DESIGN OF PROTECTIVE HEADGEAR FOR SOCCER PLAYERS THROUGH EXPERIMENTAL AND COMPUTATIONAL ANALYSIS

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ABSTRACT

The uniqueness of soccer is the fact that one is allowed to use the head to direct the ball in the game. This purposeful ball-to-head impact has become one of the causes of head injuries in soccer. Clinical studies have linked multiple soccer headings with the risk of sustaining mild traumatic brain injury. This study attempts to look into this matter from the engineering perspective. A human head finite element model was adopted from a previous study and validated against a published cadaveric experimental data of intracranial pressures and linear head acceleration. A good agreement was reached between the predicted head responses and those of the cadaveric experiment. The validated soccer ball and human head finite element models were assembled to perform soccer heading simulations. To validate the finite element analysis, a soccer heading experiment was conducted on human volunteers. An instrumented mouthpiece was used to record linear and angular head accelerations during the soccer heading trials. The simulation results match those of the experiment with more than 80% accuracy. Furthermore, the study aims to evaluate the efficacy of impact-absorbing foams in mitigating the risk of sustaining head injury due to soccer heading. Another soccer heading experiment was carried out with the volunteers wearing a commercial soccer headgear. The linear and angular head accelerations obtained were compared to those of without wearing the headgear. The results demonstrate that the headgear is incapable of reducing the risk of head injury. Finite element analyses of soccer heading with wearing the headgear were performed. The comparison of both results reveal a good agreement, which suggest that the finite element models developed is a useful tool in the development of a new protective headgear for soccer players. In addition, parametric studies of the foam material properties show that an elastomeric foam alone might not be able to attenuate the risk of sustaining head injury due to soccer heading.

ABSTRAK

Keunikan sukan bola sepak ialah seseorang pemain dibenarkan untuk menggunakan kepala untuk menanduk bola. Impak bola dan kepala ini telah menjadi salah satu punca kecederaan kepala di dalam sukan ini. Ujian klinikal menunjukkan tandukan bola sepak berkali-kali boleh mengakibatkan kecederaan otak. Kajian ini cuba untuk melihat perkara ini daripada perspektif kejuruteraan. Sebuah model unsur terhingga kepala manusia telah diadaptasi daripada sebuah kajian terdahulu dan disahkan berdasarkan data tekanan intrakranium dan pecutan linear kepala daripada sebuah eksperimen ke atas kadaver manusia. Model bola sepak dan kepala manusia tersebut kemudian dihimpunkan untuk menjalankan simulasi tandukan bola sepak. Untuk mengesahkan simulasi ini, sebuah eksperimen tandukan bola sepak telah dijalankan ke atas sukarelawan manusia. Sebuah pelindung mulut teralat digunakan untuk merekodkan pecutan kepala linear dan sudut. Keputusan simulasi didapati sepadan dengan eksperimen dengan kejituan melebihi 80%. Seterusnya, penilaian tahap keberkesanan peresap hentaman berbusa di dalam mengurangkan risiko kecederaan kepala ketika menanduk bola sepak turut dijalankan. Sebuah eksperimen dijalankan di mana para sukarelawan memakai sebuah alat pelindung kepala komersil dicipta khas untuk pemain bola sepak. Pecutan kepala linear dan sudut yang diukur dibandingkan dengan eksperimen tanpa memakai pelindung kepala. Perbandingan menunjukkan pelindung kepala komersil tersebut gagal untuk mengurangkan risiko kecederaan kepala. Analisa unsur terhingga dijalankan bagi kes dengan memakai pelindung kepala. Perbandingan menunjukkan kesepadanan yang baik, sekali gus membuktikan kebolehupayaan model-model unsur terhingga yang telah dibangunkan di dalam pembangunan sesebuah alat pelindung kepala yang baru untuk para pemain bola sepak. Tambahan pula, kajian parametrik menunjukkan bahan elastomerik berbusa sahaja mungkin tidak mampu untuk mengurangkan risiko kecederaan kepala ketika menanduk bola sepak.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Soccer is the most popular sport in the world. More than 265 million people are actively involved in this game worldwide, both registered and unregistered (FIFA.com, 2006). This represents 4% of the world's population. In Malaysia, more than half a million people are actively involved in soccer as reported in the FIFA's website. This number does not include the recreational players such as school children and teenagers who play soccer occasionally. Many Malaysians especially adolescents involve in soccer and they play soccer almost every day, both indoor and outdoor.

