# A HYDRAULIC APPROACH TO THE DEVELOPMENT OF A VARIABLE RECIPROCATING HIP MECHANISM FOR THE RECIPROCATING GAIT ORTHOSIS

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## INTRODUCTION

The hybrid orthosis system (HOS) is an assistive gait device for individuals with paraplegia that combines the stability provided by an exoskeletal brace with limb mobility controlled via functional neuromuscular stimulation [1]. A type of brace used in the HOS is the reciprocating gait orthosis (RGO) [2]. The RGO facilitates reciprocal gait by mechanically coupling hip extension with contralateral hip flexion. Hip reciprocation is however fixed at a 1:1 flexion/ extension coupling ratio (FECR), limiting hip flexion to the extent of contralateral hip extension [3]. The aim of this research is to develop a hip reciprocating mechanism for the RGO that can couple the hips at variable FECRs. This study focuses of examining the feasibility of utilizing a hydraulic system for variable hip reciprocation.

## METHODS

The proposed design of the hydraulic system for variable hip reciprocation consists of a double acting hydraulic cylinder linked to the lever arm of each thigh upright. Corresponding outlets of the opposing cylinders are connected by tubing to produce a closed hydraulic circuit. Thus, hip extension forces the adjoining piston upward, which then pressurizes the contralateral piston to move downward, resulting in contralateral hip flexion. Solenoid valves are employed to control fluid flow through the hydraulic system resulting in the locking/unlocking of a hip joint and/or the disengagement/ reengagement of hip coupling to establish variable FECRs. Pressure relief will be provided by an accumulator.

An initial prototype was developed using off the shelf components to test the efficacy of the design. Pneumatic cylinders with a 5/16 inch bore diameter were used to minimize flow rate and manual shutoff ball valves were used in replace of solenoid valves to simplify operation.

An analysis of determining the operating pressures and flow rates of the hydraulic system during gait was undertaken to resolve optimal cylinder and valve specifications and verify if these components could be supplied off the shelf or necessitated the costs of customization. The goal is to minimize flow rate through the valves while selecting a cylinder with a large enough bore diameter to sustain the pressure ranges experienced during gait. Instantaneous cylinder pressures and flow rates during gait for a series of stock cylinder bore sizes were determined by using dynamic data from a three-dimensional computer model of the HOS that incorporated a RGO with 1:1 hip FECR [4]. A valve coefficient ($C_v$) was then determined for each cylinder bore diameter.

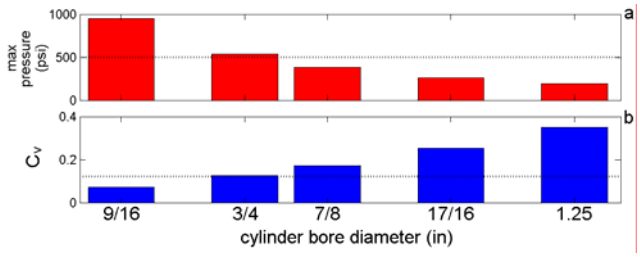


**Figure 1**: The dotted lines in (a) and (b) indicate the pressure rating for small bore cylinders and maximum $C_v$ for low powered solenoid valves respectively.

## RESULTS AND DISCUSSION

The prototype demonstrated the soundness of the proposed hydraulic design by verifying that (1) hip coupling could be readily engaged and disengaged and (2) each hip could be locked and unlocked independently without affecting the kinematics of the opposite hip.

Maximum pressures (Figure 1a) and $C_v$ factors (Figure 1b) during gait indicate that a stock cylinder with a ¾ inch bore diameter and pressure rating of 500 psi and valves with a $C_v$ of 0.12 could be used for the hydraulic variable reciprocating hip mechanism.

Current and future work includes the bench testing of the hydraulic reciprocating hip mechanism with the established optimal components and subsequent able-body testing of the new orthosis.

## REFERENCES

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