Simulation Study of a Futsal Ball Deformation in Normal Impact Using Finite Element Method

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Abstract—**The popularity of the futsal games has gradually increased since it was introduced in Uruguay. Since that, the futsal games became a medium for the young players to train to be professional footballers. Many coaches are avoiding heading tactic until they are 12 years of age. This technique can lead into the potential cause of traumatic brain injury. To date there has been no study to predict the deformation of the futsal ball in normal impact on flat surface at low speeds. The purpose of this study is to investigate the deformation behavior of the futsal ball upon impact. The free fall drop test is performed on the futsal ball size 4 when hitting a rigid target at different heights 500mm, 1,000mm, and 1,500mm. The result shows that, the higher ball drop, the higher deformation of the ball. Then, a finite element model (FEM) of a futsal ball was constructed and the simulation of the ball analysis was done by comparison between two materials, which were Butyl Rubber (IIR) and Latex Rubber (NR). The results show that, the Butyl Rubber is the better material for futsal ball construction, as there are less deformation and stress which is in allowable stress. However, further improvement needs to be done by taking into consideration of the futsal ball under large deformation as well as at a high impact.**

Index Terms—**Futsal ball, deformation, impact analysis, finite element modelling.**

I. Introduction

Futsal game originated from Uruguay in 1936 and the name of futsal was named by FIFA, which is simply a mixture of the Spanish words for 'hall' (sala) and 'Football' (futbol) then formed the futsal [1]. The game of futsal allows young people to create and expand many skills and mastery that are transferable to the 11-a-side games. Many of the top world class footballers played futsal in their youth and credit it to enhance their football playing skills, example are Pele, Kaka, and Lionel Messi.

The history of futsal in Malaysia started by the year 1990, but it is still not the favourite sport compared to other sports such as badminton and football. However, in the middle 2000 futsal had drastically become the favourite among the youth because it is easier to play and do not need many players compared to football that needs a wide range of field and a lot of players. Futsal was also well received not only amongst men, but also received encouraging response from the women. In addition, the response from the adult and the elderly is also very favourable compared to football.

In futsal games, player will obtain the ball more frequently than they do in playing football. This required the players to perform more individual techniques and required more repetitions on the games and this contribute impact between the ball and the players during the games. Past researcher such as, D.S Price, R. Jones and A. R. Harland had been conducted the research on soccer ball. Their research was to determine the mechanical properties of the soccer ball [2]. Previous researcher such as K. Tanaka and Brian J.M were more focused on the research on dynamic properties of golf and baseball. Both had determined the deformation on that sport balls by conducting the impact test [3].

Thus, the most prevalent test experiment on the sports ball is by conducting a drop test. The drop test is usually used to determine the dynamic characteristic of the sports ball. Finite Element Analysis (FEA) is an interesting method to simulate the model and to compare and collect the mechanical properties used for a material selection. This method is mostly applied in the design process, to minimize the time process and perform better materials selection.

The aim of this research is to investigate the Finite Element Model (FEM) of futsal ball size 4. The model of the futsal ball size 4 was used to perform FE analysis with two different types of material, which are butyl and latex. Deformations of the futsal ball are the parameter of interest for the measured in the analysis.

A. Problem Statement

Futsal as a game played by both gender physically brings a player into a standard one-on-one situation with essential fast kicking skill and requires heading. Since this sport is a repetition contact games, many coaches are avoiding tactic of heading until aged of 12 [4]. Compared to other contact sport, head and neck injuries reportedly have contributed 4% to 22% of all injuries in soccer. A head injury is a traumatic injury to the head that is usually evident on clinical examination by the head impact [5]. Two thirds of most soccer players may experience symptoms of head injuries over one full year of soccer participation. Heading involves repeated impact, acceleration-deceleration of the brain inside the skull, and possibly rotation of the brain [6].

B. Objectives of the Study

This research was conducted to investigate the deformation impact of futsal ball size 4 on different heights of a ball release. To achieve these objectives, major aims are addressed in this research:

a) To determine the deformation of futsal ball size 4 by performing the drop test.

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b) To determine the deformation by employing the FEA using Solidworks software.
c) To evaluate impact deformation of futsal ball at three difference heights (1500mm, 1000mm, and 500mm).

C. Scope of Work

To complete this work, initially the literature work was conducted by covering the dynamic impact behaviour and the applications of the FEM in applying on sports equipment. The drop test apparatus was developed for conducting the actual drop test with the Futsal ball size 4. Lastly, the experiment and simulation data for the deformation was analysed to achieve the main objectives of the research.

D. Novelty of Research Study

This research focused on investigates the deformation of futsal ball size 4 during impact on three different heights of ball release. This type of work is not available in the published literature. In this aspect, the current work is original and novel.

