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ISOKINETIC EQUIPMENT DESIGNED FOR THERAPEUTIC EXERCISES

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Abstract. The paper presents a type of isokinetic equipment that achieves continuous passive rehabilitation movements as part of the recovery program of patients with post-traumatic disabilities of the bearing joints of the inferior limbs. International studies have revealed that the deployment of equipments capable of performing continuous passive motions for rehabilitation purposes has contributed to diminishing rehabilitation costs by about 50%. For these reasons, a relatively short resting period needs to be followed by isokinetic motions, subsequently continuous passive, then assisted active and eventually unassisted active. The necessity of conceiving isokinetic equipment required for therapeutic exercises results from the high incidence of patients suffering from posttraumatic dysfunctions of the lower limbs. The equipment is actuated by pneumatic muscles and utilizes compressed air as its energy source in order to ensure complete absorption of the end of stroke shocks and minimizing user discomfort. Although the utilization of pneumatic muscles in various industrial applications is still in an early phase, due to the relative newness of these components, it is soon to become a feasible alternative for the electro-mechanically actuated systems.

Keywords: isokinetic equipment, pneumatic muscle, rehabilitation

1. Introduction

The paper presents a type of equipment designed for the recovery of patients with posttraumatic dysfunctions of the bearing joints of the lower limbs (knee and hip), by application of continuous passive rehabilitating motions. Pneumatic muscles actuate this equipment.

Maintenance and recovery of the functions of the human body, prevention of its dysfunctions, using in this respect kinetic and orthotic techniques, as well as various supporting and adaptive accessories represents the objectives of the rehabilitation medicine. Some methods used to alleviate the dysfunctions of the bearing joints are: passive joint mobilization exercises for avoiding contractures of the paretic limbs, muscle force exercises for correcting the contractures of the spastic muscles of the limbs, utilization of adaptive equipment for promoting the function (limb prostheses, ortheses, walking supports). The main form of recovery of the diminished functions is kinetic-therapy including techniques involving motion, as well as various forms of relaxation and immobilization (postural techniques) [1, 2].

The high incidence of patients suffering from posttraumatic dysfunctions of the lower limbs as result of the studies made sets off necessity of conceiving modern complex equipment required for the rehabilitation of such disabled persons.

After completed researches have been made, it has been proved that the utilization of such equipments would reduce the period of recovery, the patients resorting to a smaller quantity of pain medication.

2. Isokinetic Equipment

2.1. Generalities

Isokinetic equipments are instruments that allow performing muscular exercises at a constant speed along the entire range of motion. Those can be pluri-articular devices allowing the testing and rehabilitation of most major joints, and mono-articular devices aimed at a single specific joint.

Worldwide such systems have been specially designed for knee or ankle recovery, as the ones illustrated in Fig. 1.

All isokinetic equipment are endowed with computerized control allowing the real-time study of muscle functionality, as well as the plotting of a series of curves (diagrams) for the study of muscle contraction along the entire path of the motion [3].

Figure 1. Fastening of the leg in an isokinetic rehabilitation equipment (Fisiotek)

The advantage of such equipment is that it can be utilized at home by the patients, not only in specialized rehabilitation centers.

All isokinetic equipment required for continuous passive motion currently available on the market place is driven by electric motors with a rigid linkage structure. The prices of such equipment are high, in the range of thousands of Euros, often exceeding the financial possibilities of the potential users.

It is necessary to conceive pneumatic muscle actuated isokinetic equipment for the continuous passive motion of bearing joints, at a final cost below the current offers available on the market place.

2.2. Pneumatic Muscle Based Actuations Systems

One of the most attractive aspects of pneumatic actuation is the low weight of the utilized components, and implicitly their favourable response to commands. Favourable response to commands, known as compliance is due to air compressibility, and hence can be influenced by controlling/adjusting the command pressure.. Compliance ensures a soft contact as well as the safety of the human individual interacting with the working equipment.

Thus the development of light, pneumatic muscle actuated rehabilitation equipment represent a solution worth exploring, given its potential of yielding high performance kinetic-therapeutic systems [4, 5, 6].

Pneumatic muscles were conceived in 1930 by S. Garasiev a Russian inventor [4]. According to Baldwin [6], J. L. McKibben introduced it as an orthotic actuator in the late 1950's: due to the similarity in length-load curves between this artificial muscle and skeletal muscle, it seemed an ideal choice for this purpose [7, 8].

The Bridgestone rubber company (Japan) commercialized the idea in the 1980s under the name of Rubbertuators.and used them to power an industrial use robot arm, Soft Arm.

At the present, McKibben-like muscles are being brought to the market by Festo Ag. & Co.

