PARAMETRIC STUDY ON A CONCEPTUAL BADMINTON RACKET USING FINITE ELEMENT ANALYSIS

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JANUARY 2015

This study is especially dedicated to
my beloved Mother and Father, Brothers and Sisters,
for everlasting love, care, and support.

ACKNOWLEDGEMENT

First and above all, I praise God, the almighty for providing me this opportunity and granting me the capability to proceed successfully. This thesis appears in its current form due to the assistance and guidance of several people. I would therefore like to offer my sincere thanks to all of them. Dr. Muhamad Noor bin Harun, my main supervisor, my cordial thanks for accepting me as a Master student, your warm encouragement, thoughtful guidance, critical comments, and correction of the thesis. I want to express my deep thanks to my co-supervisor, Prof. Ir. Dr. Mohammed Rafiq bin Dato' Abdul Kadir for the trust, the insightful discussion, offering valuable advice, for your support during the whole period of the study, and especially for your patience and guidance during the writing process.

I would especially like to thank Dr. Ardiyansyah Syahrom of you have been there to support and encouraging me during my research. I am also would like to thank Prof. Dr. Abdul Hafidz bin. Hj. Omar, the director of Sport Innovation Technology Centre (SITC) for giving me the opportunity to perform my research at their facilities. Not forgotten, lecturers and students at Sport Innovation and Technology Centre (SITC) for providing a good atmosphere in our department and for useful discussions. In addition, thank you to all lecturers in the Faculty of Mechanical Engineering, Universiti Teknologi Malaysia who involved in completing this work. I would like to extend my sincere appreciation to my beloved parents and siblings for their relentless moral and financial support in completing this work. Thanks to all the people and friends who has offered their help and assistance in facing numerous challenges during this entire studies. They have been my source of strength and inspiration all this while.

ABSTRACT

In the sport of badminton, racket plays an important role because it is the main instrument to drive the shuttlecock. A good design of the racket is crucial to achieve better game performance. However, there is inadequate scientific study in the development of badminton racket design. The aim of this research is to identify the characteristics of racket design parameters which influence the racket performance. Designing a racket requires one to fully understand the racket performance characteristics. Basically, racket performance is referred in to term of sweet spot which is the spot on a racket head that produces more power and control if a shuttlecock hits on it. Determination of coefficient of restitution (COR) can help to determine the sweet spot on a racket. In this study, several designs of badminton racket were analyzed using finite element approach to investigate the design parameters that influence a racket performance. Each racket model was created in three-dimensional CAD software (SOLIDWORKS) and imported into ABAQUS (Explicit) for finite element analysis. The finite element simulation mimics the collision between rubber ball and badminton racket. The results from finite element simulation were compared to experimental results for validation. The parametric studies were conducted by using validated finite element model to investigate the effect of string tension, racket structural stiffness and racket head shape designs with respect to racket performance. Reducing the string tension from 34 lbs to 14 lbs could increase 2.4 % of COR. There was at least 6 % difference in COR between hollow shaft and solid shaft. Isometric head shape racket produces better COR compared to oval and round shape. It is recommended that, the racket design should consist of low string tension, stiffer racket shaft and bigger head size in order to produce higher shuttlecock speed.

