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THE ACTIVE ORTHOSES

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Abstract — This paper is about an active orthosis which is part of an exoskeleton. The purpose of this orthoses is to sustain and increase the muscular force of a person through pneumatic artificial muscles. This paper presents how this type of orthoses is working and the components that build it up. This orthosis can be used by people with locomotor dysfunction but also by military soldiers who need to be increased muscular force.

***Keywords* —** active orthoses, exoskeleton, muscular force, pneumatic artificial muscles.

I. INTRODUCTION

Research in powered human exoskeletons began in the late 1960s. There are three main types of powered exoskeletons for humans: rehabilitation exoskeletons, assistive exoskeletons and performance augmenting exoskeletons (Fig.1). Their common goal is the assistance of human gait. [1]

An active orthosis is a part of an exoskeleton design for the lower limb (an example of active orthoses in Fig.2). The research in this domain begun in 1960 both in the United States of America and in former Yugoslavia almost in the same time. The differences between is that researchers from SUA were focused on developing this type of device for the military purpose only and the researcher of the former Yugoslavia were developing technologies to help handicapped persons. [2]
Despite the differences the two fields, both face many of the same challenges and constraints, particularly related to portability and human interfaces.

This paper will present a review of the work done on active orthoses for the lower limb (Fig.2). The term “active orthoses” is generally used to describe a device intended to increase the ambulatory ability of a person who suffered from a leg pathology.

In contrast to the passive orthoses, the active orthoses have the capacity to increase and at the same time sustain muscle force of the limb, helping the rehabilitation process. Another thing that distinguishes them from the other orthoses is the potential of actively controlling the joints of the devices, rather than simply mechanical coupling common to the passive orthoses. Because of the interesting architectures in which power is added at appropriate phases of the gait cycle might be able to enable the patient to walk naturally which otherwise couldn't be possible with passive orthoses.

Another advantage of this orthoses is the potential of providing both assistance and therapy at the same time which is an extraordinary thing in the process of rehabilitation.

Fig.1. Examples of exoskeleton for the lower body [1]

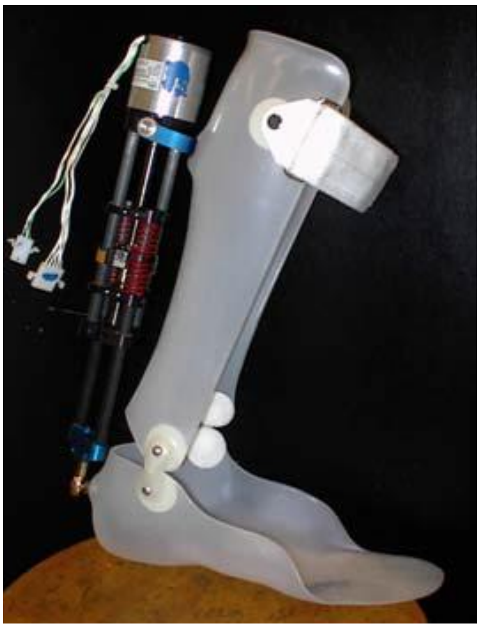

Fig. 2. Example of active orthoses for lower limb [2]

II. ACTIVE ORTHOSES DESIGN AND ITS COMPONENTS

The first step to accomplishing the active orthoses was the realization of the CAD model. The CAD model was realized with the software SolidWorks (Fig.3). The dimension of the prototype was established after my anthropometric measures combined with NASA measurements.

The CAD model was realized with curves, split lines, arch in multiple plans and was extruded with the Boss/Base-Loft feature which creates a shape by making transitions between multiple profiles and guides curves.

Fig. 3. The CAD model of the active orthoses realized in Solidworks 2016

After the CAD model was complete it was modeled by a 3D printer. The material which constituted the orthoses is PLA – Polylactic acid (Fig.4).

Fig. 4. PLA filament roll [3]

The "heard" of the orthoses will be a microcontroller Arduino Mega 2560 (Fig.5). This microcontroller represents the control system and makes the connection with a pressure sensor that is placed on the foot orthoses and a 4 module relay which represents the connection between the control system and pneumatic system.

