

Proposal by simple design of the lower limb exoskeleton of continuous use, provided of own mobility and body load support. Case: application due to an illness

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Abstract. In recent times it has established a debate between experts and academics about the social and economic impact of advances in robotics. The robotic exoskeletons mounted as suits on affected parts of the human body, represent one of the most significant examples of which is oriented towards robotics. With recent technological advances have increased the fields of application of these devices widely with respect to the first applications were teleoperation and increase in strength of a human being for various tasks. The aim of this work is to contribute as much as possible, to start a discussion about the vision of offering future developments in socio-economic terms and its impact resulting from the use of robotic exoskeletons, especially with regard to its application in medical rehabilitation of lower member and especially its use permanent, replacing cumbersome devices such as crutches, walkers, canes. All this, focused on the health sector, which is most affected by different diseases cannot have access to these devices. In this paper, only it proposes a design that could be inexpensive and used for various ailments.

Keywords: Exoskeleton, robotics, lower limb, joint, automation.



1. Introduction

The Initial studies about the movement of lower limb orthoses assisted by date from the 1960's in the United States [1] and the newly formed Yugoslavia [2] respectively, for military purposes and medical [3]. Since then, orthoses and exoskeletons have been developing prosperously in different types of structures, actuators and interfaces. Today, established from the point of view as tools to ease the hard work of physical therapists, while improving (neurological or orthopaedic) retrieves the effectiveness of patient movement—Loko Mat [4] LOPES [5] they are also the goal of helping paraplegics or quadriplegics people to recover the ability to walk in daily life—ATLAS [6] Re Walk™ [7], Ekso (Ekso Bionics, US, formerly e Legs [8]) ; which they are adopted as systems capacity increase strength in healthy people in order to carry heavy loads—BLEEX [9] Sarcos Exoskeleton [10], MIT Exoskeleton [11]. Furthermore, being placed in the use of exoskeletons of lower limb, as part of aid to the motor independence patients of Mexican health sector is necessary to consider that there are many causes that can affect the functioning of the human locomotor system, leading to the onset of joint disorders and lower limb generation atypical patterns of motion. The importance of research and development in assistive technologies to compensate for the pathological gait have been recognized since the early twentieth anniversary, and many challenges still lie ahead for clinical application a reality.

In this work, the lower limb is presented as an exoskeleton, conceived as a system of compensation and evaluation of the pathological gait, for applications under real conditions as a methodology of assistance and joint assessment of the problems affecting mobility in individuals with neuromotor disorders.

The main technological challenges are discussed with regard to detection, performance and control subsystems. A special emphasis is placed on advances in robotics for lower limb orthoses, and biomechanical requirements, considerations of structural design are analysed and existing approaches to develop robust real-time controllers, to mobile solutions with a common goal, control human motor.

2. Normal and pathologic human walking

Concerning disabilities of walking due to neurological, orthopedic or traumatic conditions, different robotic approaches, and classification of robotic exoskeletons for lower limb, is presented in rehabilitation robots, systems evaluation and monitoring and portable systems functional recovery.

The cyclic process of events during the march known as the gait cycle, and starts and ends at the moment when one foot makes contact with the ground and support phase begins. While leg moving, body moves the other leg acts as a support. So, the state of the lower extremity is divided into two phases depending on their situation with regard to the plant: impulsion phase, and phase support. During walking at normal speeds there is a short period of simultaneous support of both legs. As velocity increases a cycle in which no bipodal support is reached. The march can be characterized by a set of parameters: stride length, step length, rhythm and speed. The complexity of human locomotion involves the study of the cyclical movement which runs, considering the kinematics and kinetics (forces and moments) and work, energy and power consumed in the process. Other hand, to understand entire phenomenon, it is necessary to have a knowledge of neurological principles that control movement, sensory input peripherals or systems involved and the mechanisms that command the musculoskeletal system.

3. Exoskeleton structure

Depending on the type of interface or set the system to the extremity, unilateral or bilateral structure can be used. For example, if the interfaces cannot generate sufficient torque in the transverse plane at the points of connection with lateral bars, a unilateral system is not feasible. Conversely, if the interfaces can generate moments in the transverse plane, it is possible to use a unilateral exoskeleton, whose supports are rigid to stabilization in the sagittal plane. The alignment in a bilateral solution is a critical problem because if the two joints are not parallel, friction and undesired stress will be produced at each step. For the design of the mechanical structure of a unilateral frame it was used, with four interfaces load on soft surfaces, such as the right to test the application of compensation strategies. The configuration adopted exoskeleton consisted of two joints of the knee, which was changed last for more

efficient time consisting of a polycentric four-bar mechanism [12] that generates a more accurate instantaneous center trajectory, making this joint, which is the most sensitive for their degrees of freedom is more suitable for the exoskeleton and other ankle included only with one degree of freedom, sidebars attached to the thigh (proximal), the leg (distal) and foot (support and inserted in the shoe insole), and four fastening strips to the tip. To make the design took into account important factors such as compensation for ankle instability, compensation knee instability, the condition of impact with the ground, so that the entire mechanism was able to compensate for these instabilities actuator means mounted on the knee joints and ankle. Figure 1 shown the exoskeleton (without mounted compensating actuators) where you can observe the joint originally proposed, which was replaced by a polycentric four-bar mechanism, fairly stable phases swing in walking and support phase.

