SOME EXPERIMENTAL RESULTS REGARDING THE MOBILIZATION OF A REVOLUTE JOINT BY MEANS OF FLUIDIC MUSCLES

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Abstract: The resolution of a great diversity of practical applications makes the interest for finding new solutions of actuators increase permanently. For example, the starting up of a rotation movement in case of a simple revolute joint can be done in a variety of ways: by using systems of classical actuation- hydraulic, pneumatic, electric or non-conventional, based on “intelligent” materials or new equipments, such as fluidic muscles. They can be more and more used in different domains: construction engineering, industrial automation, device design, automotive industry, robotics, mechatronics, healthcare and rehabilitation. The fluidic muscles are part of different pneumatic presses, funnel shakers, shear tables, grippers, swivels, cranes, pneumatic brakes, lifting gears, vices, cutting machines, diverters, conveyor belts and others.

Due to the advantages that they offer, the fluidic muscles are researched in order to be implemented in prosthetic and orthotic devices, that help the disabled persons, helping them to move different articulations of the human body.

Despite their relatively simple construction, the fluidic muscles are characterized by a high non-linear behavior, and that is why the obtaining of a certain angular position requires an attentive and thorough control.

1. INTRODUCTION

The fluidic muscles – which are actually some pneumatic artificial muscles, have many common features with the skeleton muscles. Some of these are: lightweight (their weights being of tens of grams); they have reduced sizes (inner diameters which decrease to 5 or even 3 mm); high pulling forces in case of low energy consumption; behavior similar to that of a spring – both due to the air compressibility and to the variation of force due to shifting; shock absorption.

Obviously, the differences between the fluidic muscles and the biological muscles should not be neglected. The latter ones do not change their volume during the contraction; from the point of view of speed they are slow or rapid, being operated according to the demand; they have “built-in” sensors for force and stress.

However a model has been built - the Hill model [2] which approximates quite well the structure and the behavior of the biological muscles.

2. ANTAGONISTIC MUSCLES

Like in case of the skeleton muscles, the pneumatic muscles can only pull, not push. That is why they must operate in pair (agonist - antagonist) like the biological muscles that operate at the level of the human joints.

The static characteristics for the operation of a joint are determined by the muscle geometry and by the connecting element (lever or pulley) - fig.1.

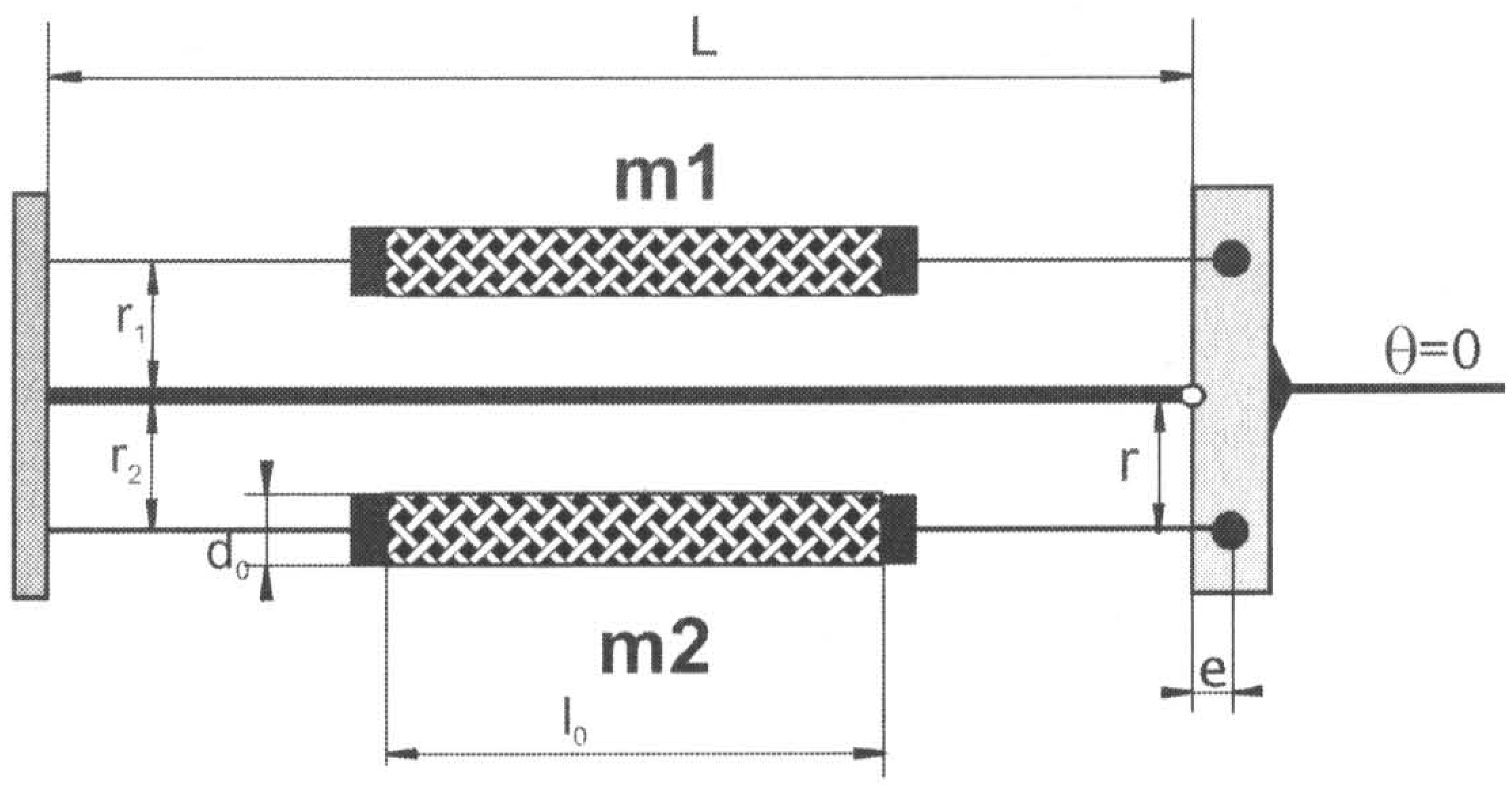

Fig.1 *Mobilization of the joint with antagonist muscles*

As one can see in fig.1, the two muscles are positioned in parallel, being fixed at an end on a stand and at the other end on the connecting element.

