SIMULATION OF FOOTWEAR BEHAVIOUR USING FINITE ELEMENT ANALYSIS

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Abstract: *The large progress of computer science has directed to the use and implementation of software tools that implicate new possibilities of designing, modelling, and analysis of objects. The Finite Element Analysis (FEA) is used in any field of activity as a tool for engineering analysis in order to predict the behaviour of assemblies that could be subjected to almost all physical phenomena. The footwear sector has not become an exception in this trend, as this powerful tool is useful in research, footwear developing and manufacturing. The goal of this paper is to make a brief overview of what has been done in footwear industry in sense of entire footwear product analysis using FEA tools.*

Keywords: *Finite element analysis, finite element method, footwear, virtual simulation.*

Introduction

Computational modelling, such as the finite element analysis (FEA) has become the dominant tool in many industrial fields of engineering. This process requires significant computational work divided into several distinct phases [1].

FEA method is used in order to make predictions about the behaviour of structures that can be subjected to almost all physical phenomena [2].

This method allows to modelling structures with irregular geometry and complex material properties and simulating complicated boundary and loading conditions in both static and dynamic analyses [3].

The footwear sector has not become an exception in this trend, but due to its complex forms and structures, most of the finite element analyses were made for simulates the interaction between the foot, sole and ground and very few researches that would involve the upper assembly as well.

Analysing FEA engineering applications in footwear may notice the main topics investigated so far in the field are: the interaction between the sole and the ground, the interaction between the sole and the foot, plantar pressure distribution, and materials behaviour. In this study it was attempted to focus on the papers which apply FEA for whole footwear product.

Short review of studies on finite element analysis in footwear

The FEA can be an addition to experimental approach to predict the load distribution which offers additional information such as the internal stress and strain of the objects. The FEA could allow efficient parametric evaluations for the outcomes of the shape modifications and other design parameters of footwear without the precondition of fabricated footwear and give to the designer important indications about the modification required in the shoe design process [3], [4].

TangYuk-Ming and HuiKin-Chuen (2011) have simulated using FEA the interaction with footwear towards footwear design in order to evaluate the deformation of the foot and footwear models and determinate its stress distribution (Figure 1) [4].

Rupérez et.a (2008) presented a computational model that simulates the deformation of materials in shoe uppers and that quantifies the distribution of forces on the foot surface in a complete step. The aim of this research was to provide functional and aesthetic valuation in CAD (computer assisted design) footwear design in order to achieve the first tool to provide footwear manufacturers with the capacity to value the functional features of a design virtually, without having to make prototypes or use footwear [5].

Two years later, Rupérez et.a (2010) presented the deformation of shoe upper materials during the gait. This research provides a physical interpretation from the point of view of the contact mechanics to the previous model used in Simucal, as well as the new form of the problem allows that new materials and models can be easily computed. The paper presents also the description of the animation database [6].

In one of the following papers, Rupérez et.a (2012) simulated using FEA the deformation of shoe upper material in gait for footwear CAD applications. The model was obtained from tensile tests and validated with two experiments: a test to measure the leather resistance to damage on lasting and a test that models the shoe forming process using lasts [7].

Tian-Xia Qiu et.a (2011) developed a foot-boot model using ScanIP, Surfacer and ANSYS. The purpose of this study was to evaluate behaviour of the entire assembly during balance standing [8].

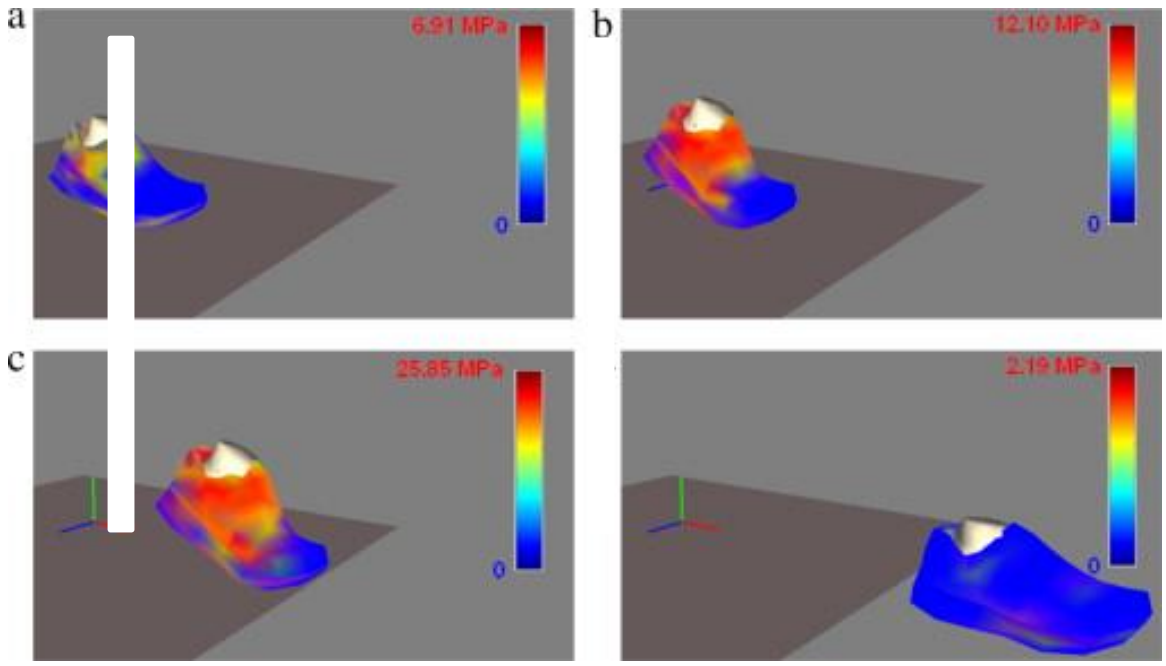

Figure 1. Simulation of the interaction between foot and sports shoe during the gait [4]

