FINITE ELEMENT ANALYSIS (FEA) FOR SOCCER BALL IMPACT

SITI SARAH BINTI ABD RAHMAN

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ABSTRACT

In this era of technology, the present day game of soccer is the implication of many developments in term of the physical evolution of players, playing rules and regulation, and the design as well as the manufacture of playing equipment has receive attention among famous manufacturers. During the typical soccer match, the ball may be kicked as many as 2000 times, with linear velocities between 25 to 30 m/s, spin rates of 5 to 600 rpm and linear acceleration values of 8 m/s (T. Asami et al, 1998). Advances in material science have driven the technological development of soccer balls. In the 19th century the introduction of vulcanized rubber was the most important discovery to enable sports ball development (L. Cordingley et al, 2002). Fédération Internationale de Football Association (FIFA) which is the soccer world governing body has introduced the Denomations program in 1996 to ensure the global consistency of soccer ball used in elite competition. The design, development and innovation of soccer ball are crucial activities in order to gain competitive advantages within the market. Regardless of the market interest, the researchers aim to improve sport performance and to reduce injuries. In this project, the simulation done using by the finite element software named ABAQUS. ABAQUS software is a suite of mutual application for finite element analysis. It provides a powerful and unified system for engineering analysis and digital prototyping in support of design and manufacturing. The early study is between the soccer ball and the rigid plate. The effects of velocity and materials properties between soccer ball and the rigid plate were investigated. The peak impact force will be investigated using the equation stated by referring to the journal. The construction of the finite element (FE) model was design in 3D between a soccer ball and a rigid plate. To determine the accuracy of present simulation, the results were compared with experimental test of soccer ball. There is also the validation with the case study from establish journal by (D. S. Price et al, 2006).

ABSTRAK

Dalam era teknologi, bola sepak yakni permainan masa ini memberi banyak implikasi perkembangan dari segi evolusi fizikal pemain, undang-undang bermain dan peraturan, reka bentuk serta pembuatan peralatan bermain telah mendapat perhatian dalam kalangan pengeluar terkenal. Dalam perlawanan bola sepak biasa, bola boleh ditendang sebanyak 2000 kali, dengan halaju linear antara 25 hingga 30 m / s, kadar putaran 5 hingga 600 rpm dan nilai pecutan linear 8 m / s (T. Asami et al , 1998). Kemajuan dalam sains bahan telah memacu pembangunan teknologi bola bola sepak. Dalam abad ke-19 pengenalan getah tervulkan adalah penemuan yang paling penting bagi membolehkan sukan bola pembangunan (L. Cordingley et al, 2002). Fédération Internationale de Football Association (FIFA) yang merupakan badan pentadbiran dunia bola sepak telah memperkenalkan program Denomations pada tahun 1996 untuk memastikan ketekalan global bola sepak yang digunakan dalam pertandingan elit. Reka bentuk, pembangunan dan inovasi bola sepak adalah aktiviti yang penting untuk mendapat kelebihan daya saing dalam pasaran. Di samping mengira kepentingan pasaran, penyelidik berhasrat untuk meningkatkan prestasi sukan dan mengurangkan kecederaan. Dalam projek ini, simulasi dilakukan dengan menggunakan oleh perisian unsur yang dinamakan ABAQUS. ABAQUS adalah perisian untuk analisis unsur terhingga. Ia menyediakan satu sistem yang kuat dan bersatu untuk analisis kejuruteraan dan prototaip digital bagi menyokong reka bentuk dan pembuatan. Kajian awal adalah antara bola sepak dan plat tegar. Kesan halaju dan sifat bahan antara bola sepak dan plat tegar telah disiasat. Daya kesan puncak akan disiasat dengan menggunakan persamaan yang dinyatakan dengan merujuk kepada jurnal. Pembinaan unsur terhingga (FE) model adalah reka bentuk dalam 3D antara bola sepak dan plat tegar. Untuk menentukan ketepatan simulasi ini, keputusan dibandingkan dengan ujian percubaan bola sepak. Terdapat juga pengesahan dengan kajian kes dari menubuhkan jurnal oleh (DS Harga et al, 2006).

