DESIGN AND DEVELOPMENT OF A MULTIMODE CRICKET BOWLING MACHINE

FERNANDEZ DHANARAJ A/L DAVARAJ

UNIVERSITI SAINS MALAYSIA

2017

DESIGN AND DEVELOPMENT OF A MULTIMODE CRICKET BOWLING MACHINE

by

FERNANDEZ DHANARAJ A/L DAVARAJ

Thesis submitted in fulfilment of
the requirements for the degree of
Master of Science

August 2017

ACKNOWLEDGEMENT

First of all, I would like to thank my research supervisor, Dr. Anwar Hasni bin Abu Hassan for all of his effort and support. Due to the guidance and motivation from him, I was able to understand the theory and processes involved in this research while improving my own knowledge. Besides that, I am grateful in the first place as he accepted and allowed me to be under his supervision.

Furthermore, I would also like to give my appreciation to the School of Electrical and Electronic Engineering providing the facilities to conduct the research. This research is sponsored by Universiti Sains Malaysia Short Term Grant (304/PELECT/60312050), Ministry of Education (203/PELECT/6740033) and MyBrain scholarship. I also owe my gratitude to my school's technician, Mr. Mohd Shahidan Bin Shafie and the Business Unit of School of Mechanical engineering for their advice and help during the fabrication process. Moreover, I would also like to give thanks to all my research colleagues who have been very supportive by sharing ideas and experiences with me.

Last but not least, again I would like to thank everyone who had helped me. I hope that the outcome of this particular project which I accomplished during my Masters will lead me to be a successful graduate in the future. With this, I hope all the knowledge and experiences obtained during this research could be used to enhance the quality of cricket and sports in general in Malaysia through the training tools.

TABLE OF CONTENTS

CHAPTER FOUR: RESULTS AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

F_D	Drag force
F_L	Lift force
C_L	Coefficient of lift
C_D	Coefficient of drag
m_b	Mass of ball
ρ	Density of air
A	Cross-sectional area of ball
V	Velocity
r	Ball radius
ω	Rotational velocity
g	Gravitational acceleration
S_R	Speed ratio
R_e	Reynolds number
L	Characteristic length

REKA BENTUK DAN PEMBANGUNAN MESIN PEMBALINGAN BOLA KRIKET PELBAGAI MOD

ABSTRAK

Kajian ini berkenaan dengan pembangunan sebuah mesin pembaling bola kriket pelbagai mod. Tujuan mesin ini adalah untuk mencontohi penghantaran bola pembaling kriket manusia. Mesin tersebut mampu membaling bola secara berterusan untuk para pemukul semasa ketiadaan pembaling. Seterusnya, kajian-kajian lampau tidak menjelaskan sesetengah kriteria berkenaan dengan pembangunan mesin kriket seperti kesan bola basah terhadap kelajuan dan hubungan kelajuan antara bola dan roda. Sehubungan dengan itu, sebuah mesin pembalingan bola kriket telah dipasang siap dan prestasi mesin tersebut telah dianalisis. Berdasarkan kinematik balingan bola kriket, keperluan-keperluan reka bentuk dihasilkan sebelum pembinaan mesin. Untuk sistem kawalan, sebuah pengawal berasaskan peraturan menggunakan mikropengawal dibina untuk mengubah kelajuan putaran roda. Tiga ujian utama untuk menganalisi prestasi adalah kelajuan, jarak, dan putaran bola. Hasil eksperimen menunjukkan kelajuan bola pada tekanan udara tayar sebanyak 6.25 psi adalah 17.53 m/s dan 19.78 m/s di bawah mod perlahan dan sederhana. Konsistensi data dibandingkan menggunakan pekali variasi. Daripada hasil eksperimen tersebut, nisbah kelajuan bola dan kelajuan linear roda telah diperoleh. Disebabkan oleh kecerunan nisbah kelajuan, kelajuan bola menurun selepas kelajuan putaran tayar sebanyak 2000 rpm pada tekanan udara 6.25 psi. Selain itu, hasil trajektori daripada model matematik yang disimulasi sebanding dengan ukuran jarak dimana ralat yang diperoleh adalah 0.67% (perlahan-mendatar), 9.31% (sederhana-mendatar), dan 12.49% (sederhana-bergolek). Untuk eksperimen putaran bola, nisbah kelajuan digunakan untuk menganggarkan kadar putaran bola

dengan ralat 12.32%. Berdasarkan anggaran tersebut, kadar putaran bola menurun apabila kadar putaran roda meningkat. Selain itu, simulasi-simulasi trajektori bola dengan aplikasi putaran telah dijalankan dan dianalisis. Simulasi-simulasi tersebut telah menunjukkan bahawa putaran bola menghasilkan kesan seiring dengan sistem berasaskan peraturan yang dilaksanakan tetapi magnitud kesan tersebut rendah akibat hubungan nisbah kelajuan dan sudut pelepasan asal bola daripada satah mendatar.

