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The effect of spin and friction on reaction forces in a soccer ball impact: A computational study

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ABSTRACT – This study investigates the effect of spin and coefficient of friction on the reaction forces in a soccer ball impact. The analysis was conducted by means of finite element (FE) method. A validated soccer ball FE model was used. Angular ball velocity and the coefficient of friction between the ball and the impacted surface were varied in the simulations. The normal and friction forces were the output parameters of the simulations. The results show that the normal force is neither influenced by the coefficient of friction nor the angular velocity, while the friction force is influenced by all impact variables. This study shows that a soccer ball impact can be influenced by several external factors.

1. INTRODUCTION

Soccer is one of the most popular sports in the world. The total number of people who are actively involved in soccer are about 4% of the total population of the world [1]. This is a contact sport, which involves many contacts between players and also the ball. One of the popular manoeuvre in soccer is ball heading. The player uses his/her head to hit the ball to another teammate or hit the ball into the net to score a goal. Several studies have suggested that soccer heading might cause traumatic brain injury [2-5]. Measurement of brain motion experimentally is very difficult, thus a computational method like the FE analysis is a very useful tool in studying such case.

During the game, the ball impacts various types of surface. Simulation studies for instance by means of FE method have been conducted to study and understand the mechanics of the ball impact [6-8]. The output of the simulations are the ball impact characteristics, namely the contact time, rebound velocity and maximum longitudinal deformation. The input of the simulation, on the other hand, is the inbound velocity. Nonetheless, these studies employed only linear ball velocity without any spin, which is

The objective of this study is to quantify the reaction forces due to the ball impact using the FE method. In the abovementioned studies, the only input was the inbound velocity. In this study, we introduce a spin to the ball by defining both linear and angular velocities. This study serves as an initial study before simulating the soccer heading manoeuvre of a spinning ball. Several parameters, namely the inbound velocity, the ball spin and the coefficient of friction were varied to investigate the influence of each parameter on the reaction forces. The following sections detail the methodology of the study and the results obtained.

2. METHOD

This investigation was conducted computationally using a validated finite element model of soccer ball. The model was developed by Taha and Hassan [8], which utilises a composite sphere shell geometry. The soccer ball model comprises of two layers, namely the inner rubber bladder and an outer composite panel. The material properties of each layer were obtained from Price et al. [6].

The model was validated by Taha and Hassan [8] through a dynamic impact test and a drop test on a force platform that measures the reaction force upon impact. Nonetheless, their simulation was performed without any ball spin. Thus, this study aims to extend the work of Taha and Hassan [8] by introducing spin to the ball before it impacts the rigid surface as shown in Figure 1.

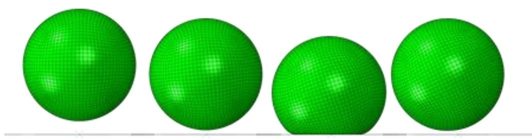

Figure 1 Soccer ball impacting rigid floor with spin.

To define the velocity of the ball, a reference point was created at its centre of mass. The reference point was coupled to the ball's surface using the structural coupling method. The structural coupling method couples the translation and rotation of the reference node to the translation and the rotation motion of the coupling nodes. By doing this, the motion of the ball is governed by the motion of the reference point. Therefore, the velocity and the angular velocity of the ball were defined at the reference point, which in turn will cause the ball to have the same motion. The velocity of the ball was varied from 9, 12, 15 and 18 m/s, while the angular velocity was varied from 5, 10, 25 and 50 rad/s.

The impact between the ball and the rigid surface involves a contact. Thus, a general contact was defined. The friction between the contact surfaces was defined using penalty method. This method permits some relative motion of the surfaces when they should be sticking. The coefficient of friction was then defined as 0 (frictionless), 0.3, 0.6, and 0.9, and varied one at a time for the parametric analysis.