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LIST OF ABBREVIATIONS

FIFA	Fédération Internationale de Football Association
ms	millisecond
m/s	meter per second
mm	millimeter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In this era of technology, the present day game of soccer is the implication of many developments in term of the physical evolution of players, playing rules and regulation, and the design as well as the manufacture of playing equipment has receive attention among famous manufacturers. During the typical soccer match, the ball may be kicked as many as 2000 times, with linear velocities between 25 to 30 m/s, spin rates of 5 to 600 rpm and linear acceleration values of 8 m/s (T. Asami et al, 1998). Advances in material science have driven the technological development of soccer balls. In the 19^{th} century the introduction of vulcanized rubber was the most important discovery to enable sports ball development (L. Cordingley et al, 2002). Fédération Internationale de Football Association (FIFA) which is the soccer world governing body has introduced the Denomations program in 1996 to ensure the global consistency of soccer ball used in elite competition. The design, development and innovation of soccer ball are crucial activities in order to gain competitive advantages within the market. Regardless of the market interest, the researchers aim to improve sport performance and to reduce injuries. Soccer ball is one of the most popular sports in the world with approximately 120 million registered players (Jordan, S. E. et al, 1996). Repetitive heading of the ball is one of possible mechanism of head injuries in soccer ball (Khalil, T. B. et al, 1993). According to Green G, and Jordan S. (1998) also stated in term of the incidence of head injuries, head impacts during heading has been found to be the main mechanism of injury. Besides, the injuries of soccer ball also

occur mostly in the lower extremities, specifically the knee and ankle. This kind of injuries caused various symptoms afterwards. Due to the increasing concern of soccer ball that consume high percentages injuries due to the increasing registered players, the simulation of soccer ball performances were discovered to allow better understanding of stress, strain, elasticity and others. The simulation was done through Finite Element Analysis (FEA).

Figure 1.1: Soccer Ball Match.

In this present study, the development of a soccer ball modeling using finite element (FE) technology was done. As the faster growth of technology, demands are being made on the behavior of the materials in a very short time. Safe and cost-effective design demands the best understanding of the behavior of the material and structures subjected to the impact loading. Thus, in engineering, one of the most important problems is the understanding of an impact well-designed structure subjected by a foreign object. The model of the soccer ball consists of two layers whereby the inner layer is to accommodate air pressure and the outer layer is to mimic the lining of the soccer ball. The materials used are polyurethane

and polyvinyl chloride (PVC). The model was validated through the comparison from the experimental test and the case study by (D.S. Price et al, 2006) where the soccer ball was impacted to a rigid plate. It was found that the combined effects of ball design and materials parameter resulted in impact properties such as coefficient of restitution, contact time, deformation, velocity before and after impact, peak impact force and the 2D shape taken up by the ball at maximum deformation, to vary with pre-impact ball orientation. The model showed good agreement with the measurements of experimental test and the case study done.

Figure 1.2: Adidas Telstar-style ball, with the familiar black and white truncated icosahedron pattern.

1.2 PROBLEM STATEMENT

Traditionally, engineers have to use the laboratory to investigate the material behavior of the soccer ball related on the impact loading. However, such reliance on time consuming and expensive equipment may contribute to be one of the problem to get the

result in a short time. Thus, the advantages of FEA are numerous and important. A new design concept may be modeled to determine its real world behavior under various load environments, and may therefore be refined prior to the creation of drawings, as it is not consume a larger amount of money to spend. Once a detailed model has been developed, FEA can analyze the design in detail, saving time and money by reducing the number of prototypes required. An existing product which is experiencing a field problem, or is simply being improved, can be analyzed to speed an engineering change and reduce its cost. Moreover, FEA can be performed on increasingly affordable computer workstations and personal computers, and professional assistance is available.