DESIGN AND DEVELOPMENT OF A MULTIMODE CRICKET BOWLING MACHINE

ABSTRACT

This research was about the development of a multimode cricket bowling machine. The purpose of the machine was to emulate the ball deliveries of real cricket bowlers during training. Furthermore, the machine could execute continuous ball deliveries for the batsmen when the bowlers are not available. Besides that, past studies had not disclosed some of criteria related to the development of the bowling machine such as effects of wet ball on velocity and speed relationship between the ball and the wheels. In response, a multimode cricket bowling machine was fabricated and its performance analysed. Based on the kinematics of the bowling deliveries, the design requirements of the machine were made prior to fabrication. As for the control system, a rule-based microcontroller system was constructed to change the wheel's angular speed. The three major experiments for analysing the performance were ball velocity, distance, and spin. Experimental results showed that ball velocities were 17.53 m/s and 19.78 m/s under slow and medium speed mode with best wheel pressure of 6.25 psi on both wheels. The data consistency was compared using coefficient of variation (COV). From the velocity results, the speed ratio between the ball's translational velocity and wheel's linear velocity was obtained. Due to the steep speed ratio gradient, the ball velocity declined after the wheels achieved an angular speed of 2000 rpm at 6.25 psi. Moreover, the trajectory results of the mathematical model simulated was comparable to the measured ball length with error of 0.67 %, 9.31 %, and 12.49 % for slow-horizontal, medium-horizontal, and medium-rolled tests respectively. For the ball spin experiments, the speed ratio equation was used to estimate the ball spin rate

with 12.32 % error. Based on the estimation, the ball spin rate decreased as the wheel's angular speed increased. Furthermore, simulations for the ball trajectory with spin applied were conducted and analysed. The simulations had shown that the ball spin produced ball trajectory effects in line with the implemented rule-based system but the magnitude of the effects was low due to the speed ratio relationship and also the initial ball release angle from the horizontal plane.

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

1.1.1 Field of Interest

The focus of this research was designing and developing an automatic cricket bowling machine using rotating wheel. Cricket is one of many ball-based sports played between two opposing teams with eleven players each on the field. Additionally, the aim of the game is accumulate as many runs as possible by the end of the match. This sport known worldwide and currently participated by 105 countries in which some of the prominent members are England, India, Australia, New Zealand, and South Africa. Moreover, the International Cricket Council (ICC) is the official world governing body and host of the three major championships namely ICC Test, ICC One Day International (ODI), and Twenty20 (T20) International (International Cricket Council, 2016). In Malaysia, this sport is locally governed by the Malaysia Cricket Association which was established in 1963 (Malaysian Cricket Association, 2016).

The essence of the gameplay is the battle between a batsman and a bowler of the opposing team. Both are placed at each ends of the field where the wickets are positioned (Cricinfo, 2016). Furthermore, the purpose of the batsman is to break the wicket defended by the batsman. Unlike baseball where the ball is thrown, bowling is the term used to describe the propulsion motion of the bowler. Bowling refers to the usage of a full arm to propel ball similar to an actual bowling sport. Moreover, the bowler can employ a number of technics in his or her bowling action to produce varying ball flight and bounce to overcome the batman's defenses. It is required for the ball to bounce at most once on the cricket pitch before breaking the wicket. Failure to do so will result in a ‘no-ball’ which the term used for fouled delivery. On the opposing end, the batsman has to defend the wicket behind him or her by striking the ball outside the field boundaries or far from the fielders to accomplish as many runs as possible. Additionally, the fielders belonging to the bowler’s team captures the stroked ball and throws it towards the wicket which ends the batsman’s run. Figure 1.1 shows the general view of a cricket field whereas Figure 1.2 shows a batsman with his equipment and the wicket behind him. Additionally, Figure 1.3 shows the placement of the players near the cricket pitch from the view behind the batsman.