The uniqueness of this game is that it permits the purposeful use of the head in directing the ball to the teammates or even scoring goals. This manoeuvre is termed 'heading'. A soccer player could be subjected to six to seven occasions of heading in a game (Tysvaer and Storli, 1981) with an estimation of approximately 800 headings a year (Matser et al., 1998). This, however, does not include the number of headings sustained during training sessions. Thus, a professional soccer player might experience up to more than a thousand headings every year.

Traditionally, soccer is not considered as a sport with a high-risk of head injury. Nonetheless, the American Association of Neurological Surgeons reported that more than 24,000 patients with soccer-related head injuries were treated in the US hospital emergency room in 2009. They also listed soccer as one of the top 10 sports with the highest head injury cases amongst children of age 14 and younger, with more than 8,000 cases reported that year. This shows that the head injuries in soccer are comparable to those of more violent contact sports such as the American football and ice hockey.

During a soccer game, a player's head could be subjected to an impact with the other player's head, elbow, knee, goal post as well as the ball. These head impacts might lead to concussion, which could result in traumatic brain injury (TBI). All of these impacts are the collision between the head and an almost rigid object, except for the impact with the ball. Even though the ball is a soft, deformable object, clinical studies have linked the soccer ball heading to brain trauma injury. This injury is caused by the linear and rotational acceleration of the head. A protective headgear, which could reduce these accelerations might protect the brain of soccer players during heading manoeuvre.

1.2 Objectives of the Study

This work attempts to analytically model the ball-to-head impact in soccer to study the kinematics of the head and brain during heading. In addition to the analytical model, the soccer heading manoeuvre is simulated by means of the finite element (FE) method. Further, the protective materials for the soccer headgear are analysed. Overall, the objectives of this study are as follows:

1. To develop and validate a simplified human head finite element model.
2. To develop and validate the finite element models of soccer ball to quantify the head accelerations due to soccer heading manoeuvre.
3. To investigate the influence of impact-absorbing foams on the head acceleration due to soccer heading manoeuvre by means of finite element analysis.

1.3 Scopes and Limitations

This work is bound by the following scopes and limitations:

- The major focus of this work is the numerical modelling of the ball-to-head impact in soccer.
- The severity of the impact is measured by the linear and angular accelerations of the head. These accelerations are used to calculate the Head Impact Power (HIP). HIP is a head injury predictor that measures the severity of head injury and it is used throughout this study.

- The models developed in this study are intended for the analysis of soccer heading, hence the relatively simple geometry. Nonetheless, the models developed were thoroughly validated to ensure acceptable accuracy.

CHAPTER 2

JOURNAL PAPER

2.1 A reaction-force-validated soccer ball finite element model

Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology

Volume 231, Issue 1, 1 March 2017, Pages 43-49

Taha, Z., Hassan, M.H.A.

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Abstract

The soccer ball is one of the important pieces of equipment in the game of soccer. It undergoes various forms of impact during the game. In order to numerically investigate the occasions of ball impact such as soccer heading, a validated finite element model of a soccer ball is required. Therefore, a model was developed incorporating material properties obtained from literature. To ensure the accuracy of the model, it was validated against an established soccer ball model and experimental data of the coefficient of restitution, contact time, longitudinal deformation and reaction force. In addition, a parametric study of the mesh density was also performed to determine the optimal number of elements. The developed soccer ball model was found to be in a good agreement with the literature and experimental data. This suggests that, the soccer ball model is capable of replicating the impacts of interest. This article details the development of the model and the validation processes.