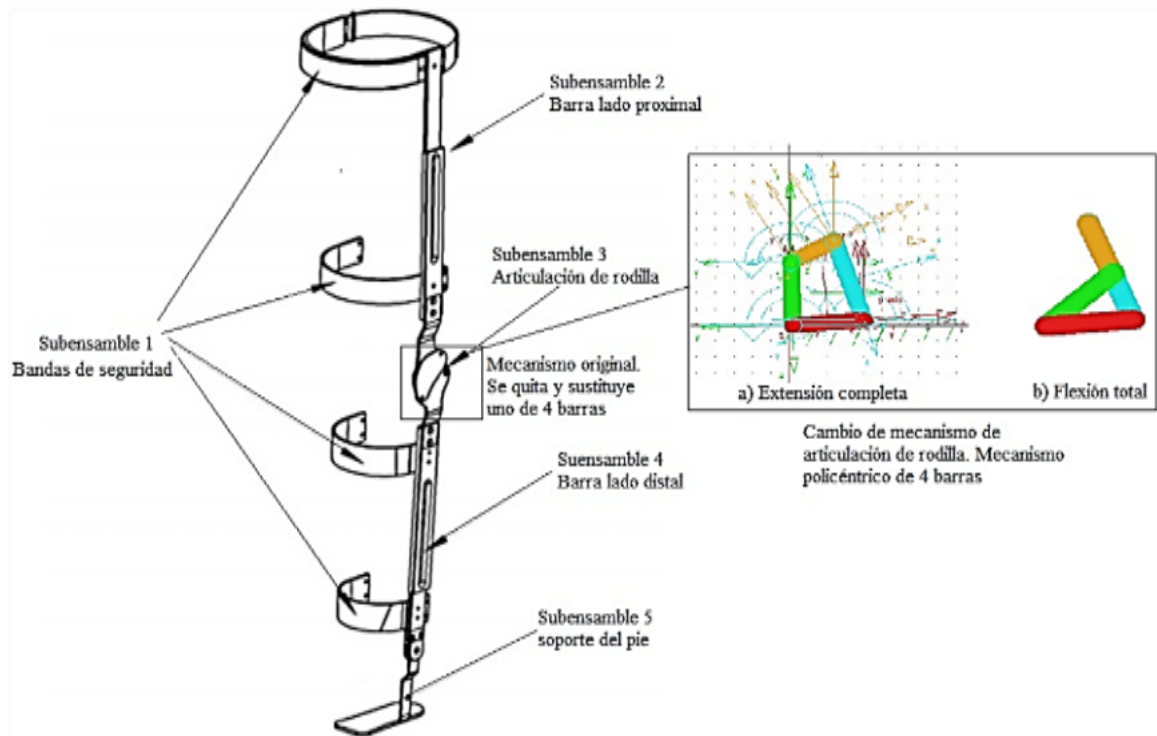


Figure 1. Complete assembly of the exoskeleton, which shows the knee joint that was changed [12].

The main movement of the knee joint is flexion and extension occurs in the sagittal plane; this is not a simple rotational movement, because if so, by rotating the femur over the tibia to the knee would end dislocated [13]. During flexion and extension of the knee, the femur, in addition to the rotary movement, makes a sliding movement on the tibial plateau, which makes the rotation axis is not fixed and therefore there is an instantaneous center of rotation (ICR). The knee joint performs its natural movement through the use of a complex structure of muscles, tendons and ligaments.

3.1. Synthesis of knee mechanism

The synthesis of polycentric knee mechanism was performed using the genetic algorithm developed by Lugo [12] which is easily adapted to the femoral and tibial structure. The general genetic algorithm for synthesis can request the author. Basically is a fairly extensive program developed by Lugo for the synthesis of four-bar linkage including polycentric (instantaneous centers of rotation), such as monocentric like the knee and ankle.

