Design of a Semi-Active Ankle Foot Prosthesis Using a Pneumatic and Hydraulic Hybrid System to Control Stiffness and Energy Return Timing

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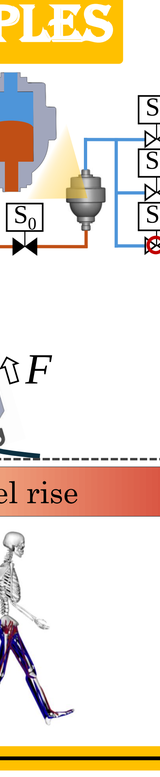
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INTRODUCTION

- Lower-limb amputees would benefit from ankle-foot prostheses with adjustable stiffness energy return timing, and sufficient push-off power for varying walking speeds.
- Most passive prostheses using carbon fiber blades (CFB) provide only single stiffnes and return energy to the gait earlier than a biological ankle.
- Quasi-active and powered prostheses are limited in their ability to fully utilize the amount of energy available with a CFB since they cannot control the energy return timing, requiring them to rely on heavy and bulky actuators to compensate.

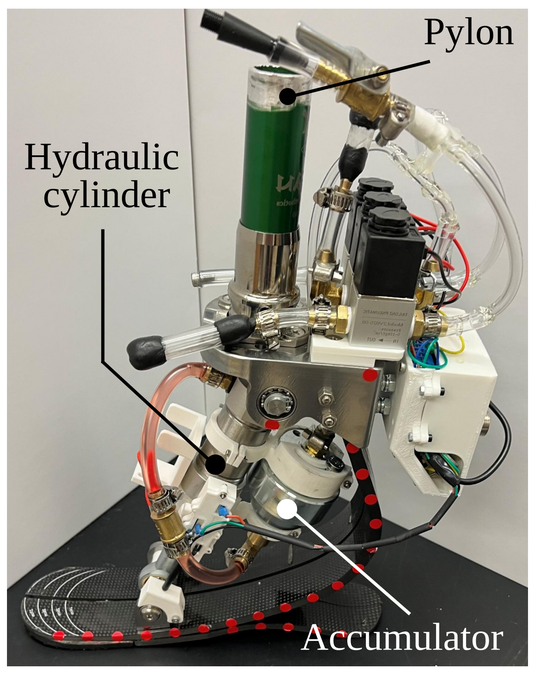


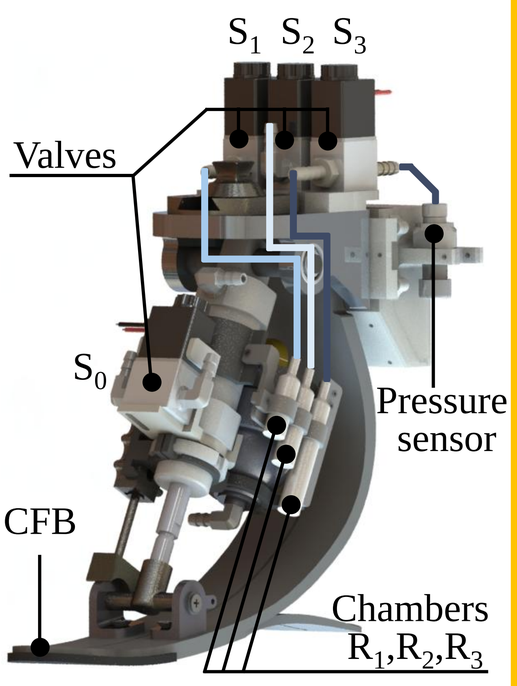


Objective

The Pneumatic and Hydraulic Hybrid Prosthesis (PHHP) can provide variable stiffness and release energy from both pneumatic compression and CFB deformation at the desired time, making it adaptable to a variety of walking conditions for lower-limb amputees.

