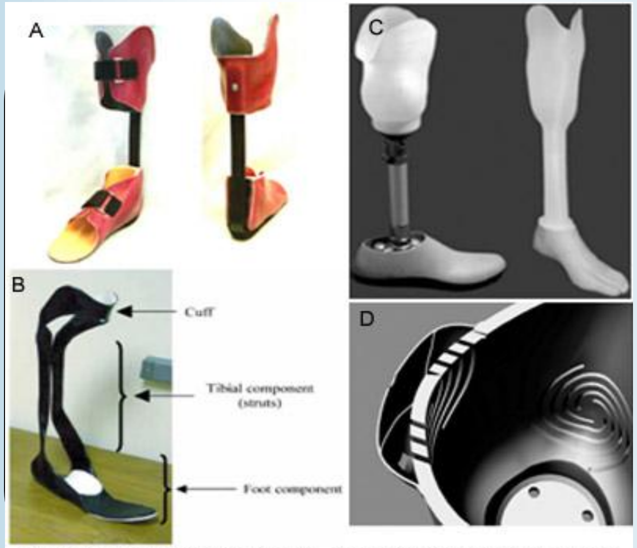
BIOMEDICAL ENGINEERING APPLICATIONS FOR COMPOSITE MATERIALS
Review on Design of Ankle-Foot Orthoses and Transtibial Sockets

Benjamin Keller (Intern), S. Yarlagadda (PhD), and J. Gillespie (PhD)

University of Delaware . Center for Composite Materials .

Functionality of Ankle-Foot Orthoses

- Ankle-Foot Orthoses (AFOs) function to correct abnormal gait by controlling ankle motions.
- Disorders such as Cerebral Palsy, Post-Stroke, and Drop-foot often require AFOs.
  - These disorders are characterized by foot-slap during initial contact and toe-drag during swing phase. Typically uncontrollable contractions of the calf muscles are the source of the problem.
- AFOs help by limiting excessive plantar flexion and assisting dorsiflexion.
  - Tend to focus on controlling sagittal plane motion.
  - Coronal and Transverse planes are typically constrained or ignored.
- AFOs have not be completely successfully at reestablishing the power needed for push-off.
  - Need for greater energy storage and release.
  - Need a better understanding of roll-over shape.



Figures: A) L-style Carbon Fiber AFO. B) Dynamic Brace Continous Carbon Fiber AFO. C) Transtibial Prostheses. D) Spiral Compliant Regions

Functionality of Transtibial Sockets

- Transtibial sockets have the difficult role of transmitting residual limb loads to the prosthesis.
  - Transtibial residual limbs have boney protrusions from the amputated fibula and tibia.
  - Residual limbs tend to be mutable (volume changes from hour to hour and week to week).
- Patellar tendon bearing sockets rely on geometry to create a interference fit.
  - Secondary attachment mechanisms include silicone suction, locking straps, and buckles.
- Use of CT scans and finite element analyses allows for patient specific socket creation.
- Main problems with current sockets are comfort, sweating, and load transmission
  - Normal and shear stresses are always focused at four anatomical locations (Patellar tendon, medial tibia, lateral tibia, and popliteal depression.)

Ankle-Foot Orthosis Design

- Three main types
  - Non-articulating: Most often used to control knee instability.
  - Articulating with plantar flexion stop: used to control knee extension instability. Also provides for better initial contact and prevents toe-drag (most common).
  - Articulating with dorsiflexion stop: used to control knee flexion instability.
- Full length footplate allows for greater dorsiflexion prior to push off.
- AFOs typically constructed of carbon fiber, polypropylene or nylon.

CCM's Concept

- Finding the anatomical center of rotation for the tibia with respect to the foot.
  - Will reduce sliding of cuff on the shin.
- Manipulating the carbon fiber layup by adding and removing plies in order to alter the stiffness in various locations.
  - The layup of the foot-plate should be such that it allows for better push-off during the final stage of stance.
- AFO applies restoring forces to counteract eversion and inversion.

Transtibial Socket Design

- Comfort can be manipulated through design (reducing stiffness).
  - Thinning the walls, creating compliant regions, adding a liner.
  - Liner stiffness and coefficient of friction highly correlate to stresses.
- More than 50% of amputees suffer from some type of skin irritation.
  - Typically a result of sweat combined with interface pressures.
  - Research should be done on breathable liners and sockets.

Possible Socket Research Areas

- Sweat-free Liner
  - Make a breathable liner that allows sweat to escape.
- Porous Socket
  - Create a breathable socket.
  - Localized porosity regions can also allow for more compliancy.

ACKNOWLEDGEMENTS

Special thanks to Dr. Gillespie, Dr. Yarlagadda, Dr. Tierney, Stephen Andersen, and Elisa Schrank. Also, thanks to all CCM staff members.