

The Dependency of Hollow Ball Deformation on Material Properties

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Abstract: The work presented in this paper details the development of a finite element (FE) model of a soccer ball, allowing for a greater understanding of the performance of soccer balls under dynamic conditions that are representative of play. The model consists of composite shell elements that include a hyperelastic strain energy potential equation to define the latex bladder layer and a plane stress orthotropic elastic material model to define the anisotropic woven fabric outer panels. The model was validated through a series of experimental tests whereby the ball was impacted normal to a rigid plate at an inbound velocity of approximately 34 ms^{-1} (76 mph), with each impact recorded using high speed video (HSV) techniques. It was found that the combined effects of ball design and panel material anisotropy caused impact properties such as impact contact time, deformation, 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 experimental measurements and was able to represent the effects of anisotropy in ball design.

Keywords: Elasticity, Fabrics, Anisotropy, Hyperelasticity, Impact, Shell Structures, hollow sphere, soccer ball engineering.

1. Introduction

Soccer is the most popular ball game in the world, with over 250 million active players and a television audience peaking at 1.7 billion for the final of the 2002 FIFA World Cup championships. The primary equipment requirement for the game of soccer is the ball, and, with annual sales estimated at 40 million units (Stamm and Lamprecht, 2001), the soccer ball market is as competitive as the game itself. The soccer industry provides a plethora of sponsorship and advertising opportunities and gives leading multinational sports companies a platform to market their products. This places the emphasis on brand image and product quality meaning that the design, development and innovation of soccer balls are crucial activities in order to gain competitive advantage within the market.

Soccer has been played in many different forms in all corners of geography and history. From its origins as *tsu chu* in ancient China 2500 BC, the spread of the game throughout the world proceeded. Early forms of ball juggling were conceived in Thailand, and the ancient game of *kemari*, which originated in Japan throughout 600BC, was also played (Murray, 1994). The Greeks and Romans developed ball games entitled *epyskyros* and *harpastum* respectively,