Figure 1.1 Cricket ground at St. Lucia with the strip of land in the middle known as cricket pitch (Cricket Island, 2014).

Figure 1.2 South Africa batsman defending the wicket by striking the ball (The Guardian, 2015).

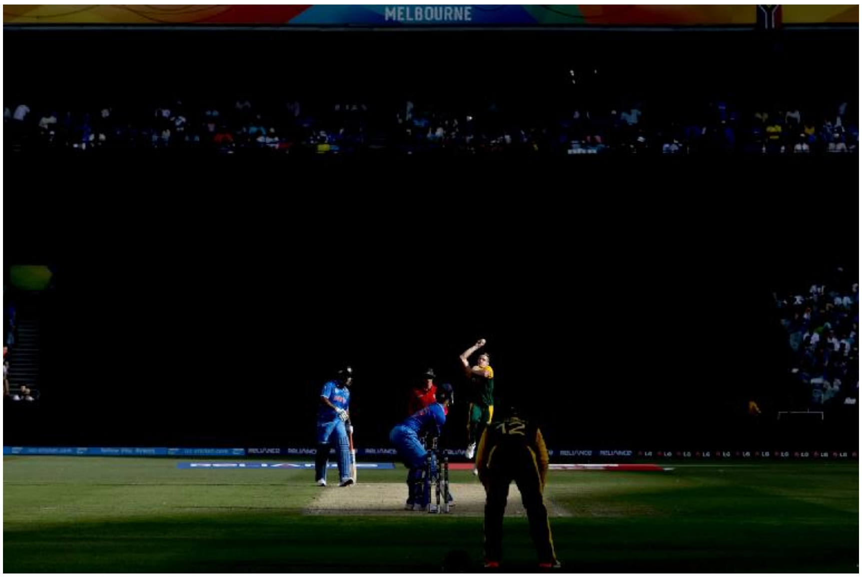

Figure 1.3 The bowling action viewed behind the batsman (The Guardian, 2015).

1.1.2 Cricket Bowling Machine

Over the past years, commercial cricket bowling machines have been built for use in training by cricket players. The machine's purpose is to replace the bowler for activities that require repetitive bowling with varying styles. Furthermore, the delivery methods employed by existing machines are rotating wheels, pneumatic, and spring actuated propulsion (Alger, 2013; Lewis and Barberi, 2013; Edson, 2014; Hart, 2016). Detailed descriptions of these methods are discussed in the thesis where the two-wheel propulsion method was selected. Regardless of delivery methods, the machine has to emulate bowlers who are often divided into two major categories; fast and spin bowlers. Fast bowling can be further divided into seam and swing bowling which relies on the ball seam orientation and surface condition whereas for spin bowling, the ball's rotational component is a major factor. The cricket bowling machine has the potential to improve the sport as a whole in Malaysia in ways such as training assistance at upper secondary school or university levels and promoting the sports especially towards younger generation where future talents may lie.

The trajectory of the ball can be calculated using equations that take into account the forces on the ball during flight such as drag, lift and gravity (Robinson and Robinson, 2013; Wójcicki et al., 2011). Furthermore, the study of the ball's trajectory is important in the development of the cricket bowling machine as it allows us to determine the ball's length and line on the cricket pitch and the similarity degree with bowling done by real bowlers. Alam et al. (2010) had studied the aerodynamic properties of cricket balls which proved to be essential in predicting the ball's flight. Similarly, Cross (2011) and Mehta (2008) had also investigated the aerodynamic properties of different sport balls.

Other than the physical characteristics of the bowling machine, there are other factors that may affect its performance such as wet environment. In cricket, dew factor is a natural phenomenon known to affect the overall gameplay be it bowling, batting or fielding (Bhattacharjee, 2017; Krishnaswamy, 2016; Vohra, 2016). According to the authors, for bowlers, a wet ball is harder to manipulate due to slip and when spin is applied, the ball may not be able to grip the pitch well. This caused the ball to skid, deteriorates its swing and spin becoming similar to a straight ball's behaviour after contact with a wet ground. Under the hot and humid environment of Malaysia including seasonal rains, the same problem would be encountered when using the cricket bowling machine.

