Identifying the Optimal Damping Coefficient for a Passive Prosthetic Knee

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***Abstract*—This study presents a methodology and testing of the optimal damping coefficient for controlling the flexion of a fully passive prosthetic knee during terminal stance and swing phases. The optimal damping was calculated from able-bodied gait data and then adjusted for asymmetry in swing phase common for transfemoral gait. The theory was validated in a motion capture experiment involving three subjects with a transfemoral amputation walking with a passive single-axis prosthetic knee. The results from the study has shown that the optimal damping enables the desired knee kinematics.**

Keywords—prosthetic knee, biomechanics, design metric

I. Introduction

Multiple studies have estimated over 230,000 transfemoral amputees in India alone [1, 2]. Over 47% of persons with amputations reported facing severe socio-economic stigma resulting in change or loss of occupation [1]. Even though currently available prostheses provide the required stability, they do not enable able-bodied kinematics, which is one of the most important requirements as for prostheses in developing countries. Affordable prosthetic knee joints use friction-based dampers that result in an uneven, intermittent walking pattern. Using fluid-based dampers could enable a smoother gait; however, the damping coefficient must be large enough to prevent hyper-flexion in early swing while still allowing adequate knee flexion for toe clearance.

II. Methods

An optimal damping coefficient that could best replicate the target able-bodied knee moment during terminal stance was computed [3, 4]. However, previous experiments have shown that persons with transfemoral amputations tend to walk slower and have an asymmetrical gait compared to able-bodied gait. Using published data, it was found that the optimal damping coefficient was invariant with walking speed [5]. The asymmetrical gait, however, results in the prosthetic knee flexing faster than that of the sound side during swing; and the optimal damping coefficient had to be scaled by 49% in order to account for this asymmetry [6]. After adjusting for this asymmetry, the predicted optimal damping coefficient for swing flexion was 0.0117 Nm/(kg*(rad/s)).

In order to validate the optimal damping coefficient, shear-based rotary hydraulic dampers [7] were built with different damping coefficients in order to account for different body masses. Afterwards, a clinical study was conducted at the Northwestern University Prosthetics and Orthotics Center (NUPOC) where subjects walked on level ground with the different dampers attached to a test prosthesis [8].

III. Results and Discussion

The results of the clinical study showed that increasing the damping coefficient decreased the mean peak knee flexion angle. Moreover, the no damping condition resulted in hyperflexion, demonstrating that damping is required to achieve able-bodied kinematics. Lastly, the optimal damping coefficient allowed for either flexion angle close to the able-bodied kinematics reference or allowed symmetry with sound leg.

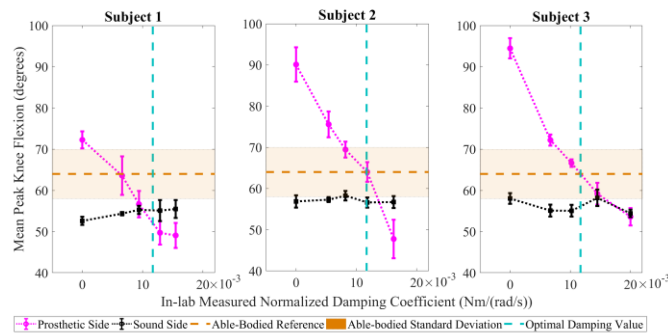

Fig. 1. The measured mean peak knee flexion of the prosthetic (pink) and sound (black) sides during swing with respect to the damping coefficient. The orange dashed line and shaded area show the target able bodied knee flexion with standard deviation. The blue vertical dashed line shows the predicted optimal damping.

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