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Zahari Taha and Mohd Hasnun Arif Hassan

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Keywords

Finite element model, soccer ball, reaction force, experimental validation, sports ball

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Introduction

Soccer is estimated to be the most popular sport in the world, with more than 270 million people actively involved in the game.[1] One of the most important pieces of equipment in a soccer game is the ball itself. The first vulcanised soccer ball was developed by Charles Goodyear back in 1855; 7 years later, the first inflatable rubber bladders for balls were introduced.[2] Significant advancement in the materials used in the soccer ball production has been seen, from porcine's bladders to vulcanised rubber, to leather and synthetic leather, and finally, to a combination of several materials such as rubber bladders and polymer foam. Today, ball manufacturers continue to improve the soccer ball by incorporating new technologies and more advanced materials in the manufacturing process.

In a soccer game, the ball impacts different objects such as the foot, the ground, a goal post, the hand and the head. To further understand the mechanics of soccer ball impact, researchers have attempted to develop finite element (FE) models of a soccer ball. Published studies with regard to this topic include Price et al.[3–6] Price et al. developed an advanced FE model of a manually stitched 32-panel soccer ball and validated it against experimental data.[3] This study was then used to investigate the effects of anisotropy on the ball design.[4] In addition to material anisotropy, the influence of panel stitching, panel configuration,[5] viscoelastic material properties and ball dynamic characteristics were studied.[6] The work by Price et al. with regard to the FE modelling of a soccer ball is without doubt very extensive, and it serves the purpose of understanding the dynamics of ball impact. However, to accurately model a soccer ball impact, a ball model validated against reaction force data is required.

Soccer is a contact sport; hence, soccer players are susceptible to various injuries. One of the most dangerous injuries is concussion. In soccer, concussion might occur due to the impact of the head with external objects such as other player's head, the ground, a goal post or the ball itself during a soccer heading manoeuvre. Studies have shown that the head accelerations that occur during heading might lead to brain trauma.[7–10] It has been reported that the highest

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CHAPTER 3

CONFERENCE PROCEEDINGS

3.1 Development of a soccer ball launching device

Lecture Notes in Mechanical Engineering

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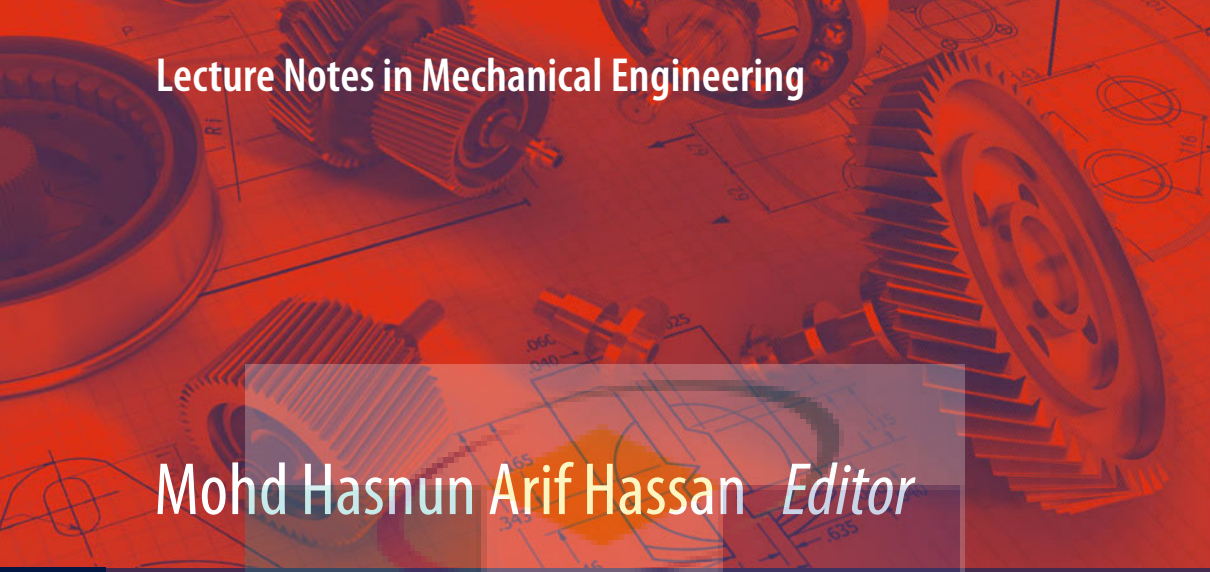
Abstract
Soccer players are allowed to use their heads to direct the ball to the teammates during the game. Studies have shown that purposeful heading of the ball in soccer might cause long-term traumatic brain injury. In order to analyze the impact of soccer heading on the brain in the laboratory, a device that can launch the ball at constant speed is required. This project aims to develop a device, which can launch the ball towards a target such as an instrumented dummy headform at desired speeds. Two counter-rotating wheels that are rotated by two AC motors were used as the launching mechanism. The use of AC motors is economical, but their speeds cannot be easily controlled. Thus, a release mechanism that automates the switching of the motor as well as feeding the ball was developed. Testing shows that the device is capable of launching the ball up to a maximum speed of 18 m/s. This corresponds to the reported maximum heading speed in soccer. The use of the release mechanism allows the ball speed to be varied. A soccer ball launching device was successfully developed. The device is not only economical, but also capable of launching the ball at desired speeds.