Covill et.a (2009) outlines in their paper the use of FEA to describe the heat transfer between the foot, sock and shoe taking into account the conduction, convection and radiation. The study shows that the major contributors to the in-shoe conditions under dry heat transfer were the ambient temperature and the initial temperatures of the foot, while the heat flux and sock conductivity also had a minor affect [9].

Jia Yu et.a (2013) analysed a three-dimensional finite element model of coupled foot–ankle–high heel shoe assembly during the three major stance phases namely heel strike, midstance and push. The study highlights the way foot and footwear reacts while walking (Figure 2) [10].

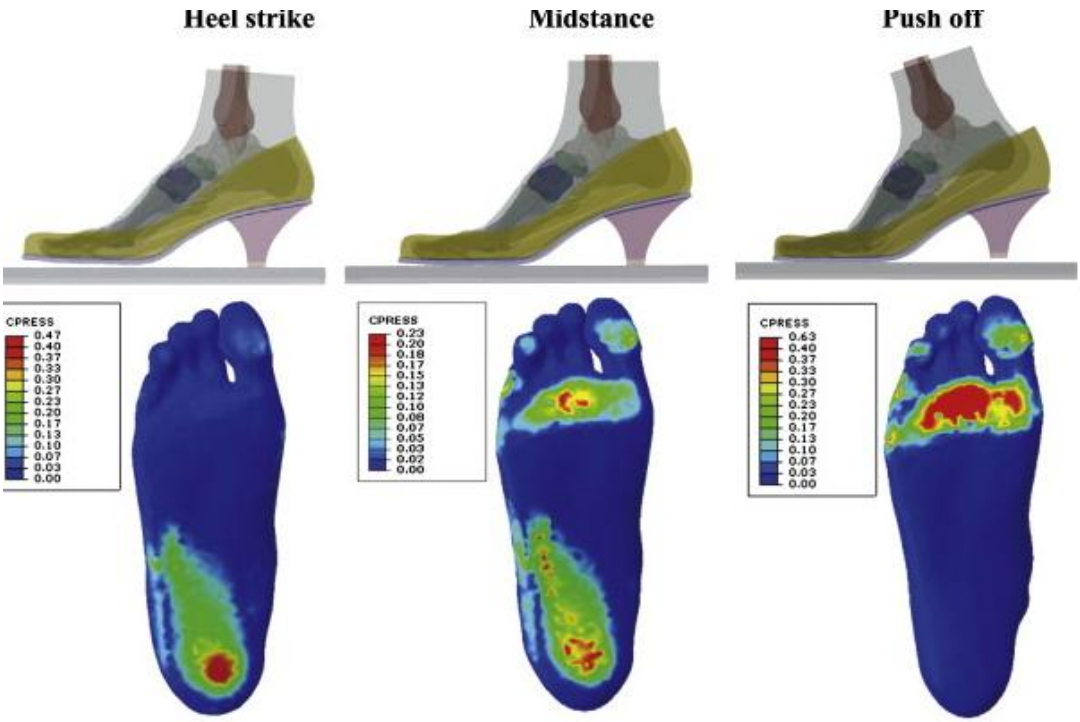

Figure 2. Simulation of the interaction between foot and high heel shoe during gait [10]

Another field of footwear industry where FEA was applied is sport shoes. Hideyuki Ishii et.a (2014) studied the performance of a new soccer shoes during the kick process and how it influence the ball behaviour (Figure 3) [11].

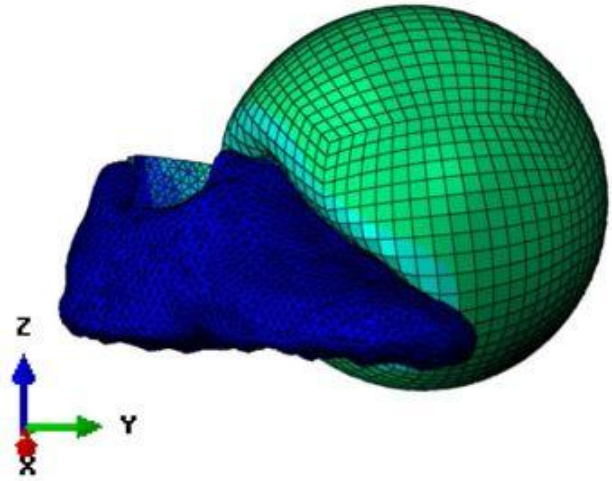

Figure 3. Impact of foot-shoe assembly with the ball [11]

Conclusion

Studying the researches done in footwear field using FEA in order to simulate the interaction between foot and footwear, could notice that almost of them are focused on analysis of stress distribution and product deformation. Other interactions between foot and footwear, such as the ones with linings and uppers, or the influence of various design lines, or stitching and assembling rows, for example, were not investigated, knowing the fact that they also could significantly influence the comfort footwear.

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