ABSTRAK

Dalam sukan badminton, raket memainkan peranan yang penting dalam mengawal permainan dimana ia merupakan alatan utama untuk memacu pergerakan bulu tangkis. Reka bentuk raket yang baik adalah penting bagi mencapai prestasi permainan yang berkualiti. Walau bagaimanapun, masih terdapat kekurangan kajian saintifik dalam pembangunan reka bentuk sesebuah raket badminton. Tujuan kajian ini adalah untuk mengenal pasti ciri-ciri parameter reka bentuk raket yang mempengaruhi prestasi raket. Mereka bentuk raket memerlukan pemahaman terhadap ciri-ciri prestasi raket. Pada asasnya, prestasi raket merujuk kepada terma ‘sweet spot’ iaitu titik di kepala raket yang menghasilkan lebih kuasa dan kawalan jika buku tangkis dipukul pada titik tersebut. Mengenal pasti perkali pengembalian (COR) boleh membantu dalam menentukan kedudukan ‘sweet spot’ pada raket. Dalam kajian ini, beberapa reka bentuk raket badminton dianalisa dengan mengunakan pendekatan unsur terhingga untuk menyiasat parameter reka bentuk yang mempengaruhi prestasi raket. Setiap model raket dihasilkan dalam perisian tiga dimensi CAD (SOLIDWORKS) dan dimasukan ke dalam perisian ABAQUS (Explicit) untuk analisa unsur terhingga. Simulasi unsur terhingga meniru perlanggaran antara bola getah dan raket badminton. Hasil daripada simulasi unsur terhingga kemudiannya telah dibandingkan dengan keputusan eksperimen untuk tujuan pengesahan. Kajian parametrik telah dijalankan dengan menggunakan model unsur terhingga yang telah disahkan untuk mengkaji kesan ketegangan tali, struktur kekakuan raket dan reka bentuk kepala raket terhadap prestasi raket. Mengurangkan ketegangan tali dari 34 lbs kepada 14 lbs mampu meningkatkan 2.4 % daripada COR. Terdapat sekurang-kurangnya 6 % perbezaan COR yang dihasilkan antara aci berongga dibanding dengan aci pepejal. Raket berkepala isometrik menghasilkan COR yang lebih baik berbanding dengan reka bentuk raket berkepala bujur dan bulat. Adalah dicadangkan bahawa, reka bentuk raket hendaklah terdiri daripada ketegangan tali yang rendah, aci raket yang lebih keras dan saiz kepala yang lebih luas untuk menghasilkan kelajuan bulu tangkis yang lebih tinggi.

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LIST OF ABBEVIATIONS

COR	-	Coefficient of Restitution
COP	-	Centre of Percussion
COM	-	Centre of Mass
MOI	-	Moment of Inertia
HSC	-	High Speed Camera
3D	-	Three-dimensional
N	-	Newton
MPa	-	Mega Pascal

LIST OF SYMBOLS

m	-	Mass
w	-	Width
L, l, l_o	-	Length
d_o	-	Outer diameter
t	-	Thickness
v_1	-	Initial/incident velocity
v_2	-	Rebound velocity
h_r	-	Rebound height
h_d	-	Drop height
E	-	Modulus of elasticity
I	-	Moment of inertia
P	-	Load
y_{max}	-	Maximum deflection
k	-	Stiffness
g	-	Gravity
σ	-	Stress
$\emptyset$	-	Cross-sectional diameter
ρ	-	Density
ν	-	Poisson’s ratio

CHAPTER 1

INTRODUCTION

1.1 Research Background

Badminton was commonly known as the fastest racket sport due to the shuttlecock speed produced during games. Based on Guinness World Records, the official record for the fastest smash produced in competition was 332 km/hrs done by Fu Haifeng during the Sudirman Cup 2005 tournament [1]. In 2013, Malaysian men doubles, Tan Boon Heong has unofficially beaten this record by producing smash speed of 493 km/hrs during the experiment conducted by Yonex to test their brand new racket model [2]. Thus, it shows badminton is a highly intensive game which requires players to have good stamina, speed and agility [3]. The ability to produce powerful strokes was one of the advantages and a key point for players in the quest of winning a game. It was proven that a smash shot was indeed the most effective stroke in gaining points during a badminton game [4]. Moreover, besides the physical and physiological factors such as technique, strength, stamina, and speed, the racket design is undoubtedly considered as among the key factor that brings significant improvement on stroke power and accuracy [5-7].

In badminton, racket holds an important role in controlling the game whereby a good racket should have the ability to communicate effectively with its handler. Hence, racket design and its traits need to be highly reliable and whilst maintain consistent performance throughout a match. The innovation in sport technology brings to the development of varies racket designs and each design has its own functional criteria that would significantly enhance the racket performance. In essence, racket performance was usually assessed based on its ability in commanding good control and power [7,8]. Power is referred to the rebound speed of the shuttlecock, while control is the precision of the stroke [8,9]. Therefore, within the same context, the development of a good racket design would be imperative in achieving an optimum speed, precision and accuracy of racket handling.