II. Literature Review

The British industrial revolution provided a catalyst for the development of the ball into its present day as the introduction of the rubber. It was the revolutions of the allowed development of the balls use the rubber materials as to replace animal bladders. In the early year of balls history, a ball was built using the animal bladder and covered with leather for better shape retention [7]. The rubber vulcanized ball was designed and built by Charles Goodyear in era 1800's. Charles's was the first inventor for the first vulcanized rubber bladder by depending on animal bladder. The balls with the rubber bladder were to ensure that the ball remained hard and oval after the impact. In 1862, H. J. Lindon has developed the first inflatable rubber ball bladder [8].

Deformation plays a significant role in thoughtful of the impact mechanics. Ball deformation results from the abrupt deceleration connected with its impact against another body [9]. This is evident from a reduction in the ball's diameter perpendicular to the impact surface. The measurement of ball deformation is a part importance parameter in analyzing the behavior of the ball. The ball deformation is likely to have an influence on the players' perception of ball hardness of softness. Deformation influences the trajectory strike of the direction of the ball. The deformation normal (d_n) and deformation tangential (d_t) ratio can be calculated using the equations:

$$d_n = 100|D_n - D_o|/D_o \quad (1)$$
$$d_t = 100|D_t - D_o|/D_o \quad (2)$$

where D_o, D_n and D_t indicate the initial ball diameter, normal diameter, and tangential diameter [10].

The finite elements methods are approaches used to simulate and validate the theoretical experiment data from the impact and compression test. A present-day, soccer ball are normally made of 32 manually stitched panels that are pressurized through an internal latex bladder. The 32 panels, mainly used in competition, consist of 12 regular pentagons and 20 regular hexagons, arranged in truncated icosahedrons spherical geometry [11].

Some researchers have applied FE to simulate the sport equipment, such as soccer ball [12], cricket [13], and golf ball [14]. Most of the researcher had applied the FEM to determine the static and dynamic properties of the sport equipments. Besides that, it had shown that, the FEM were applicable tools for determine the material developments of sport equipments. The developed FEM had shown relatively good agreement data with the experiment data. Some of FE software had been employed such as Abaqus and ANSYS/LS-DYNA.

Other than that, many researchers have applied FE to simulate the drop test on deformation of agriculture products [15]-[16]. It had shown that, FEM is applicable as a computational tool for determining the deformation behavior of agriculture products.

The drop test simulations were conducted for agriculture product to analysis the damage of the product in the drop scenario, and the stress was a main parameter for the analysis.

III. Research Methodology and Experiment Setup

Prior to model development, experiment were designed and carried out to investigate the impact behaviour of the futsal ball size 4 in order to establish a benchmark that can be used to validate the developed ball model.

A. Material

Adidas FIFA standard futsal ball size 4 with a diameter of 200 mm was used for the experiment and as a standard for ball modeling.

B. Solid Modeling of Futsal ball

The model of the futsal ball size 4 was developed in Solidworks 2015 software. The model of futsal ball was as shown in fig. 1 and fig. 2 respectively. The futsal ball was assumed to be a hollow ball with thickness 3mm and modeled in dodecahedron shape, which consist 12 pentagons and 20 hexagons.

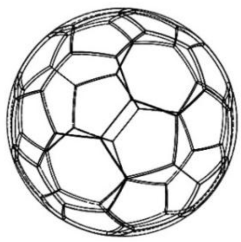

Fig. 1. Wireframe model of futsal ball

Fig. 2. Solid model of futsal ball

TABLE I: Mass Properties of Futsal Ball Size 4

Mass	0.341 Kg
Volume	0.355 m^3
Density	0.961 Kg/m^3

TABLE II: Model Information

Body Name	Futsal Ball size 4
Analysis	Drop Test Analysis
Mesh Type	Solid Mesh
Solution Time	300 microsecond
Result Time	50 microsecond

C. Drop Test Simulation

The ball manufacturers strive to improve the performance of the each ball, by minimizing the hit distance and increase a balls control. In fact, finite element method is widely used in the design process in line with the technology and software advances. Experiments are required to get the data and comparison it with the simulation. Therefore, the purpose of this study was to examine the deformation behaviour of the futsal ball size 4 with respect to different height of drop.

In this study, the SolidWorks simulation FEM was utilized for the drop case simulation of the futsal ball. In the simulation, the ball drop is in the direction of gravity as a rigid body until it hits the rigid plane. It is assumed that there is no ball rotation. In this study, the futsal ball is assumed as a linear isotropic material and the frictions were ignored. As most materials used in a bladder inside a futsal ball are normally made from Butyl and latex, the study was done to compare the simulation with these two materials. The Young's modulus, Density, and Poisson's ratio are as shown in table 3 [17]-[18]. The software solvers for this analysis were using explicit time integration.

