Characterizing Heel Tissue to Develop a Dynamic Finite Element Model of the Foot

The Challenge:

Quantify Heel Tissue Response to Dynamic Input to be Used in a Finite Element Model

Background

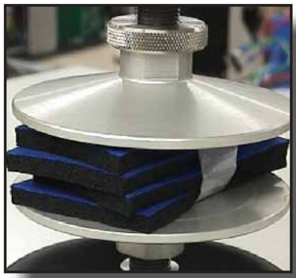
In 2007, 23.6 million people or 7.8% of the population in the United States were diabetic. About 60% to 70% of people with diabetes have mild to severe forms of nervous system damage that results in impaired sensation or pain in their feet. This often causes the patient to be unaware of high pressure, or stress concentrations, on the foot that would normally be sensed and avoided by a healthy person. Diseased individuals are often unaware of a problem until after severe damage has already occurred. Severe forms of diabetic neuropathy and resulting tissue over-stressing are a major contributing cause of lower-extremity amputations.

If physicians have a tool to model a patient's gait and foot, they may then be able to predict potential 'high pressure' zones on the patient's feet. They may then prescribe an orthosis to better distribute the load and improve the survivability of the diabetic patient's feet.

Meeting the Challenge

Research led by Dr. William Ledoux at the VA Puget Sound and the University of Washington has focused on viscoelastic models of the soft tissue beneath the foot. These models will be incorporated into a finite element model of the foot. The foot model will be used to study the effect of foot shape and muscle imbalances on plantar pressure. It will also be used in the future to develop orthotic devices to redistribute plantar pressure for diabetic neuropathic patients.

In order to properly characterize the heel tissue, an actuator had to be found that would provide the fast rate 'ramp and hold' protocol required of the viscoelastic soft tissue model. The model assumes that no relaxation occurs during the ramp portion of the testing. The worst case scenario is a displacement of 15 mm in 20 to 25 ms.

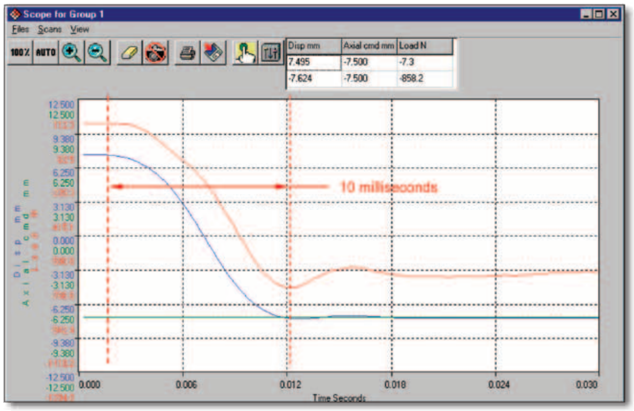


A survey of conventional servo-hydraulic test systems indicated that durations of less than 35 ms would require significant investment in larger hydraulic supplies and valves. As space and cleanliness are also important in a hospital research laboratory, the hydraulic systems proved to be undesirable for this task.

The ElectroForce® 3400 test instrument was chosen for its high dynamic response as well as its cleanliness due to its all-electric design.

Results

The ElectroForce 3400 instrument was benchmarked using a soft tissue analog material. The initial tests indicated an uncontrolled compression of 8 milliseconds. When properly damped to ensure no overshoot, the system reached 15 mm compression in 10 milliseconds (see graph below).



Summary

The Veterans Administration & the University of Washington are using the ElectroForce 3400 instrument to characterize cadaver heel tissue to provide inputs for their finite element model.

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