The pneumatic muscle system is based on a contracting membrane, which increases its diameter and decreases its length, proportionally with the action of compressed air. The pneumatic muscle carries out a certain stroke, according to the level of the feed pressure. In Figure 2 is presented the working principle of a pneumatic muscle.

A pneumatic muscle includes an interior tube that can have various lengths and is made from an elastic material, typically neoprene. This tube is wrapped in a multilayer tissue made from nylon, strengthening and protecting it from the influences of the working environment. The enveloping angle of the tissue, denoted by α, is of 25.4º in the relaxed state of the muscle and of 54.7º at maximum contraction. The force developed by pneumatic muscle is given by (1) [7].

$$F = p \cdot \frac{\pi}{4} \cdot d^2 \cdot \left[\frac{3 \cdot \cos^2 \alpha - 1}{1 - \cos^2 \alpha} \right] \qquad (1)$$

where p is the working pressure and d the interior diameter of the pneumatic muscle.

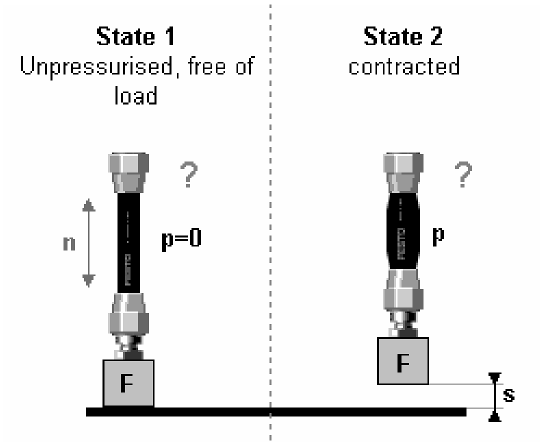

Figure 2. Working principle of a pneumatic muscle

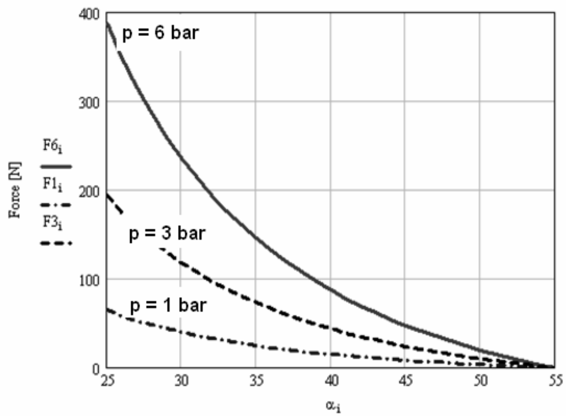

Figure 3. Force versus enveloping angle and working pressure

The behavior of the pneumatic muscle is similar to that of a spring, meaning that upon completion of the maximum stroke the developed force is equal to zero. Equation (1) allows plotting of the graph featuring the force developed by a pneumatic muscle versus the enveloping angle and feed pressure (figure 3) [8].

2.3. Necessity of isokinetic equipment

The necessity of conceiving isokinetic equipment required for therapeutic exercises results from the high incidence of patients suffering from posttraumatic dysfunctions of the lower limbs. The Rehabilitation Clinic of the INRMF of Bucharest in one of its studies has revealed that in the period from 2002 to 2005, of 4323 admitted patients a number of 835, representing 19.32% were suffering from posttraumatic dysfunctions of the bearing joints. Other 877 patients, representing 20.29% were suffering from degenerative rheumatisms, therefore also qualifying as potential beneficiaries of kinetic-therapy.

Research carried out on a sample population of 150 patients having benefited from kinetic-therapy has yielded the following conclusions:

a. improvement of the pain score by 30.02%;

b. improvement of physical dysfunctions by 14.99%;

c. improvement of disabilities by 24.22%;

d. improvement (reduction) of medication consumption by 21.82 %;

e. improvement of the general average score for the entire lot by 24.12%, the highest values corresponding to the group suffering from hip fracture (27.74%), followed by knee fractures (22.85%) and ankle fractures (19.76%).

Within the studied sample, the distribution of posttraumatic dysfunctions was: 43.33% of the cases with hip fractures, followed by knee fractures (30% of the cases) and ankle fractures (26.67% of the cases) [3].

These studies argue for the necessity of introducing kinetic-therapy with isokinetic equipment as an efficient instrument in posttraumatic treatment of the bearing joints.

Continuous Passive Motion (CPM) is a postoperative treatment method that is designed to aid recovery after joint surgery.

In most patients after extensive joint surgery, attempts at joint motion cause pain and as a result, the patient fails to move the joint. This allows the tissue around the joint to become stiff and for scar tissue to form resulting in a joint which has limited range of motion and often may take months of physical therapy to recovery that motion.

