



Mechanical investigation of ball-ground impact under high and low speed

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ABSTRACT

Football collision is a common phenomenon during football matches, but mechanical approach to study football collision process was quite limited. This study was using force platform and high speed video system to monitor the football collision under low and high speed conditions. The high speed collision was nearly double compared the speed of low collision. But the contact time under these two collision conditions was not discrepancy a lot. We found when the speed increasing, the collision power will increase a lot. Therefore, in the football match, especially the player shots or rescues dangerous ball, if the ball hit directly on one part of human body, it may produce harm to the body even damage. We should do some buffering action to minimize the impact and protect our body. Some meaningful value in this study, were very helpful to football training and relating product development, providing certain theoretical guidance and improve the development of the football sport.

Keywords: Football, Force Platform, Collision, High Speed

INTRODUCTION

Football refers to a number of sports that involve, to varying degrees, kicking a ball with the foot to score a goal. The most popular of these sports worldwide is association football, more commonly known as just "football" or "soccer". In Europe, early footballs were made out of animal bladders, more specifically pig's bladders, which were inflated. Later leather coverings were introduced to allow the balls to keep their shape [1]. However, in 1851, Richard Lindon and William Gilbert, both shoemakers from the town of Rugby (near the school) exhibited both round and oval-shaped balls at the Great Exhibition in London. When you kick a soccer ball, multiple things happen. First of all, your leg is putting kinetic (or "movement") energy into the ball. Here the kinetic energy equals one half of the mass of your leg multiplied by the velocity of your leg, as it hits the ball, squared. Another thing that happens when you kick the ball is that the ball deforms.

Football collision is a common phenomenon in football match; its characteristic is the duration extremely short [7]. As is known to all, in a football match, in addition to football players' tactical level, location, weather conditions, the referee scale were associated, performance of football itself is also a factor cannot being neglected [2]. So, what characteristics in football collision stage, what will happen in collision process? It is necessary for us to study to find some rules. Therefore, research the phase of football collision using a biomechanical method to find out some meaningful for football training and goods production. It can also provide some certain theoretical guidance and improve the development of football. Football at present, the level of tactics skills has reached a very high level, and the improving space is getting smaller and smaller. The corresponding football pros and cons become very important. As is known to all, the world famous sports company brand Adidas has been committed long to the development of football performance [3, 4]. Since 1970 Adidas company became to provide official ball for the World Cup, up to

now it has supplied ten kinds of the World Cup special ball. Each type of football's launching attacks fans around the world. Especially the "flying bolide" football in 2002 World Cup held in Japan and South Korea and "the star of the group" match ball in 2006 World Cup held in Germany, the performance of the football were promoted to a high altitude. It spent Adidas company three years to research and development "the star of the group" ball, the ball to overthrow the traditional football is made of 32 pieces of leather. It using the new special-shaped pieces and seamless lamination technology unprecedentedly reducing football's surface patchwork to 14 pieces, making the ball's quality and performance in every shot process remain unchanged. Compared with it domestic football no matter in quality, performance and other aspects has a very big disparity. This study wants through the experiment research of high quality football, hoping for giving some valuable information to domestic football manufacturers and providing some theoretical information.

EXPERIMENTAL SECTION

In order to soccer movement process analysis, we considering the method using the football and the force platform collision, a short period of time the speed dramatically changing the magnitude and direction (Figure 1). The football choosing in this test was Finale 12 Official Match Ball (Adidas, Germany). The Adidas UEFA Champions League Finale 12 Official Match Ball will be used in all group stage matches of the 2012/2013 competition, and the new design features an outer coating texture designed to provide optimal grip at the point of impact. The artwork within the iconic star panel construction uses bold colours (white/lab lime/dark violet) and is designed to reflect a tactics board of precise on-field movements in addition to the geographical locations throughout Europe linked together as a result of the competition. The top and bottom thermal bonded stars on the match ball, based on the design of the UEFA Champions League logo, contain co-ordinates of Nyon, Switzerland, and Herzogenaurach, Germany, the homes of UEFA and Official Match Ball supplier adidas respectively.