The analysis of the machine's performance to determine its accuracy and consistency of ball delivery which would then be compared to the trajectory results collected from the simulated mathematical model. Some examples have shown that coefficient of variation is a good measure of consistency when comparing data sets with different means and standard deviations (Ball and Hrysomallis, 2012; Brechbuhl et al., 2016). Those examples also described their respective experimental procedures with could be emulated to assess the developed cricket bowling machine. The magnitude of the ball velocity bowled by the machine is another important criteria in the assessment. There are several ball velocity range stated by previous researchers related to the player skill level and bowler type (TalkCricket, 2017).

1.2 Problem Statement

A bowling machine can be used for solo training by batsmen or with at least one other person without the need for an active bowler. This allows for extended training time especially during repetitions against a particular bowling style which would be taxing if done by a real bowler. Repetitive batting training for batsmen is important in improving their responses and decision-making skills towards varying bowling styles. Furthermore, by using a bowling machine during extensive batsmen training, the risks of injuries experienced by bowlers can be reduced. Based on a past research on the types of injuries experienced, the most common ones are towards the lower back with 37%-55% occurrence rate among junior fast bowlers (Crewe et al., 2012). By the age of 18, 4%-8% of the general population experienced lumbar spondylolysis which refers to degenerative changes in the lumbar spine. However, the occurrence rate was reported to be 11% within a cricket season and 24% within four years among junior fast bowlers. The same study also noted that majority of the tested fast bowlers who were aged between 15 to 19 years, may experience accelerated degeneration which was inferred to be the result of multiple factors' combination such as bowling technique and workload. Those factors increased the risk of stress fracture development succeeding the adolescent growth spurt compared to normal population.

It is important to note that while young cricket players have higher risks, older players still experience such injuries. On the other hand, spin bowlers were reported to have a lower incidence of sustaining injuries due to less physiological demands. A recent study, however, has shown that these bowlers may still be susceptible to such injuries depending on the bowling technique employed (Middleton et al., 2016). It was concluded that certain techniques used during off-break delivery contributed to the probability of experiencing a lower back injury. This was due to similar physiological movements to that of a fast bowler. Subsequently, utilising a cricket bowling machine during a batsman's training would reduce the workload experienced by the bowler and thus lowering injury risks. As mentioned earlier, the machine could be used in training for both professional and amateur players in Malaysia especially younger generations. Currently, there are no locally developed bowling machines and the only other option is from overseas purchase either directly or through a third party which would incur high costs making them less favourable to those with tighter budget constraints.

Recent studies on cricket bowling machines have not disclosed performance analysis on certain parameters such as wetness of ball. Although cricket sport is not usually played during raining periods, the machine could be used on the field after such periods. Wet grounds would cause the ball to become wet and thus possibly affecting its velocity after bowling. There are no data on the performance variation between dry and wet ball from past studies.

For this research, the two-wheel propulsion method was selected which utilised pneumatic wheels. This gave rise to another parameter, the wheel's pneumatic pressure. A researcher who worked on the development of an automated sepak takraw machine had run experiments on his machine for varying tyre pressures to find the optimum value that would produce the best ball velocity (Ontam, 2010). Likewise, due to different wheel size and brand, it is also important to determine the appropriate value for the cricket bowling machine. Moreover, while there are commercial machines that could produce varying bowling style such as off-break and leg-break, literatures on the methods employed to achieve them are not available. Studies on the cricket ball kinematics for different bowling styles may provide insight on achieving them using a two-wheel cricket bowling machine.

1.3 Objectives

In order to address the issues mentioned in the problem statement, two objectives have to be achieved as listed below:

1. To fabricate a multimode cricket bowling machine using two rotating wheels.
2. To analyse the performance of the fabricated machine.

The first objective is meant to solve the first problem of this research. The design and fabrication of the cricket bowling machine falls within this objective including the control system. Moreover, the kinematic data of the cricket ball bowling trajectory would be studied to determine part of the design requirements. The second objective on the other hand involves analysis of the machine performance to determine if the design requirements are met. This includes the experiments that are essential to determine the appropriate parameter values such as wheel's tyre pressure. Under the second objective, the controller used for automating the wheel's angular speed is also be tested. The consistency of the ball velocity and distance are equally evaluated. The wet ball effect on its trajectory properties are part of the experimental procedures for performance measurement.