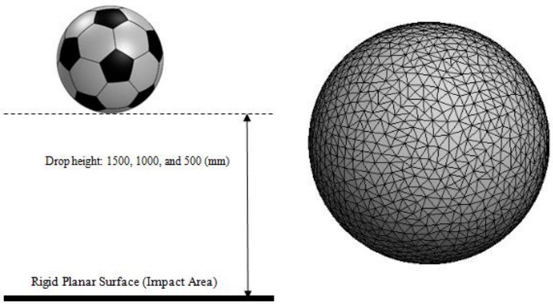

Fig. 3. Drop case and mesh construction of the futsal ball.

The aim of the study was to examine the deformation behavior of the futsal ball in the drop case. To achieve this, both experimental and simulation method were used. The dropped case was free dropped from three different heights, 1500 mm, 1000mm and 500mm high onto a rigid planar surface under the earth's gravitational effect. The dynamic behavior before, during, and after impact was recorded using a Sony DSLR Camera. The dropping moments were recorded with a slow-motion mode that captures up to 60 frames per second (fps). Marking was placed on the specific area on the ball to get the ball dropped with the same face at the initial position.

TABLE III: ELASTIC MATERIAL PROPERTIES

Components	Material Types	
	Butyl (IIR)	**Latex (NR)**
Young's Modulus (MN/m^2)	2	4
Density (Kg/m^3)	920	940
Poisson's Ratio	0.48	0.48

To analyze the maximum ball deformation quantitatively [10], the deformation normal (d_n) ratios were calculated using the equations below.

$$d_n = 100|D_n - D_o|/D_o$$

where D_o and D_n indicate the initial ball diameter and normal diameter. The initial and normal diameter was analyzed using the ImageJ software.

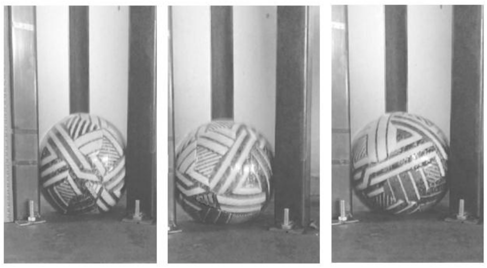

Fig. 4. Impact figure from drop test for 1500mm (Random).

IV. DATA ANALYSIS AND FINDING

The drop analysis was performed by using the Solidworks Simulation 2015 software. Analysis of drop test was performed in three different height to predict the suitable material for the manufacturing the futsal ball.

A. Butyl Rubber Material (IIR)

The FEA results of a ball obtained through Solidworks made form Butyl Rubber is shown in Table IV.

TABLE IV: RESULT FOR BUTYL MATERIAL

Drop height (mm)	Stress (N/m^2)	Displacement (mm)	Strain
1500	213225	1.794	0.053
1000	133618	1.442	0.055
500	92296	0.930	0.030

B. Latex Rubber Material (NR)

The FEA results of a ball obtained through Solidworks made form Latex Rubber is shown in Table V.

TABLE V: RESULT FOR LATEX MATERIAL

Drop height (mm)	Stress (N/m^2)	Displacement (mm)	Strain
1500	253065	1.799	0.058
1000	236554	1.442	0.035
500	188977	0.944	0.022

The results obtain from the SolidWorks simulation for the both material were the same. Both butyl rubber and latex rubber experience deformation in the range of 0.9 – 1.8 mm. There was a slight difference between the experiment and simulation results for deformation (Fig. 5). The deformation increases as the drop height increases.

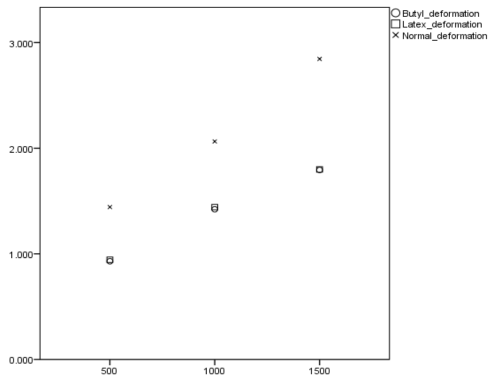

Fig. 5. Ball deformation versus drop height.

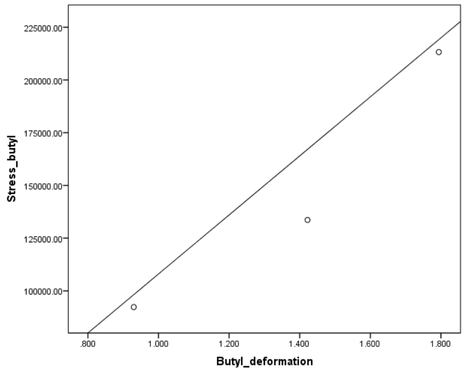

Fig. 6. Stress versus deformation for butyl rubber material.

