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Issue 57

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Niagara Prosthetic Foot: Material and Structure Working Together

According to the International Campaign to Ban Landmines, landmines threaten adults and children in at least 72 countries. Millions of landmines of various types remain hidden around the world, waiting to be triggered by the innocent. The ICBL publication *Landmine Monitor 2011* estimates that over 4,000 casualties occur each year from landmine explosions, many of them resulting in the loss of limbs.

In 1998, the landmine situation around the world was even worse and landmine casualties numbered in the tens of thousands. These awful statistics prompted prosthetist Rob Gabourie of Niagara Prosthetics and Orthotics International Ltd., to design and develop a flexible, durable, and inexpensive prosthetic foot as part of the landmine victims relief program of the Canadian Centre for Mine Action Technology (CCMAT).

The Niagara Foot is a simple and elegant design, but the biomechanics are complex. The foot is formed as a single part, with a heel area, a toe area, and a strong dynamic C-section at the ankle. Each of these act as springs providing elastic energy storage and return during the gait cycle. The properties of the material partnered with the unique structure let the foot mimic biological foot action. Moreover, its comparative low cost means it is potentially accessible to many more people. However, it has taken several years of research and testing for the foot to achieve this performance.

In 1998, at the start of the project, Mr. Gabourie invited Dr. Tim Bryant of the Human Mobility Research Centre in Queen's University (Ontario) to collaborate on the design and help with the biomechanical testing and material analysis. DuPont, the science company, also became involved in the project to help determine what kind of material should be used to make the foot. The designers tested various materials before selecting the DuPont™ Hytrel® advanced polymer.

Testing for material characterization, biomechanical evaluations, and overall durability has factored strongly into the development of the foot. Much of the materials characterization testing was performed using Instron® static and dynamic testers at DuPont research laboratories.

Static testing on the foot structure was performed at Queen's University using an Instron testing system. Forces were applied to the toe and the heel of a foot, and held for a period of time. The goal is to ensure that the structure can meet or exceed standard values that represent high loading conditions, such as jumping, as set by standards such as ISO 10328 (Prosthetics — Structural testing of lower-limb prostheses) and ISO 22675 (Prosthetics — Testing of ankle-foot devices and foot units).

Cyclic durability testing was undertaken using an Instron pneumatic fatigue tester designed and built at Queen's University. It comprises four stations, each with a pneumatic loading cylinder for the heel and toe. Cylinder actions are computer-controlled to produce an axial force waveform similar in shape to that observed in a normal gait. At the same time, the peak force values at the heel and toe are programmed to be consistent with those required in the ISO standards. More than 3 million cycles did not result in failures or significant wear. The combination of the simple shape and effective material selection has resulted in a foot prosthetic that is more durable.

The Niagara Foot has gone through field-testing in Thailand and El Salvador that followed disciplined protocols.

A major benefit of the Niagara Foot lies in its ability to be locally customized to the needs of the owner, each with varying weights, heights, and activity levels. Local modification is accomplished with the prosthetist using a simple hand file to reduce the thickness of the heel, toe, and C-section and adjust their profiles using guidelines that accompany the foot. This ability to easily adjust the foot to tune its performance is unique among existing prosthetic feet and makes it ideal for use in developing countries.

The Niagara Foot was commercially released recently as the Rhythm Foot (www.rhythmfoot.ca). Earlier this year, the foot won the gold award in the rehabilitation and assistive-technology products category in the 2012 Medical Design Excellence Awards in Philadelphia.

Professor Bryant is quick to emphasize the collaborative nature of the development process. The involvement of several major companies, universities, and organizations from different countries was an underlying factor for the Niagara Foot won the MDEA award, Bryant shared. Some of the organizations included Niagara Prosthetics & Orthotics International Ltd., DuPont Engineering Polymers, Centennial Plastic Mfg. Inc., and Universidad Don Bosco in El Salvador.

Data Rate and Bandwidth

Performing tests with the appropriate data rate and bandwidth is critical in obtaining accurate and meaningful data.

The data acquisition rate of a computer or data acquisition system is the speed at which raw data points are captured. The rate should be based on the speed at which the incoming signal is changing. If the incoming signal is not changing quickly, then high data rates lead to excessive data being captured with large files and wasted disk space.

The following variables should be considered in the data rate discussion:

1. Actual signal being measured
2. Bandwidth of the signal conditioner (filtering)
3. Data acquisition rate

Actual Signal

One of the most critical aspects of proper measurement is to understand the rate at which things occur during a test. For example, when testing composites, the signal contains short, sharp peaks (or signals) indicating that the data is changing quickly, whereas tensile tests on plastics typically do not show high frequency changes.

Bandwidth

In order to properly capture these actual events, signal conditioning with the correct frequency bandwidth needs to be calculated.

Bandwidth can be loosely defined as the frequency above which signal changes are not measured; those changes are filtered out and flattened. For example, it is not possible to measure 100 Hz peaks with a 10 Hz signal conditioner; the peaks will be invisible.

Data Acquisition Rate

The ideal data acquisition rate is a function of the signal conditioning bandwidth, which should be matched to the rate of change of the actual event. A rule of thumb is that a data rate more than 10 times the signal conditioning unit bandwidth produces little more than wasted disk space, because the same data is being sampled over and over.

For a complete review of data rate, signal conditioning, noise filtering and how they affect mechanical testing results, consult ASTM Standard Guide E 1942.

Q. What is the best way to grip soft biological tissues for tension testing?

A. The most common challenges associated with tensile testing of soft biological tissues are specimen slippage and breaks near the jaw faces. For most delicate soft tissues, use pneumatic grips with either SurfAlloy® faces or smooth faces with low grit sandpaper. One of the key features of the pneumatic grips is the adjustable gripping pressure. Gripping force can be reduced to minimize jaw breaks or gripping force can be increased it if specimen slippage occurs. The SurfAlloy® faces or the use of sandpaper with smooth faces increase the surface friction between the specimen and the jaw faces, thereby reducing slippage. For other needs, Instron has a wide variety of jaw faces available to customize to various circumstances.

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