1.3 OBJECTIVES

The objectives of this project are:-

i. To develop 3D modeling of soccer ball and rigid plate for impact simulation.
ii. To determine the force impact and other mechanical properties.

1.4 SCOPE

1.1 The 3D model of size 5 soccer ball is developed according to regular standard by FIFA.
1.2 Soccer ball model is developed in two layers whereby the inner layer is to accommodate air pressure and outer layer is to mimic outer lining.
1.3 Rigid plate model represents a part that is so much stiffer than the soccer ball that its deformation can be considered negligible.
1.4 The impact encountered between soccer ball and rigid plate is linear.

1.5 THESIS OUTLINE

This thesis consists of five chapters. Chapter 1 gives the introduction of this project. In this introduction part, there will be brief explanations about the background of this study, the problem statement, the objective of this study, and the scope/limitation in this project. This chapter is as a fundamental for the project and act as a guidelines for project research completion.

Chapter 2 discuss about the literature review of this present study. Literature review will be mainly discussed on history of soccer ball, injuries related on soccer ball, soccer ball impact, simulation of soccer ball impact, finite element analysis (FEA), and modeling of soccer ball.

Chapter 3 describes the methodology part of the study. Methodology gives information about the modeling, selection of the boundary condition and simulation of finite element analysis on Soccer Ball by using software (Soccer Ball impact simulation).

Chapter 4 discuss about the result and discussion part of the study. The result for force impact, contact time, soccer ball deformation and velocity after impact will be analyzed. Hence, the objective of this project will be achieved in this chapter.

Chapter 5 will give the overall conclusion of the project. The conclusion made will be based on the simulation and result analysis. Recommendation will be provided based on the simulation of finite element analysis on Soccer Ball by using software (Soccer Ball impact simulation).

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

It is a natural fact that every action starts with a purpose. There are several sub-topics will be discussed on the idea that drives toward the further studies about soccer ball throughout in this section. The sub-topics will begin with the history of the soccer ball from the ancient time to the modern time that much development was done. Due to the increasing concern toward the registered players that increases from time to time, there are also the studies on the injuries related with soccer ball that will be explored wider in this section. Same goes to the soccer ball impact that becomes one of the causes of the injuries to the players. Thus, the simulation and the finite element analysis (FEA) were act as some of the solution in this injuries problem as well as to improve the performance of the soccer ball.

2.1 HISTORY OF SOCCER BALL

In 1863, the Soccer ball Association has been laid down the specification of soccer ball. Previously, the soccer balls were made up of inflated leather with later the leather covering it help soccer ball to maintain their shape. Several years later, the specification of the soccer balls were revised, and these rules have been left fundamentally unchanged as defined by the International Soccer Ball Association Board. Due to this, the variety of

soccer ball created as there is various effect related on difference materials used. Soccer ball has gone through a dramatic change over the years. Balls were normally made from an outer shell of leather filled with cork shaving during the medieval times (D.S. Price et al, 2006). On the other hand, animal bladders also been used for the inside of the ball to make it inflatable. However, it is easy to cause the ball to puncture and was inadequate for kicking when using these two styles for creating the soccer ball.

Figure 2.1: Leather ball used in the football tournament at the 1936 Summer Olympics.

The development of soccer balls do not stop until the 19th century as the soccer balls have much been improved into what soccer ball looks like today. In 1838, the discoveries of vulcanization and the introduction to use the rubber done by Charles Goodyear and Domenico Nobili was dramatically improved the soccer ball. Vulcanization act as a

treatment of rubber on some qualities such as strength, elasticity and resistance to solvents. It is also help the soccer ball to moderate the heat and cold. In addition, the vulcanization of rubber also helped to create the inflatable bladders that pressurize the outer panel arrangement of the soccer ball. This innovation increased the bounce ability of the soccer ball and made it easy to be kicked. The soccer balls were then made up of leather and rubber which is suitable for bouncing and kicking. Nevertheless, when the player is heading the soccer ball it was usually painful. This problem is due to the water absorption of the leather from rain which caused a considerable rise in weight that lead to head and neck injury.

