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Human Upper Limb Orthosis

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Abstract: The present work reviews existing orthoses and proposes a new approach to their construction. Some shortcomings have been taken into account and fixed on existing prototypes. The applied direct drive of the orthosis axis leads to greater positioning accuracy and to possibility of achieving a higher speed of elbow flexion/extension. Real experiments with volunteers have achieved very good results.

Keywords—active elbow orthosis

I. INTRODUCTION

Orsthosis is a technical device whose purpose is to improve mobility in case of upper limb injury. The reasons for which upper limb orsthosis have to be used are hand injuries caused by trauma (as a result of warfare, transport accidents, industrial accidents) or diseases of the human musculoskeletal system (bone cancer, diabetes, blockage of blood vessels). The production of modern orsthosis, with an aesthetic appearance, functions approximating to those of natural limbs and comfortable handling, had a great social impact, as it helps the disabled to return to normal life, to integrate into society, to feel useful, independent and fulfilled.

Artificial limbs have existed since the early 19th century [1], but today, with the advent of new, advanced technologies, microchips and new materials, prosthetic devices are increasingly approaching natural limbs in functionality and appearance.

Orsthosis are made individually, depending on the site of injury. There are four types of orsthosis /prostheses: artificial hand, above-elbow prostheses and shoulder disarticulation prosthesis, when the amputation is of the whole limb and the shoulder joint is not functional.

The most significant issue is the issue of propulsion and control of the orsthosis. The most commonly used orsthosis in Bulgaria are those with passive drive, accomplished with straps and cords through the movement of other parts of the body (shoulder girdle or other strong arm) [2]. Such orsthosis are cumbersome, slow, and unnatural, but their maintenance is easy and does not require highly skilled specialists for fitting and training. Dentures with external, active drive [3] are usually based on electric motors and batteries (servo-driven, pneumatic prostheses also exist – the so called Edinburg arm).

The main problems with them are the dimensions and weight, as well as what control signals to use [4]. The most fashionable orsthosis at present are those with myoelectric control [5]. These use signals from functioning upper limb ischialis muscles (EMG signals) which are conducted from surface electrodes [6] embedded in the inner shell of the orsthosis, amplified and transmitted to the electrical control [7]. Perhaps the first such full upper limb orsthosis with external actuation and myoelectric control using only two muscles was the UTAH ARM [8]. There are also combination prostheses, of the "hybrid" type, combinations of electric and mechanical actuation (e.g. electric arm and mechanically actuated elbow).

Fig. 1. Muhlenberg and Le Blanc orsthosis [2]

The most famous orsthosis manufacturing companies in the world are Otto Bock (founded in Berlin in 1919, a world leader and distributor offering high quality orsthosis /prostheses and orthopedic components at affordable prices), Liberating Technologies, Inc. /LTI/ (the company specializes in the manufacture of upper limb orsthosis for children and adults, designs and manufactures orsthosis devices such as the Boston Digital™ Arm System and VariGrip™ , Hosmer (the company was founded in 1912. and developed the first orsthosis arm hand piece), Motion Control, Inc. (American manufacturer of orsthosis arms powered by external sources using myoelectric control signals), TRS Inc. (founded in 1979 by amputee Bob Radocy and an innovator in the field of body motion powered orsthosis) [9]. In Bulgaria, orsthosis and prostheses are supplied from Russia and fitted at the

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II. MATERIALS AND METHODS

The elbow joint is a complex one and allows two independent motions – flexion/extension and pronation/supination. For the purposes of rehabilitation, an elbow orthosis can have only one DOF – flexion/extension, the natural range of which is around 150 degrees. Pronation/supination can be limited by the device. The proposed prototype of an active elbow orthosis consists of two light ergonometric plastic parts – arm and forearm – designed using a CAD program and printed by a 3D printer. The lengths of the arm and forearm of the orthosis are chosen according to mean values of human upper limb segments [10]. Their lengths are 241.6 mm for the arm and 229.5 mm for the forearm. The weights of the two parts (without motor, gear, etc.) depend on the material used for printing, and in the current variant they are 227 g for the arm and 203 g for the forearm. There is no option to adjust the current lengths according to the individual subject sizes. Three prototypes with three different mechanical designs of the orthosis sizes (small, medium, and large) are planned to be made in the future [11]. The two parts form a rotation joint connected by a toothed-belt reduction gear, which provides reverse rotation movements induced by the motor [13] (Fig. 1). The gear ratio can vary, depending on the patient's needs, by changing the sizes of the gear wheels. A general view of the orthosis prototype with marked movement of the eccentric compensators which stretch the belt The orthosis is driven by an electric motor, which is placed in a specially designed holder constructed in such a way that if some mechanical conflicts occur.