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Mohd Hasnun Arif Hassan *Editor*

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Development of a Soccer Ball Launching Device

Mohd Hasnun Arif Hassan, Zahari Taha, Mohd Ali Hanafiah Shaharudin, Lim Kok Wee and Zulfika Anuar

Abstract Soccer players are allowed to use their heads to direct the ball to the teammates during the game. Studies have shown that purposeful heading of the ball in soccer might cause long-term traumatic brain injury. In order to analyze the impact of soccer heading on the brain in the laboratory, a device that can launch the ball at constant speed is required. This project aims to develop a device, which can launch the ball towards a target such as an instrumented dummy headform at desired speeds. Two counter-rotating wheels that are rotated by two AC motors were used as the launching mechanism. The use of AC motors is economical, but their speeds cannot be easily controlled. Thus, a release mechanism that automates the switching of the motor as well as feeding the ball was developed. Testing shows that the device is capable of launching the ball up to a maximum speed of 18 m/s. This corresponds to the reported maximum heading speed in soccer. The use of the release mechanism allows the ball speed to be varied. A soccer ball launching device was successfully developed. The device is not only economical, but also capable of launching the ball at desired speeds.

Keywords Soccer ball launcher · Ball shooter

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CHAPTER 4

BOOK

4.1 Mechanics of Soccer Heading and Protective Headgear

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CHAPTER 5

CONCLUSION

The FE models of soccer ball and human head were developed and assembled to simulate soccer heading manoeuvres. The ball and the head were positioned similar to that in the experiment. Simulation results show that the predicted peak linear and angular head accelerations agree with those measured in the experiment with an accuracy of more than 80% and 90%, respectively.

Parametric studies of soccer heading was also conducted to investigate the impact of the head angle and ball pressure on the head responses. Both parameters were found to be sensitive to the HIP_{max}. Increasing the head angle resulted in an increase in the HIP_{max}, albeit the reduction of the angular acceleration. Furthermore, increasing the ball pressure resulted in an increase in both linear and angular head accelerations, impact force and the HIP_{max}, except for the COR. This suggests that the ball pressure has no impact on the heading performance. Owing to this findings, it is recommended to inflate the ball to the lowest possible pressure according to FIFA's regulation to reduce the risk of sustaining head injury during soccer heading manoeuvre.