Figure 2.2: Charles Goodyear patented vulcanized rubber.

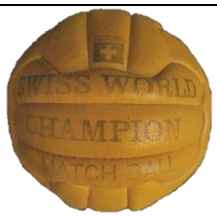
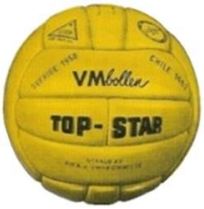
The sport good industries strive to improve the equipment available for each sport and soccer is no exception. The deformation of the soccer ball when it is kicked or when it hits a surface become one of the essential element to be tested today. Here, the Sport Technology Research Group of Wolfson School of Mechanical and Manufacturing Engineering in Loughborough University developed the Finite Element (FE) modeling of soccer ball. Basically, the spherical shell with isentropic material properties was

considered. The improvement of the soccer balls were made from time to time, as the various companies such as Adidas, Nike and Puma are releasing a soccer ball made up of new materials where they are more accurate flight and increases the performance of the soccer ball.

Nowadays, the soccer balls are more complex compare to the previous one. Twelve regular pentagonal and twenty regular hexagonal panels positioned in suitable spherical geometry consist in most modern soccer ball (D.S. Price et al, 2006). To make sure it is enables to be pressurized the inner part of the soccer ball is made out of latex bladder. The soccer ball's panel pairs are stitched along the edge as this procedure can be performed either by manually of by using machine. By using the technology, the development of the soccer ball can be done easily and saving cost as just a few equipment is needed to run the finite element modeling of the soccer ball compare to traditionally experimental test. However, in order to improve performance of soccer ball the development was done to reduce injuries.

Table 1: The following footballs were used in the FIFA World Cup finals tournaments.

World Cup	**Ball (s)**	**Image**	**Manufacturer**
1930	Uruguay		-
1934	Federale 102		ECAS (Ente Centrale Approvvigionamento Sportivi), Rome.

1938			Allen, Paris.
1950	Duplo T		Superball
1954	Swiss World Champion		Kost Sport, Basel
1958	Top Star		Sydsvenska Läder och Remfabriken, Ängelholm
1962	Crack Top Star		Senor Custodio Zamora H., San Miguel, Chile Remmen
1966	Challenge-4 Star		Slazenger
1970	Telstar		Adidas

1974	Telstar Durlast		Adidas
1978	Tango		Adidas
1982	Tango España		Adidas
1986	Azteca		Adidas
1990	Etrusco Unico		Adidas

1994	Questra		Adidas
1998	Tricolore		Adidas
2002	Fevernova		Adidas
2006	Teamgeist		Adidas
	Teamgeist Berlin		
2010	Jabulani		Adidas

	Jo'bulani		
2014	Brazuca		Adidas

2.2 INJURIES RELATED TO SOCCER BALL

During soccer ball match, the players usually use their head and leg to pass the ball between each other. Thus, by repetitive heading soccer ball or kicking them it may lead to some injuries toward the player. There will be divided into two small topics that will be discussed about head injuries and leg injuries while playing the soccer ball.