Previous tennis studies have done remarkable works in investigating the effect of racket design parameters on the racket performance. Based on tennis literatures, sweet spot, swing weight, and swing speed were some of the parameters that affect the performance of racket. Sweet spot can be described as the spot on racket string that can improve power and accuracy to the shuttlecock [10-12]. For example, hitting shuttlecock on the sweet spot can give lot advantages, such as reduce the jarring on the griping handle, produce more accuracy, and imparts maximum speed to the shuttlecock [11]. Other contributing factors that would affect the performance of racket are swing weight and swing speed. Theoretically, swing weight can be described as the moment of inertia (MOI) of racket while swing speed is commonly referred to the angular velocity of swinging racket [13]. Racket that is equipped with higher swing weight and swing speed is able to produce more power to the ball. Previous studies on tennis racket were conducted to find the correlation between swing weight and swing speed to its performance [9]. Similar approach of studies should be emulated and performed on the badminton racket in order to produce a more responsive, highly reliable and enhanced commanding ability by its handler.

1.2 Problem Statement

It is safe to state that the understanding of a badminton racket especially in subjects pertaining to design, traits, and physical characteristics in relation to its performance is still at its infancy compared to its tennis counterpart. This would lead to a poor racket selection relative to the player and may compromise the performance of the latter. Conventionally, a player would choose the racket based on their experiences, personal attachment and mostly by recommendations from the coaches. There were less to almost non-existence of scientific approaches and methodologies that have been adopted in addressing the racket-player pairing selection [8].

A good racket would communicate and response promptly to every command given by a player. It would complement well with the player's agility, by producing a highly precise shot, a more robust pattern play and ultimately enhances the physiological ability of a player. With huge selection of racket models and designs available in the open market, there is an urgent need to develop a set of assessable design parameters that would find a perfect match between a racket and its player. An in-depth analysis and understanding of the racket design parameters could greatly improve the racket performance. Against the above context, a clear methodology needed to be developed in order to determine the effect of design parameters on a racket performance.

Finite element method was one of the techniques that widely used in the development of sports equipment. Several studies on tennis racket managed to analyse several racket design parameters using this approach [14-18]. To the best of author's knowledge, there was no research conducted to analyse design parameters on badminton racket using finite element approach. Unlike other racket based sports such as tennis, there is still lack of research to analyse design parameters of badminton racket. Enhancement on the design of the racket can improve the performance of the player. Therefore, this study was conducted to investigate the design parameters that affect the performances of the badminton racket.

1.3 Objectives of the Study

The objectives of this study are as follows:

i. To develop the finite element model of badminton racket.
ii. To validate the finite element model of badminton racket with the empirical study.
iii. To investigate the effect of design parameters on the performance of badminton racket

1.4 Scope of the Study

The scope of the study permeates on the followings:

i. The three dimensional (3D) model of badminton racket as the foundation of the finite element study.
ii. This study develops the computational methodology using finite element analysis to analyse the design parameters of the badminton racket. This study will limit the finite element simulation in the static condition only.
iii. The finite element simulation will be validated with empirical study.
iv. Perform parametric studies to examine the effect of racket design parameters towards its performance. The parametric study comprises of the stiffness, length and head design of a badminton racket.

1.5 Significance of the Study

This study provides further understanding on the design characteristics of badminton racket and its influence to the performance of the same. The finite element analysis was done to investigate several important parameters that affect the design of badminton racket. It would be an effective approach to improve the racket design without having to produce multiples of actual prototypes. Moreover, the information obtained from the parametric study can be utilized to help players and coaches to improve their understanding on the design characteristic of badminton racket that could enhance player performance. As a result, players and coaches are able to make an informed-decision in selecting an appropriate racket that best match player's abilities. Furthermore, this study will propose numerous recommendations of badminton racket design that could be essential in developing a superior racket design.

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