We used high speed video camera system (Photron Fastcam SA3, Photron Ltd. Japan) at a sampling rate of 250 Hz. The video data was further analyzed through SIMI motion analysis software (SIMI Reality Motion Systems, Unterschleissheim, Germany). The camera's axis height is about 1 meter, the distance between camera and football plane is about 8 meter. Players and coaches over the years realized that the kicking game was very important in determining the outcome of a football game. Many kickers that have tried to attempt a field goal either have missed the goal completely, or the ball just did not have enough force behind it to reach the goal. Although various techniques can be used in kicking, the soccer instep kick was the best for player potential distance and accuracy [11]. That's why we select the professional football player using the instep kick method to shoot the ball to the force platform. The player was age (22 years), height (173.00 cm) and weight (67 kg). The selected player has readily agreed and volunteered to act as subject for the study. Through low speed and high speed on football collision in two sets of experiments, each measure will try 6 trials, scale placement before and after.

The Kistler force platform (Kistler, Switzerland) is fixed on the wall of the bracket, football is placed on the ground with a same fixed point, the distance between ball and force platform is 2.8 meters, testing low speed and high speed's collision strength, each measure will try 6 trials. After testing, we using the Kistler Bioware collect data and analysis the recording power value. From the beginning of athletes do ready to play to the ball bounces back will need a short time. The collision force is a kind of impact strength and its action time is very short. In this experiment if we set the shooting time too short, the athlete's preparation time will be very hasty. It's likely to cause the movement deformation while hitting the ball and leading to not kicking the ball in correct position or not completing the acquisition data. But if the shooting time set longer, not only the operating time prolong, and also bring the test data processing a lot of trouble. This is because the tests showed the power data with a power curve. The vertical axis is power value, transverse is the time power elapsed. When testing time extension, making the curve of the transverse has extended. Therefore, when reading the power data, must intercept the curve repeatedly. Through analyzing the preliminary experiment, the appropriate sampling time is 5 seconds. This can make athletes to make full preparation, also making the test strength curve abscissa length substantially matches the effective length of the curve, which saves the time of testing. Force platform's average time is about eight over one thousand seconds, time is extremely short.

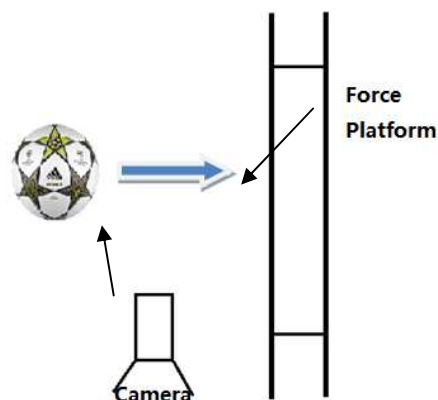


Figure 1. Set up illustration of football collision

RESULTS

Sorting and processing data we gained with statistical methods, we can obtain the before and after football collision touch the table speed, maximum strength, maximum impulse, average power data, which eliminate the experiment data deviation large data.

There is a direct relationship between the ball rebound velocity incident speeds. The greater strike speed, the greater rebound speed. Taking the ball in touch process part of the kinetic energy will convert into internal energy into account, from the perspective of the conservation of energy, the rebound speed of the ball will certainly less than the launch rate. Based on collecting football strike velocity, and rebound speed data. We can see that no matter low or high speed touch the platform, the bounce speed of the ball is less than the incidence rate, which verify in the collision process part energy of the football transfers. When the speed hit the stage below the average speed is 10.1m/s, the bounce rate is 8.6m/s, the rate is reduced by 1.5m/s; when high-speed hit the stage in an average speed is 22.3m/s, the bounce rate is 17.2m/s, the rate is reduced by 5.1m/s.

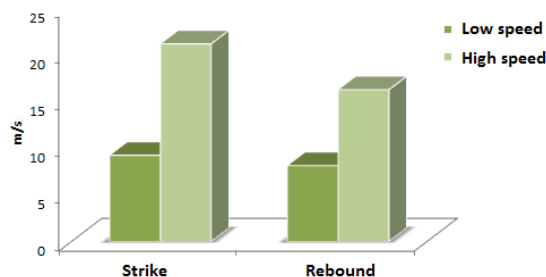


Figure 2. The average strike and rebound speed during two different collision

From the result we can see in the low speed collision process, Football with force plates in contact time and maximum hitting power incident speed is small, and the correlation between the impulse and the average force incident speed large correlation between 0.912 and 0.823, impulse incident speed is highly correlated. When the football strike force platform in a high speed, soccer's biggest vertical force's average was 4836.3 ± 876.3 N, the maximum impulse was 16.8 ± 0.76 ms, the contact time was 0.0072 ± 0.0009 s. Compared with the correlation, we can found that but for the collision time, maximum force, average force, maximum impulse and incident velocity were positively correlated, which average force and maximum impulse incident speed completely positive correlation, while the maximum strength shows low correlation and time collision with incident velocity is perfectly negatively correlated. As can be seen from the results, football dynamometer station when the collision contact time and maximum hitting power incident speed shows low correlation; impulse and average power of the incident speed of correlation respectively is 0.96 and 0.79, both of them are positively correlated and related greatly, impulse and incident speed was highly correlated.

