

Shoulder Mounted Gyroscopic Prosthesis for Assisting Arm Amputees During Walking*

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I. OVERVIEW

The human arms play a significant role in stability and efficiency during walking [1-4]. For forequarter and shoulder disarticulation amputees the effects of the arm are no longer a part of their biomechanics. This can lead to detrimental effects on spine health and gait mechanics [5].

To address this problem a compact shoulder prosthesis is proposed for arm amputees that can restore some of the static and dynamic contributions of the human arm. The device is easily customizable to match the weight of the missing arm, and fits within the form factor of the human shoulder (Fig. 1). Inside the device, a gyroscopic element moves in sync with the user's stride to exert a moment on the trunk similar to that of the arm during walking. The size, ease of use, and relatively low manufacturing cost of the proposed device makes it an attractive complement or alternative to standard prostheses, especially for amputees who pursue rigorous or prolonged physical activity. These benefits of restored arm dynamics, a balanced torso, and the gyroscopic stabilizing effects of the proposed device can represent a significant improvement to quality of life for arm amputees.

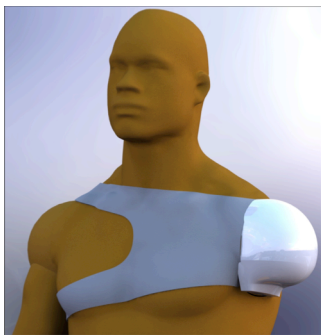


Figure 1. Device concept rendering.

II. RESULTS

The prototype actuator shown in Fig. 2 is currently undergoing testing. It includes a 7.6 cm (3 in.) diameter brass 2.5 cm thick (1 in.) disk spinning at 3,000 RPM to create the angular momentum required to exert sufficient arm-like moments on the user. The device is expected to

perform similarly to calculations performed in SimMechanics (Matlab). The simulation shows an actuator of this size is capable of over 180x torque magnification, creating a 3.6 Nm peak output torque for a 20 mNm input (Fig. 3). Initial tests of the prototype actuator at low speed (1000 RPM) demonstrate functionality of the device and match expected results from the theoretical model. In the coming months, the prototype actuator will continue to be tested to verify several key performance parameters of the device, including: (1) torque multiplication capabilities, (2) bandwidth, and (3) power consumption.

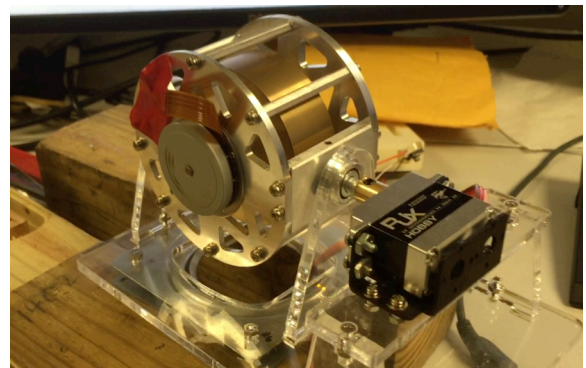


Figure 2. Prototype gyroscopic actuator.

The actuator will respond to the movements of the user's trunk by using inertial data collected from an IMU also mounted at the shoulder. Control of the device will focus on two characteristics: (1) gait frequency, and (2) stride length. Initial IMU data has been collected from the shoulder motion of a healthy subject walking at several speeds. Using this data, a control scheme is under development that can identify desired gait characteristics and command the actuator frequency and magnitude to accurately complement the user's movements.

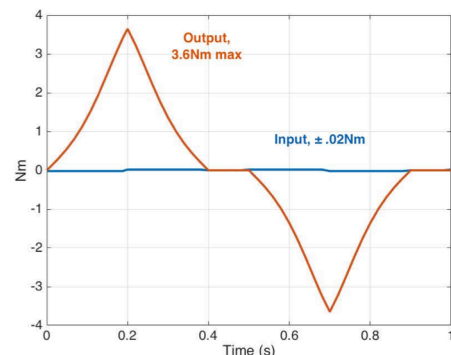


Figure 3. Simulation results demonstrating the torque multiplying capabilities of the actuator.

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III. APPLICATIONS

Relative to biomimetic arm prostheses for shoulder amputees, the device proposed herein promises ease of operation, low cost to acquire and maintain, and increased durability. The device's primary benefits focus on dynamic assistance during movement, making it particularly suitable for amputees who pursue rigorous or prolonged physical activity, such as endurance sports, that requires dynamic contributions from the missing arm.

A production-size device is currently being designed that can integrate sensing, actuation, on-board power, mass customization for individual users, and an attachment scheme to the trunk. Testing of this device on subjects will contribute greatly to refining the control scheme and ultimately measuring the effect and usability of the device.

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