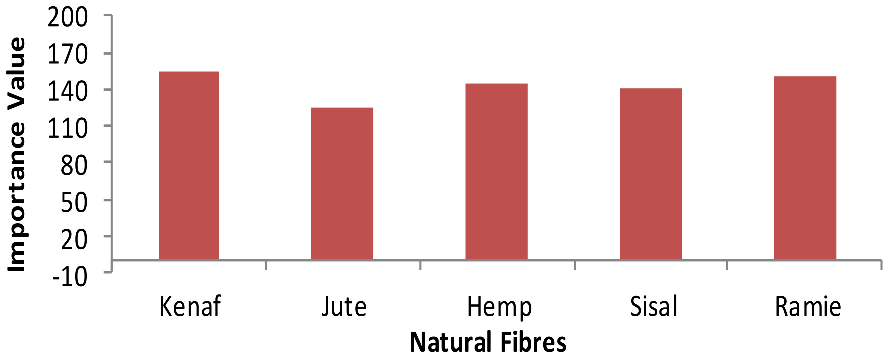

Figure 4: Importance value of natural fibres

Therefore, as a conclusion kenaf natural fibre was selected as a replacement material to produce new table tennis blade. On development process, the assumption and prediction if some contradictions occurred during production of table tennis blade was analysed. Thus, the Theory of Inventive Problem Solving (TRIZ) was used, to obtain the most appropriate solution and improvement criterion on a quality of new table tennis blade production. TRIZ is a structure that has original inventive, consists of philosophy, methods and tools, as mentioned by Ekmekci & Koksal (2015). Table 7 shows the TRIZ approach, based on customer requirement, contradictions, possible solution and solution selected. Contradiction was created for increasing value of system and improving the quality of a system, but decrease the value of other system, as proposed by Altshuller [16].

Table 7: TRIZ approach . Customer requirement, contradictions, possible solution and solution selected.

Customer Requirement	Contradictions	Possible solution	Solution Selected
Lightweight table tennis blade	#1. Weight of moving object #9. Speed	# 2. Taking #8.Anti-weight #15. Dynamics #38.Strong oxidizing agents	#18.Anti-weight.
Size table tennis blade	#32 .Easy to produce #28. Accuracy of measurement	#1.Segmentation #35. Parameter Changes #18.Mechanical vibration	#35.Parameter changes.
Control fell using table tennis blade	#1. Weight of moving object #2. Force	# 8.Anti-weight #10. Early action #18. Mechanical vibration #37. Thermal expansion	# 18. Mechanical vibration

4.0 Conclusions

In this study, the novel ideas is to produce new table tennis blade to replace existing materials used, which is wood. One of the issues is, to ensure the sustainability of forest areas and indirectly will reduced the global warming condition. Therefore, this study was conducted and shows that kenaf natural fibre, have a possibility to replace wood as a main material for the next table tennis blade production. The final result based on supported technique by design approach, which is Quality Function Deployment (QFD) and Theory of Inventive problem Solving (TRIZ). However, as a conclusion, this study need to be enhanced on others scope of study, to ensure it can be commercialized and creating a same characteristic behaviour with an existing table tennis blade.

Acknowledgement
The author would like to express their gratitude to Universiti Tun Hussein Onn Malaysia for supporting these research activities.

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