The Ankle Mimicking Prosthetic (AMP-) Foot 2.0

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1 Introduction

In general, today's prosthetic feet can be classified into three categories: Conventional feet (CF), "Energy-storing-and-returning" (ESR) feet and bionic feet. The most common conventional feet are probably the SACH-foot, or Solid Ankle Cushion Heel [1], and the uni-axial foot [2]. ESR feet, compared to CF feet, are capable of storing energy in elastic elements and returning the major part of it to assist in forward propulsion [3]. Hereby the push-off is improved and thus moving forward is made easier for the amputee. Examples of the first ESR feet are the Seatle foot and the Jaipur foot [1]. Thanks to better knowledge and understanding of the human gait and biomechanics, new types of ESR prostheses [4] were developed as the Flex-foot, the Springlite foot and the VariFlex to name a few. To increase the amount of energy returned for propulsion, researchers have developed the Ankle Mimicking Prosthetic Foot (AMP-Foot 1.0) [5], an articulated ESR-type foot using locking mechanisms to store harvested energy during the dorsiflexion (DF) phase of stance, and to release it at push-off. To improve even more the push-off properties of passive prostheses, Collins et al. [6] have developed the so-called Controlled Energy Storing and Returning foot (CESR foot). While storing energy during stance, the CESR foot uses also the weight of the body at initial contact to store energy and releases it when needed [7]. Still on research level are the so-called bionic feet. By using an actuator (pneumatic [8] or electric) to inject energy in the system for forward propulsion, gait is improved and the metabolic cost of the amputee is decreased. Examples are the Sparky project [9] and the MIT powered ankle-foot prosthesis [10]. One can conclude that passive energy storing devices (ESR feet) are energetically efficient but do not provide the extra power needed for propulsion during walking. On the other hand, actuated devices are able to provide the necessary energy, but need heavy and bulky actuators capable of producing high torques in small periods of time. With the AMP-Foot 2.0, the authors propose a new design of an energy efficient, powered transtibial prosthesis. Its design enables the actuator to work at low power during a much longer time period while energy is stored in springs and released when needed. Thanks to this, the size and weight of the actuator can be decreased considerably while still providing the full power necessary for forward propulsion.

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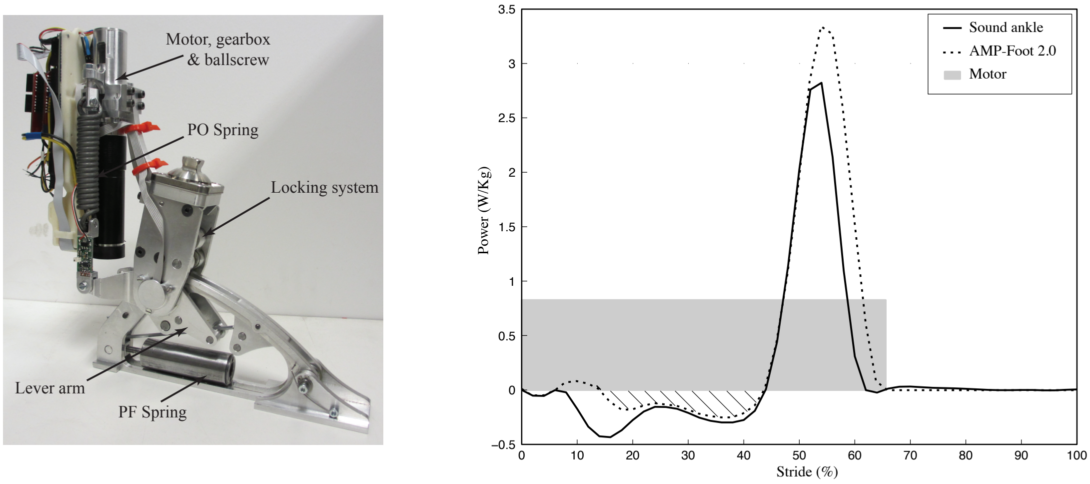
2 The AMP-Foot 2.0

Figure 1(a) shows the AMP-Foot 2.0. The device consists of three bodies pivoting around the anke axis (the leg, the foot and the lever arm), a plantar flexion (PF) spring, a push-off (PO) spring, a locking mechanism and an electric motor. Fig. 2(b) shows the power generation of the AMP-Foot 2.0 during one gait cycle. During stance, until HO, the lever arm is fixed to the leg by means of a locking mechanism. This mechanism consists of a four bar linkage locking when in singular position. Unlocking of the four bar linkage is achieved with a solenoid. Because the leg is moving back and forth during the first part of stance, energy is stored into the PF spring. During the same period the electrical drive, which is attached to the leg, elongates the PO spring which is connected to the lever arm. Since the lever arm is still fixed to the leg all the energy produced by the motor is stored into the PO spring. At HO, when the heel is being lifted from the ground, the locking mechanism is disengaged and the lever arm is free to move. At that particular moment, the energy stored in the PF spring and in the PO spring is combined and transferred to the ankle joint. As a result of this, the ankle torque jumps to its nominal value and provides propulsion of the subject. Because of the mechanical construction, the springs are connected in series after disengaging the locking mechanism. Therefore, after HO, a new rest position of the ankle joint is created. As a result of this, the ankle joint is able to move from approximately +10° at HO to -20° at TO while the torque is decreasing slowly until entering the swing phase. During swing, the motor moves back to its initial position (unloaded) and the whole system (foot and lever arm) returns to its 0° rest position by means of a reset spring. Thus from HS to HO, the AMP-Foot 2.0 acts as a common ESR foot. But in contrary with existing bionic feet, the actuator of the AMP-Foot 2.0 is also working before the actual push-off. Therefore, its working time is much longer and thus the power of the actuator can be signicantly reduced. The actuation of the prosthesis consists of a Maxon RE30 (60W) motor with a gearbox and a ballscrew transmission.



(a) (b)

Figure 1: (a) AMP-Foot 2.0. (b) Ankle power during one stride. The solid line represents the power generation of a sound ankle while the dotted line represents the resulting power of the AMP-Foot 2.0. The gray rectangle shows how the actuator power is spread over one gait cycle while the shaded area represents the energy harvested with the PF spring.

3 Conclusions

With this abstract, the authors present the AMP-Foot 2.0, an energy efficient powered transtibial prosthesis mimicking non-pathological ankle behaviour. The innovation of this study is to harvest energy from motion with the PF spring while storing energy produced by a low power electric motor into the PO spring. This energy is then released with a delay when necessary for push-off thanks to the use of a locking system. The device is designed to provide a peak output torque of 120 *Nm* with a range of motion of 45° to fullfill the requirements of a 75 *kg* subject walking on level ground at normal cadence. Its total weight is ± 2.5 *kg* which corresponds to the requirements of a sound ankle-foot. Currently, the AMP-Foot 2.0 is being assembled. Preliminary tests should be performed at the end of february 2012.

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