ENERGY FLOW IN HIGH HEEL SHOES IN WALKING

F. Ju, F.S. Cui, Z.S. Liu, *H.P. Lee and C. Lu
Institute of High Performance Computing, 1 Science Park Road,
#01-01 The Capricorn, Singapore 117528; email: hplee@ihpc.a-star.edu.sg

INTRODUCTION

High heel shoes lead the feet weak and prone to injury and serious foot ailments. Hansen et al. [1] investigated the effects of shoe heel height on the rollover characteristics of the biologic ankle-foot system. Stefanyshyn et at. [2] studied the Influence of high heel shoes on mechanical behaviours of normal female gait with four different patterns shoes with high heels. The effect of insoles on the plantar pressure distribution was studied by Lemmon et at. [3] with the finite element method (FEM). More recent research on the foot-shoe system with FEM approaches can be found in [4] and [5]. Studies and observations have found that women walking in high heel shoes experience the excessive side to side motion at the ankle joints and feet, resulting in excessive stresses in the foot ball, calcaneus and joints. These stresses are caused by the contact-impact between the shoe and the ground and, sequentially, propagate into the foot. The whole course can be viewed as a process of energy transformations.

The objective of this study is to investigate the energy flow transmission in high heel shoes under contact-impacts during walking. The effect of the stiffness of shoe soles on the stress distribution in the foot-shoe system will be highlighted.

METHODS

A simplified 2D finite element model including the shoe sole and the foot is established to investigate mechanical and structural characteristics of the foot-shoe system. Only the shoe sole is considered to focus on the interactive effect of the foot and the shoe. The foot is modeled as bones, joints and a layer of soft tissue material at the bottom of the foot. The nominal stiffness, a product of Young's modulus and sole thickness, is used to represent the elasticity of shoe soles.

Structural Intensity (SI) method is employed to characterize the energy flow transmission and stress distribution and propagation in system under various impact-contact conditions. The concept of SI was first introduced to extend the vector acoustics approach to energy flow in structures-born sound fields. SI is the power flow per unit area of cross section elastic medium and offers full information of the paths of energy transmission and positions of sources and sinks [6].

RESULTS AND DISCUSSION

Shoes with the heel height of 3, 6 or 9 cm and various stiffness of shoe soles are used for numerical study. Different stages during walking are considered in the analysis. Figures 1 and 2 show respectively the SI vector and stress contour of the flat and high heel shoes, which clearly indicate the paths of energy transmission and stress distributions in the system. The energy flow patterns show that strain energy distributes and transmits favorably in a flat shoe due to the presence of the soft sole layer, while it reaches the calcaneus with a higher intensity in a high heel shoe regardless of the sole. Soft shoe soles with smaller stiffness can greatly improved the stress concentration at the calcaneus area and ankle joints for flat shoes. However, much greater stress concentrations are found for high heel shoes and soft shoe soles can hardly improve the uneven distribution of stresses in most cases.

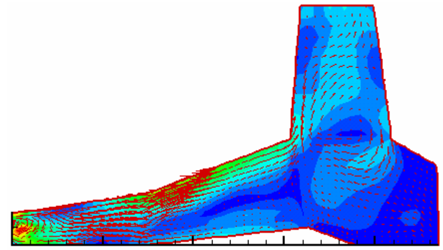

Figure 1: SI vector and stress contour of a flat shoe under contact-impacts

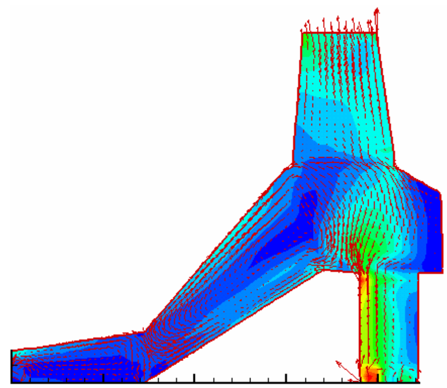

Figure 2: SI vector and stress contour of a high heel shoe under contact-impacts

CONCLUSIONS

Structural Intensity provides rich information for energy flow transmission in foot-shoe system under the contact-impact during walking. Severe stress concentrations in the calcaneus area are found for high heel shoes, and soft shoe soles do not help much in evening up the stress distribution.

It is relevant to indicate that 2D models are effective to study the mechanical phenomenon of the walking impact of the foot-shoe system but too restrictive for quantitative analyses. 3D models will be developed in our further study.

REFERENCES

1. Hansen AH, et al.. *J of Rehabilitation Research And Development* **41**(4), 547-554, 2004.
2. Stefanyshyn DJ, et al.. *J App. Biomech* **16**,309-331, 2000.
3. Lemmon D, et al.. *J Biomech* **30**, 615-62-, 1997.
4. Chen W, et al.. *Clinical Biomech* **18**, S17-S24, 2003.
5. Lewis G. *Bio-Medical Materials & Engrg* **13**, 75-81, 2003.
6. Liu ZS, et al.. *Int. J .of Impact Engineering*, (Available online 10 August 2004 via ScienceDirect.)