On the basis of the above-described construction a year later was applied, the idea of creating a new concept with "direct- drive" driven [1]: instead of the conventionally used ones gears to .This ensures a smooth transmission of the rotational movements from the engine in a suitable the developed rotary joint within the safety stops embedded in the structure, such as in addition, it frees the shoulder joint from excess details. Units were lightened based on force analysis using the finite element method and ensuring a better attachment of the belts to the orthosis. It was created a new CAD model that was detailed and made in its main part on a 3D printer.

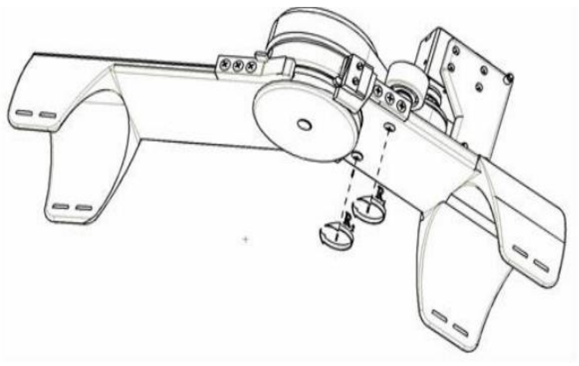

Fig. 2.   CAD model and orthosis prototype with ccentric compensators and stretch the belt, Pat. BG 67615 B1 /16.09.2021I

Fig. 3.   The light version and its application.

The mechanical module consists of an engine fixed on the stationary body by means of properly made holder. To the engine shaft is attached shaft driving the orthosis, on which is built bearing unit by means of stabilizing bushings, some of which are fixed to the fixed shoulder. Part of the shaft is made as a threaded part., On the mobile and fixed arm are built-in rigidly fastened and movable latches that determine the angle of rotation of the movable arm of the orthosis, in order to protect the arm from trauma.

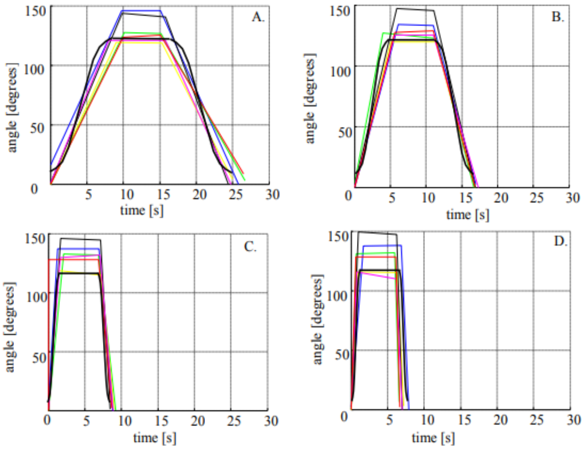

Fig. 4.   Approximation of the law for angle change of the orthosis axis for the four flexion/extension velocities. Colored lines represent data from the six experimental subjects. The bold black line represents the angle of the orthosis. A) 1-st speed, B) 2-nd speed, C) 3-rd speed, D) 4-th speed. All movements here are without load.

III. CONCLUSION

The aim of the presented work was to verify experimentally the developed prototype of an active elbow orthosis driven by an electrical motor. The orthosis has one degree of freedom – flexion/extension, while the second degree in the elbow, pronation/supination, was not allowed. The lengths of the arm and forearm of the orthosis cannot be changed, but different means are provided for adapting the orthosis moment to the individual needs, such as eccentric compensators and different sizes of the reduction gear.

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