2.2.1 Frequent Soccer Ball 'Heading' May Lead to Brain Injury

According to the researches at Albert Einstein College of Medicine of Yeshiva University, they have proven that soccer players who frequently head the ball have brain abnormalities. Usually, soccer players head the ball six to twelve times during match, where the soccer balls speed can achieve more than 50 miles per hour while during practice, the players commonly head the ball 30 or more times. The human head is one of the most vulnerable parts of the human body when exposed towards the impact loading (Lichte H. et al, 1975). Over the years, many numerical studies have been presented that simulated an impact on the human head and that have tried to identify the mechanism which causes a particular injury. When the level of energy being rapidly subjected a bit much to the head, there will be the traumatic head impact injuries occur (L. Cordingley et

al, 2002).Accidents, falls, assaults and injuries occurring during occupational, recreational and sporting activities are the causes of neurotrauma. Ordinarily, the body weight and muscles strength are difference according to the gender. The head and neck joint of human body has a complex structure, which consists of bones, muscles, ligaments and others. The material properties of the body tissues also have complex characteristics and high non-linearity. In this study, a simplified material properties model has been used which be represented by the isotropic, linear, elastic materials as a first order analysis.

From the reading stated that the female players as the female body weight and muscles strength is lower than that of a female but the ball weight used in the women's football is the same as that of the men's football. According to the some previous researches have reported study of ball heading but the stress distribution at ball impact and the influence of low body weight on women and young players are still not clear (Gronwall D et al, 1975). A study by (Matser et al, 1999) again revisited the question of heading causing brain damage. In their study, swimmers and track athletes were compared with soccer players. The soccer players scored significantly lower on tests of planning and memory.

Figure 2.3: The player is heading a soccer ball.

In the literature, there are many realistic human head models are reported but when focus on the author's knowledge, it is found that only models performed by (Ruan et al, 1994) have been validated against experimental data. Only one case of the frontal impact cadaver tests was referenced in the bibliography performed by (Nahum et al, 1977). However, in previous times ago, this kind of modeling permitted a better understanding of brain injury mechanisms. In the above cited papers, there is also a first proposed approach of accident simulation in order to estimate the human head tolerance threshold.

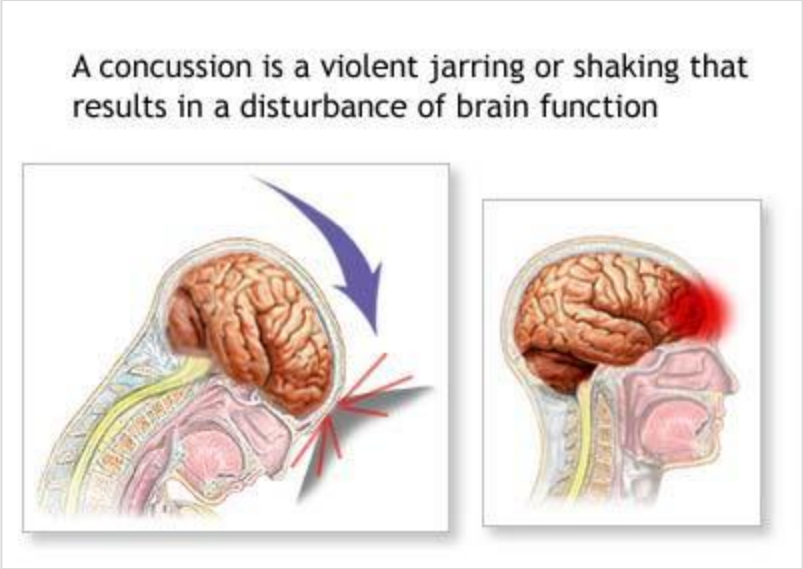


Figure 2.4: Brain injuries.

2.2.2 Mechanisms of Leg Injuries

On the other hand, the soccer game also contributes to the leg injuries mainly affecting the lower extremities, particularly knees and ankle (Ekstrand et al, 1982). The injuries are often due to collision, contact and non-contact activities. In soccer, there is frequent contact but infrequent collision. It may lead to serious injuries because of the speed at which the game is played. The quadriceps and hamstring muscle groups are the primary movers of the sport. Jumping and ball kicking related with the role of quadriceps group while the hamstring plays an important role to control running activities and stabilizes the knee turns. By kicking the soccer ball, it can develop the quadriceps muscle