From the two kinds of speed collision process we can see, when the football transferred from low to high speed, the maximum power, average power and maximum impulse have significantly increase, the largest average power increased from 2157 N to 4836 N (Figure 3), the power in high speed is almost two times than low speed. Average strength increased to 1123 N, the average power generating in high speed is more than two times compared with low speed. We could see when the speed increasing, the collision power will increase a lot. Therefore, in the football match, especially the player shots or rescues dangerous ball and also the speed of the ball is quite quickly, if the ball hit directly in the part of human body, if light hit he will feel very pain, if heavy it may produce harm to the body even damage. According to the theorem of momentum, when momentum is given, the longer time contact the less power contact. So in the face of the ball, we should do some buffering action to minimize the impact and protect our body.

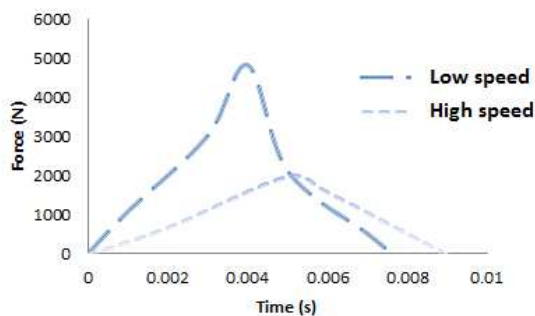


Figure 3. The typical reaction force curve during two different collision

DISCUSSION

After analyzing the biomechanical characteristics of speed touch table experiment process in low speed and high, there still exist some problems need further research to give the testing method some supplemented and complement, make its mechanical characteristics and kinematics characteristics more comprehensive for football training, teaching, football product development and testing provide a more solid theoretical foundation. Previous studies underlined the importance of an appropriate technique during soccer kicking trials [8, 9]. This technique includes the proper movement of the soccer player accompanied by the proportional coordination of the segments. It is possible that when a soccer kick does not lead to the desirable result, in our case when the kick does not hit the target, an error of the movement sequence has occurred [10, 12]. The results of the present study showed that the player could highly controlled the ball launching speed. In theory, accuracy and level of skill may differ in professional players as opposed to amateurs. Moreover, our experiment was performed under laboratory conditions where kicking targets are pre-designed and can only simulate real game conditions. In the present study, instep kicking techniques was acceptable for the repeating ball speed in high or low conditions.

In this paper we use low-speed and high-speed two cases to study biomechanical characteristics of ball collision. We select incident velocity value average is 9.8 m/s in low speed, select incident average speed is 22.3 m/s in high speed. We all know that football flight speed is very fast, such as free kick to goal in football match. Many of the world's best football players' velocity is quite huge. The famous Brazil left-back Robert Carlos had a free kick goal in the 2002 Korea-Japan World Cup Brazil to China's group match, which is the strongest, the rapidest direct free kick, and its speed reached amazing at 41m/s [5]. It is nearly double compared to the maximum speed we got in experimental. This experimental 22.3 m/s has a very big disparity with it. Whether the speed 22.3 m/s indicator setting for high speed is suitable or not, it needs to be improved in future research. The elastic restitution coefficient of the football depends on the performance of the ball itself, and the elasticity of the ball is related to many factors, different balls have different elastic restitution modulus. For certain material objects, the ratio of collision speed before and after are almost constant. From the experimental results, with the increasing of the incidence rate, football elastic coefficient will be smaller. Results of Joseph et al., [6] on Lacrosse recovery coefficient reached the similar conclusions.

CONCLUSION

Mentioned on this result and the collision mechanics deep step recovery coefficient almost unchanged different, why appear this kind of result, there still remains to do a further research. Elastic recovery coefficient can be used as an important index as evaluating football elastic. If a football's elasticity changes too quickly then the football must exist some problems. Lacking of flexibility in the play process, the football will become very hard, the players' feet can't bear and it is easy to cause foot injury, human's body the ball hitting is very painful at the same time.

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