3. RESULTS AND DISCUSSION

Figure 2 and Figure 3 show the magnitude of total forces due to frictional stress for different ball spins and coefficients of friction. It is seen that the friction force is influenced by all parameters.

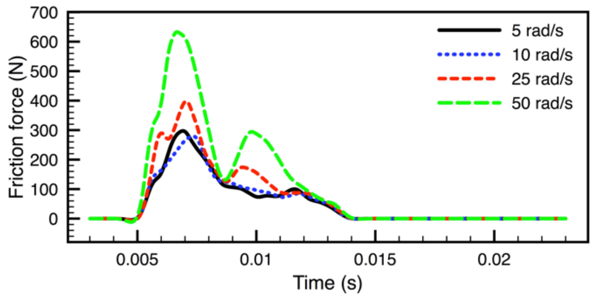

Figure 2 Friction forces with respect to the ball spins.

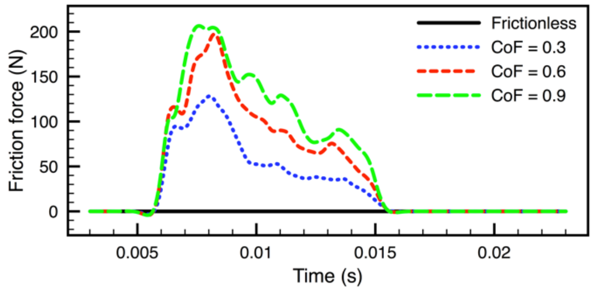

Figure 3 Friction forces with respect to the coefficient of friction.

The larger the ball spin and coefficient of friction, the larger the friction force. In Figure 2, it is observed that the 5 and 10 rad/s spins have different friction forces pattern compared to that of 25 and 50 rad/s spin. Nonetheless, the contact time is almost the same in all cases, regardless of the magnitude of the angular velocity.

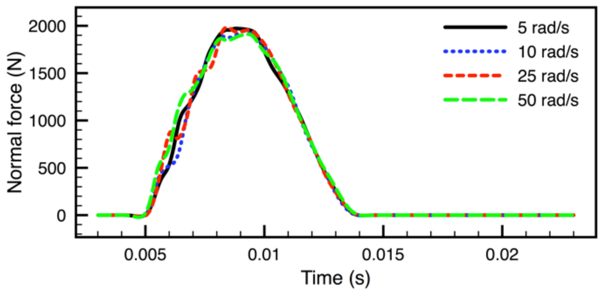

Figure 4 Normal forces with respect to the ball spins.

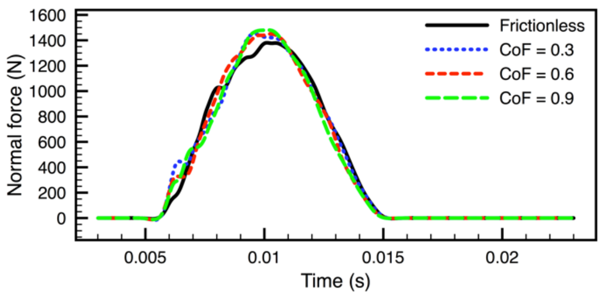

Figure 5 Normal forces with respect to the coefficient of friction.

Further, Figure 4 and Figure 5 depict the magnitude of total forces due to contact pressure for different ball spins and coefficients of friction. It was found that the ball spin and coefficient of friction were found to not influence the normal forces as shown in both figures.

4. CONCLUSIONS

This study uses the FE method to investigate the influence of the ball spin and coefficient of friction on the friction force and normal force. The friction force was found to be influenced by all parameters. The larger the magnitude of these parameters, the larger the resulting friction force. The magnitude of normal force, as obtained from the simulations, was not influenced by the ball spin and coefficient of friction. This study provides an initial insight of the impact characteristics of a spinning ball. Future study will be looking into the effect of ball spin on the head motion in a soccer heading manoeuvre.

ACKNOWLEDGEMENT

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