Fig. 5. Arduino Mega 2560 [4]

The pressure sensor will provide the data which will be analyzed of the microcontroller (Fig.5). After that, the microcontroller will command the relay (Fig.7) which is connected to a solenoid (electro valve) who will late the gas pass through the pneumatic system (Fig.9).

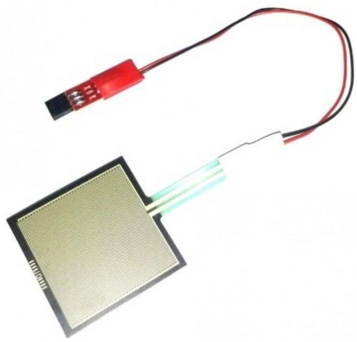

Fig. 6. Pressure Sensor [5]

Fig.7. 4 Module Relay [6]

The electro distributor is the X-Valve® Solenoid which is a miniature pneumatic solenoid valve measuring only 8 (mm) in width.

Fig. 8. X-Valve Solenoid 3/2 way [7]

The compact size, light weight and low power consumption of the X-Valve® is the ideal solution for portable applications and those applications with limited space and available power. The body construction of the X-Valve® is suited for manifold or barbed-tube pneumatic connections and is available in 2-way normally closed and 3-way universal configurations. You can find the performance characteristics in the table below. [7]

TABEL I
PERFORMANCE CHARACTERISTICS OF X-VALVE SOLENOID 3/2

Typical Applications	Portable Equipment, Blood Pressure Monitoring, Wound Therapy, Air and Oxygen Delivery, Sensor Zeroing
Performance: Flow Rate Range	0 to 11 (slpm - standard litre per minute)
Performance: Pressure Range	0 to 100 (psi)
Dimensions: Width	0.31 in (7.87 mm)
Dimensions: Height	0.48 in (12.20 mm)
Dimensions: Length	0.92 in (23.37 mm)
Wetted Materials: Body	PBT, 430 Series Stainless Steel, 302 Series Stainless Steel
Wetted Materials: Seals (Elastomer)	FKM, EPDM, Silicone
Cleanliness	Standard
Valve Configuration Type	2/3 Way NC, 2/3 Way NO, 3 Way Distributor
Life (# cycles)	Up to 25 Million Cycles
Pneumatic Connection Options	Barbs, Manifold Compatible
Electrical Connection Options	Short Pins, Long Pins
Leak Rate	as low as .016 (sccm - standard cubic centimeters per minute)
Response time	as low as 20 (msec)
Power Requirement (W)	0.5W, 1W
Weight (lbs)	0.16 oz.(4.5g)

The pneumatic artificial muscles are from Festo (Fig.9) and they represent the solenoid (electro valve) and the source of gas the pneumatic system.

Fluidic Muscle is a tensile actuator which mimics the natural movement of muscle. It consists of contractible tubing and appropriate connectors. The contractible tubing is made up of a rubber diaphragm with a non-crimped fiber made of aramid yarns on the inside. The diaphragm provides a hermetic seal enclosing the operating medium.

The yarns serve as a reinforcement and transmit power. When the internal pressure is applied, diaphragm extends in the circumferential direction. This creates a tensile force and a contraction motion in the longitudinal direction. The usable tensile force is at its maximum at the start of the contraction and then decreases with the stroke.

The muscle expands lengthways when it is pretension by an external force. When pressure, on
the other hand, the muscle contracts, i.e. its length decreases.