Passive range of motion means that the joint is moved without the patient's muscles being used. Continuous Passive Motion devices are machines that have been developed for patients to use after surgery, capable of applying the optimum motions to the joints, necessary for rehabilitation.

Completed research has proved that the utilization of such equipments would significantly reduce the period of recovery, the patients resorting to a smaller quantity of pain medication. Hence, the total costs of recovery are significantly diminished.

3. Proposed Isokinetic Equipment

The proposed isokinetic equipment is a variant of rehabilitation equipment, capable of achieving continuous passive motion, by means of a pneumatic muscle actuated system. This type of equipment is presented in figure 4.

Figure 4. The proposed isokinetic equipment

The equipment can be utilized for both the right and the left leg, due to its axially-symmetrical construction. The continuous passive motion is generated by a pneumatic muscle moving a sliding block, as follows from figure figure 5 [9].

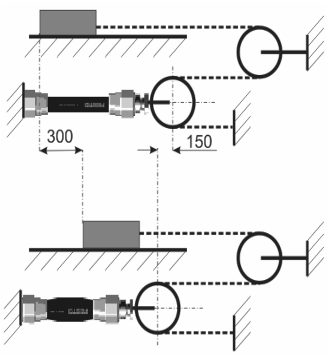

Figure 5. Actuation of the isokinetic equipment

The required stroke of the sliding block is of 300 mm, as shown in the Figure 5. The pneumatic muscle used in the construction of the equipment is of 20 mm interior diameter and initial length of 750 mm, the maximum possible stroke of the free end of the muscle being of approximately 20% of its length in relaxed state (that is 150 mm). A mobile pulley was placed between the muscle and the sliding block in order to amplify the sliding block stroke to the required value.

The working principle is shown in the Figure 6.

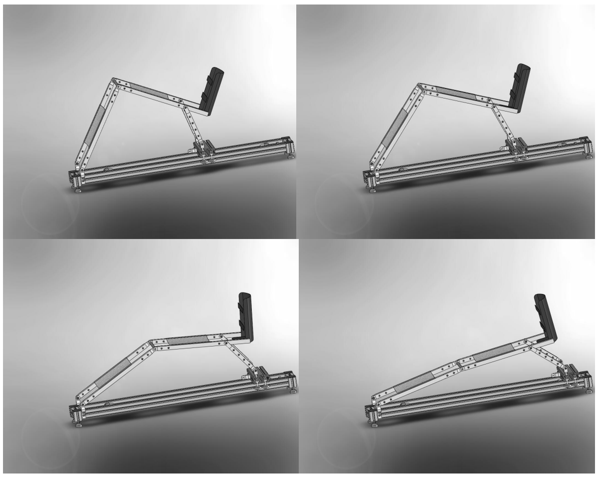

Figure 6. Working principle

The presented isokinetic equipment includes a significant number of components. While some of these were selected from Festo Catalogue, others were manufactured based on the author's designs.

Muscle type and dimensions were selected by means of a program supplied by Festo: the input data in the considered case were the desired displacement (length difference), feed pressure and diameter (Figure 7) [10].

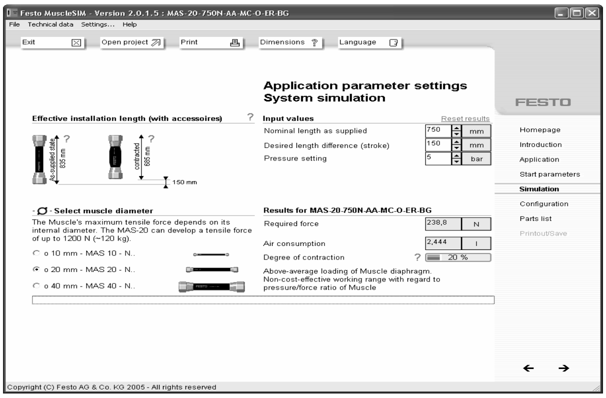

Figure 7. Application parameter settings

The following components were selected from the Festo Catalogue: profiles, profile fasteners, clamping bracket with flexible joint, screws, leveling feet, guide components (rollers).
The components manufacture based on the designs developed by the author include a number of rod eyes and rod clevises.

4. Conclusions

The proposed isokinetic rehabilitation equipment benefits from a cost efficient, simple and robust construction, being easy to use by persons affected by dysfunctions of the bearing joints. The proposed system has another major advantage in the fact that the utilized as source of energy - namely air completely absorbs all shocks occurring at the ends of the stroke. The current, electro-mechanically actuated rehabilitation systems introduce shocks upon reversion of the sense of motion, thus causing discomfort to the user.

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