

## **Development of a lower-limb exoskeleton robot for gait rehabilitation**

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Diseases such as stroke, Parkinson's, brain and spinal cord injuries that affect the functional motor abilities are increasingly found among elderly population in the present society. Patients with such diseases have to undergo clinical rehabilitation. Biorobotics devices such as exoskeleton robots have the potential to increase the effectiveness of clinical rehabilitation. This paper proposed a four Degrees of Freedom (DoF) lower-limb exoskeleton robot for gait rehabilitation. It can generate hip flexion – extension, and knee flexion – extension motions of both left and right limbs. The robot consists of 6 main components: hip attachment, hip joint, length adjustable thigh linkage, knee joint, length adjustable shank linkage and ankle joint.

A computer aided design (CAD) of the exoskeleton robot is first developed by considering the design factors; joints and linkages design, safety mechanisms, and human-robot interfacing. Aluminium alloy (7075) and Nylon101 are used in linkages and other structural components respectively to reduce the overall weight of the structure. Ensuring safety of wearer's limbs from perilous rotations is a prime concern. Therefore, both mechanical limiters and software feedback control are used to keep the joint rotations within safe limits. In order to interface the robot with the human wearer, thigh and shank linkages are designed to have adjustable lengths to accommodate different body sizes. Furthermore, a spring mechanism is inserted in each link to absorb the impulses while walking. Two DC motors fixed at the hip and knee joint assemblies are used to actuate the robot. Each joint angle is measured from potentiometer feedback. A PID controller is used to generate the required motion based on rehabilitation algorithm.

A finite element analysis proved the mechanical strength of the components under desired loading conditions throughout the gait cycle. A motion analysis experiment was conducted giving an input signal of a sinusoidal wave for hip joint and knee joint to verify the motion generation of the robot. Maximum motion range for both joints were obtained and this result substantiate the accordance of the robot with applicable motion ranges of human lower-limb. Further experiments conducted using *SimMechanics* demonstrated the compliance of the joint velocities for arbitrary input signals. The results validated that the proposed exoskeleton robot has adequate structural integrity and proper accordance with human motion.