OVERALL DESIGN

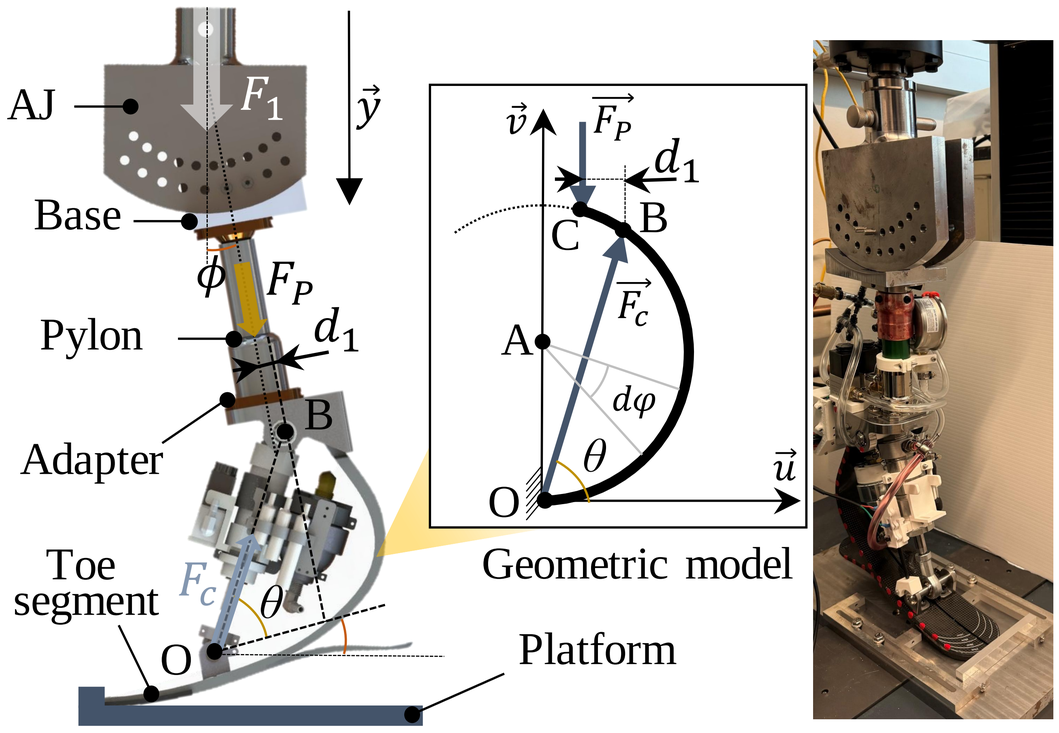




WORKING PRINCIPLES

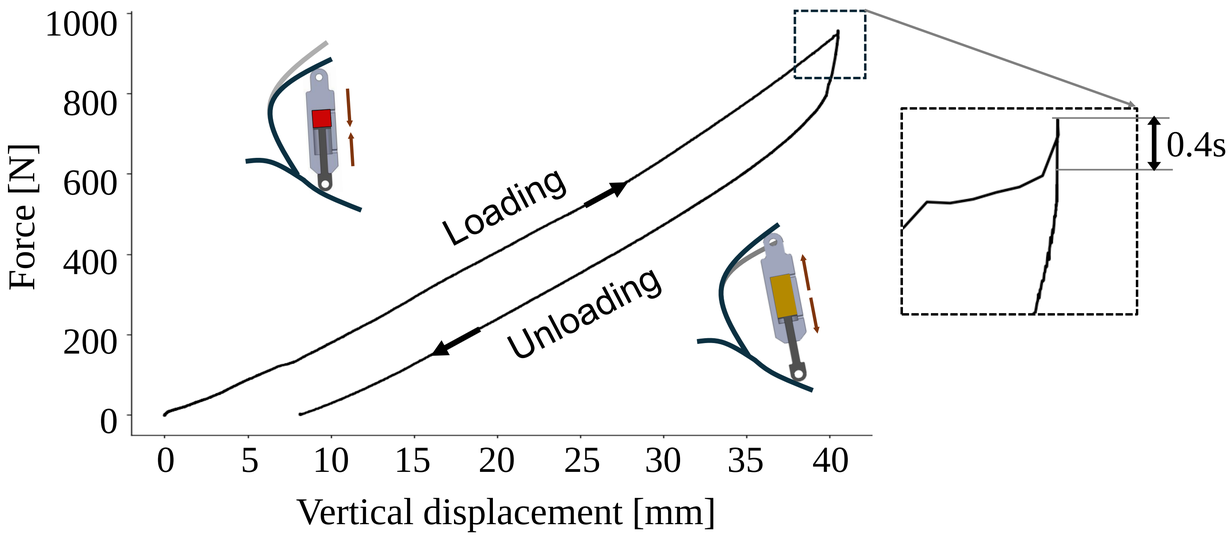
EXPERIMENTAL SETUP

Bend Tester Experimental Setup

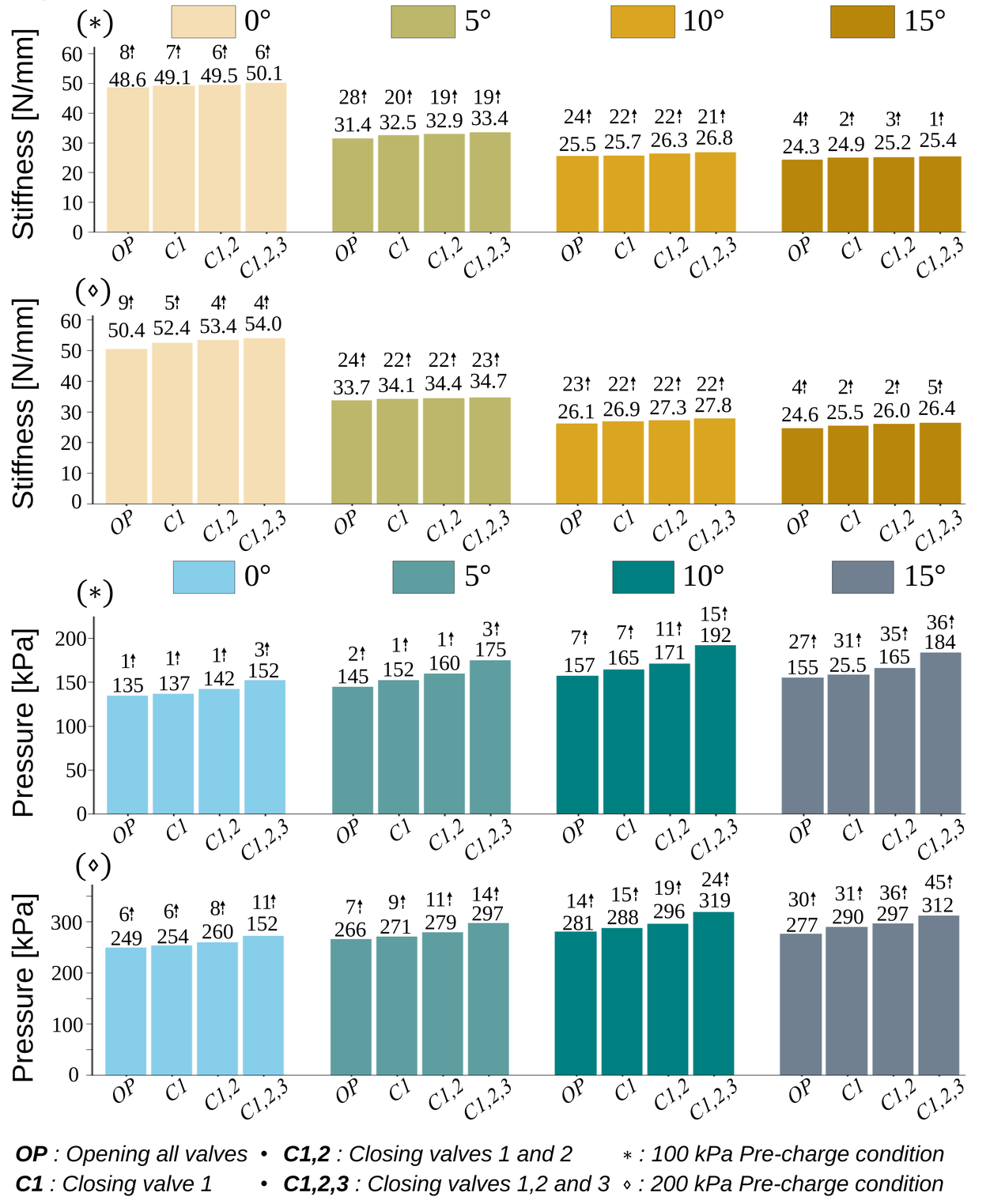


RESULTS

Energy Return Timing with Hydraulic Valve Actuation



Experimental and Theoretical Results of *Variable Stiffness System*



- ***OP*** *: Opening all valves*
- ***C1*** *: Closing valve 1*
- ***C1,2*** *: Closing valves 1 and 2*
- ***C1,2,3*** *: Closing valves 1,2 and 3*

∗ *: 100 kPa Pre-charge condition*

◇ *: 200 kPa Pre-charge condition*

↑ *: Theory–experiment discrepancies*

CONCLUSION & DISCUSSION

- The carbon fiber foot maintains deformation for approximately 0.4 seconds.
- Linear stiffness is comparable to commercial devices: 25 N/mm to 54 N/mm.
- Stiffness increases by 4.7%, 6.7%, and 7.9% for the "Close 1", "Close 1,2", and "Close 1,2,3" configurations, respectively.
- Energy return efficiency ranges from 72% to 84%.

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