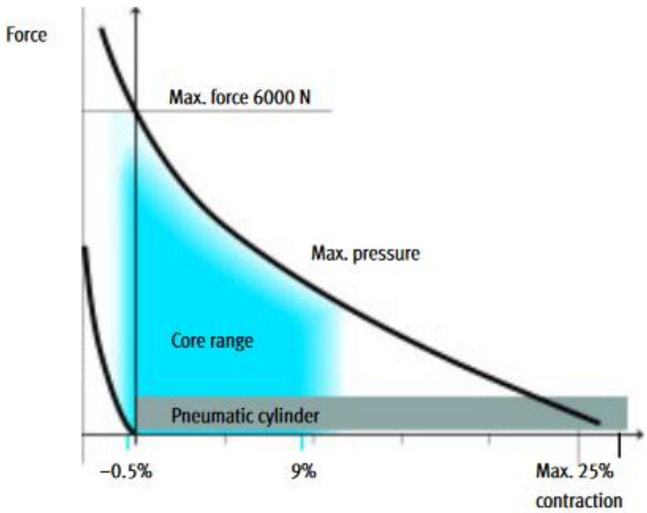

Fig. 9. Force profile and operating range [9]

Fig. 10. Pneumatic artificial muscle/Fluid muscle Festo [9]

In the simplest case, the Fluidic Muscle operates as a single-acting actuator against a mechanical spring or a load. The mechanical spring pretensions the muscle out of its normal position when in the expanded, non-pressurized state how you can see in Fig. 10.

Ideal: 0.5% of nominal length. This operating state is ideal with regard to the technical properties of the Fluidic Muscle: in the unpressurized state, the diaphragm is not compressed. When pressurized, a muscle pretension in this way develops a maximum force with optimum dynamic characteristics and minimum air consumption.

The most effective operating range is provided with contractions below 9%. The smaller the degree of contraction of the Fluidic Muscle, the more effectively it works.

The muscle behaves like a spring when there is a change in external force: it follows the application of force. With the Fluidic Muscle, both the pretension force of this "pneumatic spring" and its spring stiffness can be varied. The Fluidic Muscle can be operated as a spring with constant pressure or constant volume. This produces different spring characteristics that enable the spring effect to be matched perfectly to the application.

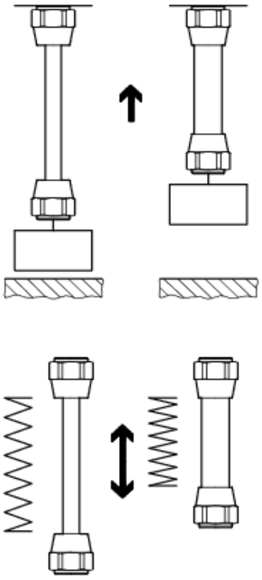

Fig. 11. Relaxation and Contraction of the pneumatic muscles [2]

III. CONCLUSION

This type of orthoses is a part of an exoskeleton and is a new concept of orthoses for lower limb. These orthoses are different of the classic orthoses due to the possibility to sustain and increase muscle force. The active orthoses can be used to relieve pain in pathological limb cases. This way the time of rehabilitation will be shorter and the results will be better than the use of passive orthoses.

This type of orthoses can be used also by a military soldier who need more muscle strength.

The active orthoses can be improved by replacing the pneumatic system with a hydraulic system. The hydraulic system will offer more power to the muscles and will participate to the mineralization of components in this case total weight will be lower too.

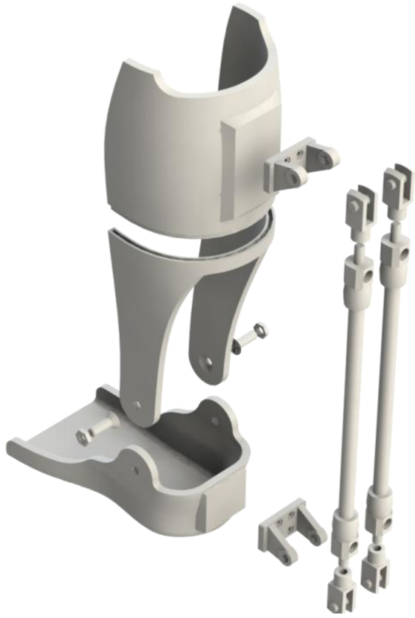

Fig. 12. The active orthoses propose

In the figure above you can see how the active orthoses should look in the end, without the supply elements and control system.

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