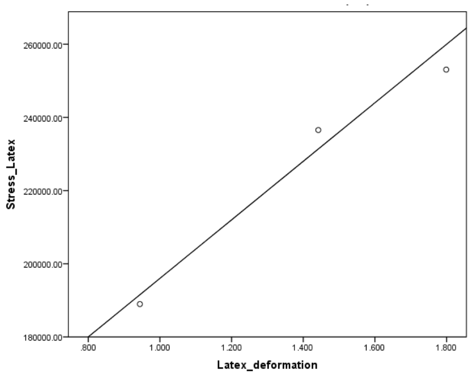

Fig. 7. Stress versus deformation for latex rubber material.

From the graph of stress and deformation (Fig. 6 and Fig. 7), it is shown that the correlations between the variables are very high. This shows that stress increases as the deformation increases. These cases are applied for both types of materials. For butyl material, 93% (Pearson Correlation: 0.966^2) of the stress increase are affected by the deformation of the ball. The higher the deformation, the higher the contact surface and the higher of the ball drop. The maximum and minimum, stresses for butyl are 213kN/m^2 and 92kN/m^2 respectively.

For the latex material, it shown that it has higher stress compared to butyl. The minimum and maximum stresses for the latex are 188kN/m^2 and 253kN/m^2 respectively. The relationship between the stress and deformation shows a correlation of 97% (Pearson Correlation: 0.984^2). This is shown by the results of deformation that latex has a high deformation compared to butyl.

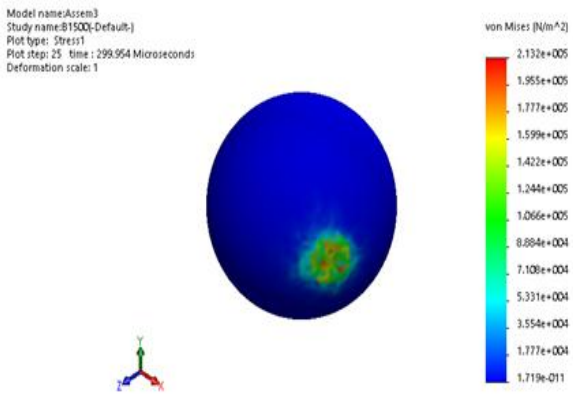

Fig. 8. Stress distribution for Butyl ball for drop height 1500 mm impact a rigid plate.

This research set out to determine the drop impact deformation of the futsal ball, and to compare simulation two types of materials, butyl rubber and latex rubber. Butyl and latex was chosen as a material for futsal ball, as the butyl and latex are normally used as the bladder inside the cover of the futsal ball. The experiment and simulation data show a slight difference of values. The high-speed cameras that can capture up to 500 fps are required for more detailed deformations. Besides that, the maximum stress of the impact between butyl and latex was determined. The latex material has the higher stress compared to the butyl. The maximum stress that is allowable for the head is 235kN/m^2 [19]. From the correlation, it was shown that, as the deformation increases, the stress will also increase.

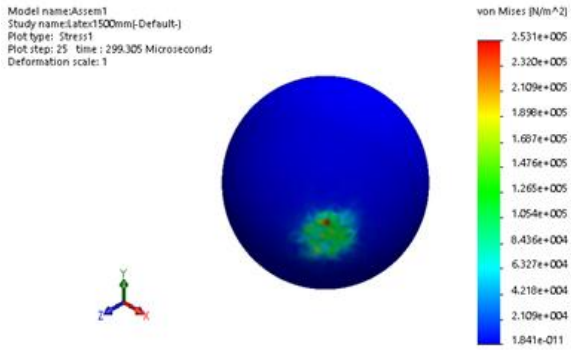

Fig. 9. Stress distribution for Latex ball drop height 1500 mm impact a rigid plate.

V. Conclusions

In this study, Solidworks simulation has been used to simulate the drop test of a futsal ball. The drop test was conducted for two types of material that are normally used for the bladder of futsal ball. The material used namely, butyl rubber (IIR) and latex rubber (NR). The results have shown that, the maximum deformation and stress that have been observed from latex rubber material, that are 1.799mm and 253kN/m^2 respectively. Butyl is a better material for the manufacturing of futsal ball, as the maximum and minimum stresses for the butyl are in between 92kN/m^2 to 213kN/m^2 respectively which is below limit 235kN/m^2 that can cause fatal injury.

In conclusions, the findings from this study can give a benefit mostly to futsal ball manufacturer to enhance their player's performance by using technology especially in the selection of futsal ball material.

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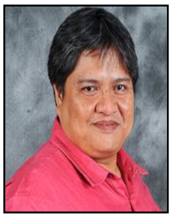

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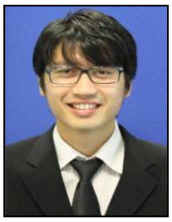

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