3.2. Balancing the knee joint

Given the linear rotations was found that the performance of gaskets set for some phases of the gait cycle, the operating principle of the actuator knee (Figure 2) is given by: an elastic element K2 is activated to heel contact, with lock in B1 in the phase of initial position, the application of stiffness K2

in the knee corresponding to a bending angle maximum longitudinal path restriction. An elastic element K1 (compression spring) is activated in the terminal phase support, by unlocking B1 to release the joint and allow free oscillation, given that $K2 \gg K1$. The element has a maximum longitudinal displacement, corresponding to the restriction of knee flexion. Total lock on B1 to keep the entire leg in extension and provide security when standing or climbing stairs or slopes. The K2 elastic element, configured using disks stacked Belleville, has a maximum trajectory of 13 mm corresponding to 15 degrees of flexion, which enables safe load response and consequent extension before turning. The elastic element has a maximum displacement K1 of 55 mm, which corresponds to a knee flexion 95 degrees. The actuator for balancing the knee joint was selected in the catalog of Festo [14] which conform to the restrictions of movement of flexion and extension of the knee, in the case of flexion to 95° by providing a similar rigidity normal knee extension and leaving almost free but limited very close to zero degrees to prevent extension by the actuator hyperextension, as described in Figure 2.



Figure 2. Linear actuator for balancing knee joint

3.3. Balancing the ankle joint

The mechanism ankle is much easier to synthesize, since it is a mechanism articular pivoted only by a bolt, where only the lengths mentioned were selected to determine the damping in flexion and extension as described in this section. The passive system acting on the ankle contains springs which are dimensioned according to the linear relationships given by K3 and K4 which model the operation of the board, the operating principle of the actuator ankle (Figure 3) is given by: A K3 elastic element which is compressed, stored energy and controls the dorsiflexion of the support phase. In compression, K3 has a maximum longitudinal trajectory equivalent to a restriction of ankle dorsiflexion. Energy stored in dorsal flexion recovers towards a path plantarflexion before pivotable extension K3. An elastic member that adds rigidity K4 extension to control plantar flexion posture and prevent foot drop during the swing. The element has a maximum longitudinal trajectory equivalent to a restriction of ankle plantar flexion.

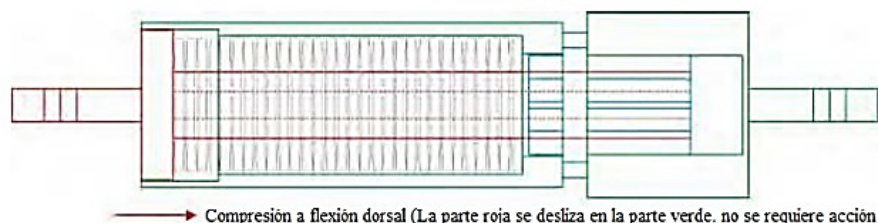


Figure 3. Linear actuator for balancing ankle joint.

Finally, it should be mentioned, in particular, to design the actuator knee integrated into the ankle joint, the elastic element K3 (disks Belleville stacked) is compressed with a history of 15 mm equivalent to 20 degrees of ankle dorsal flexion. The elastic element compression K4 has a maximum displacement

of 6.5 mm plantar flexion, equivalent to 15 degrees of flexion. The final design of integrated drive system bi-articular in full exoskeleton structure is shown in Figures 4 and 5.

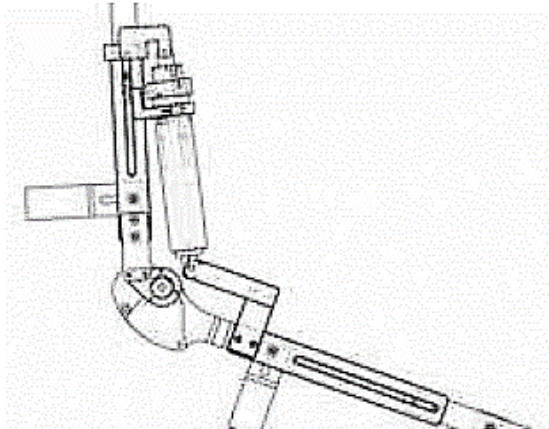


Figure 4. Complete knee joint.



Figure 5. Complete ankle joint

4. Results

The results obtained are specifically shown as follows:

1. The armature is very slender, which does not sacrifice strength, since it is made of duraluminium and because of this it is very light.
2. The cost of the exoskeleton is relatively low, compared to other robotic systems trademarks.
3. Due to the type of fastening the lower member, assembly and disassembly is easy.
4. Exoskeletal system was integrated into a polycentric high efficiency articulated of four-bar linkage and very stable, in most of the flexion-extension movement.

5. Conclusions

Conclusions obtained from this work are very encouraging, since to be manufactured and used in the health sector, could be made experimental tests in different patients, which would throw valuable results to improve aspects of the exoskeleton and optimize for the exclusive use of the sectors of the population who have no access to private medical care systems, This project proposes the design of an exoskeleton , inexpensive and is accessible to low income patients in the Mexican health sector

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