Design of a Passive Prosthetic Foot with a Tension Energy Recovery System

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Introduction

A new mechanical energy storage and return system is being designed to work within a retrofitted passive design. The mechanism utilises a number of principles found in a biological ankle-foot system to provide an additional boost in power for push-off.

Fig. 1 Mechanical ESAR system components.

Design

On its own, the prosthetic acts like most other passive models available, deflecting and returning energy at heel strike and pushing off to drive the limb forward. However, the design includes a unique mechanism that uses a cam based system to store energy by deflecting a tension rod elastically, amassing and then releasing the energy in a controlled manner back to the user, through a centralised lever.

This mechanism is given the name; Tension Energy Recovery system (TER system). The novel TER system doesn't come into action until mid-stance phase, as the main body deforms the central lever moves with it, which rotates the gear system and cams. The cams in turn pull down on the tension rod via the attached wire looped round them. The energy is stored in the tension rod until push/toe off event of stance is reached, at which point the tension rod is released and the energy is directed back through the cams and the central lever which provides and additional push-off assistance.

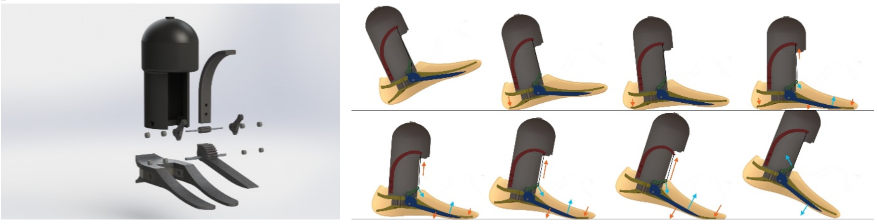

Fig. 2 The ESAR mechanism as it is mounted in the retrofitted prosthetic and animation stills of the functioning system.

Design Simulation

The design has been imported into the FEA tool ANSYS® and ran through simulations with boundary conditions based on the ISO 10328 Structural testing of prosthetics. The simulations are used to design various components used in the feet.

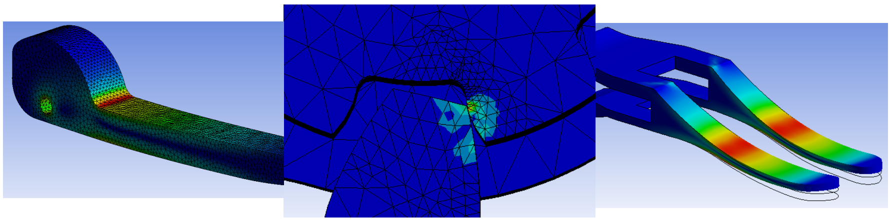

Fig. 3 Screenshots taken from component simulations conducted in ANSYS®

Work in Progress

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Current work is focusing on using design of experiments tools integrated into the ANSYS® simulation software. The ISO standard is used to ensure safety requirements are met, whilst methods such as a topological optimisation are utilised to refine the design.

The system has three key variables that can be adapted on a patient specific basis. The central lever (Figure 3, first component on the left) determines the timing of push-off through the modification of its length. Secondly, the additional push-off power generation can be adapted by adjusting the geometry of the tension limb and the profile of the cams (Figure 1).
At the moment, a number of tension limb variations are being created with layers of graphene infused carbon fibre (Figure 4). These will be tested as part of the design process to optimise the energy response of the TER system.
Additionally, the passive section of the design has been printed for use in experimental studies that will verify the accuracy of the simulations.

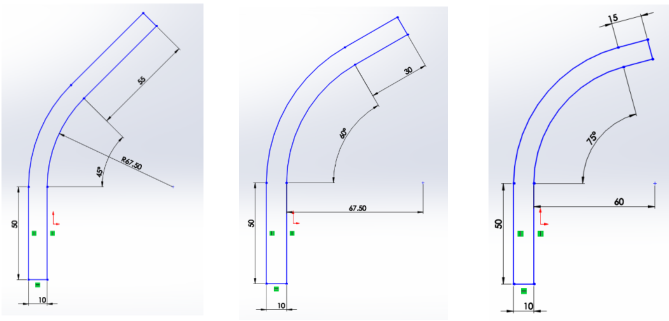

Fig. 4 CAD sketches of tension limb variations to be tested with varying layers of graphene.

Results

Once the design has satisfied the ISO standard and been through a few design modifications, the objective is to take feedback from prosthetic foot users and manufacturers. If the abstract is accepted into this conference, results from the simulations and experimental studies will be presented alongside a working prototype.