The following elements are important: the size of the lever arm *r*, the length l_0 and the diameter d_0 of the muscles in non-activated state, the length of the central pillar *L,* the angular domain of the lever oscillation θ. The position and the stiffness of the joint are determined by the operating pressures of the two muscles. The compressed air activating the muscles, is introduced by a fitting with radial sleeve and situated at the fixed end of the muscle. The distribution and the control of the flow-rate and of the pressure is achieved with pneumatic valves. They can be standard (discrete) [4] or, more suitable, proportional directional control valve. The last ones achieve an adjustment of the pressure at the desired values at the same time with the adjustment of the flow-rate going through them fig. 2.

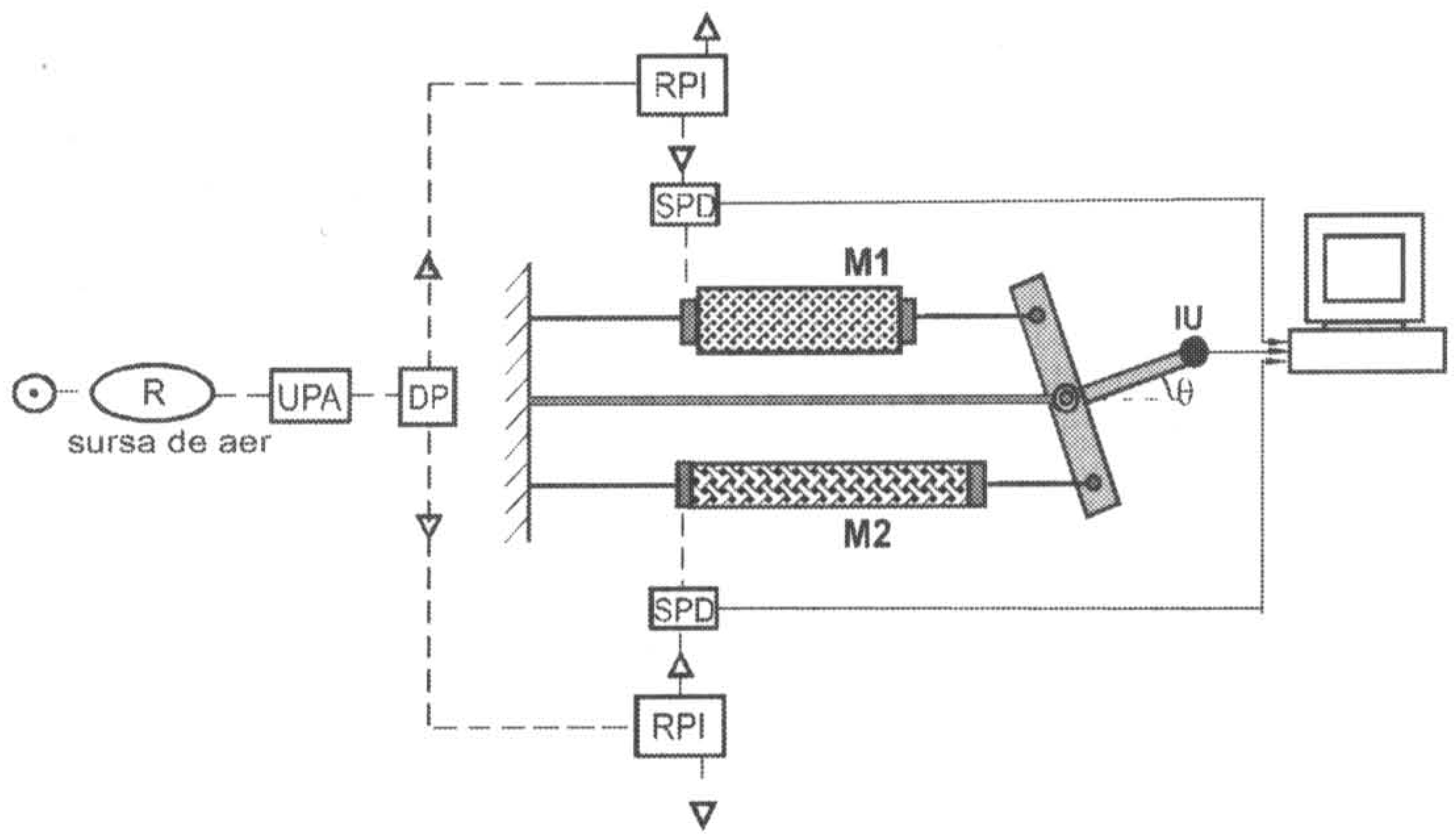

Fig.2 *Diagram of the stand of pneumatic operation of the fluidic muscles.*

3. EXPERIMENTAL STAND

In order to mobilize a lever in rotating movement, two identical fluidic muscles of the type MAS10-200N-AA-MC-K have been chosen, with the sleeves and the adapters supplied by FESTO Co.

Previously several attempts have been made in order to verify the isotonic characteristics of the muscles, by recording the changes suffered by the geometrical parameters (*l, d*) while the operating pressure varies, and for several constant loads fig.3 [1].

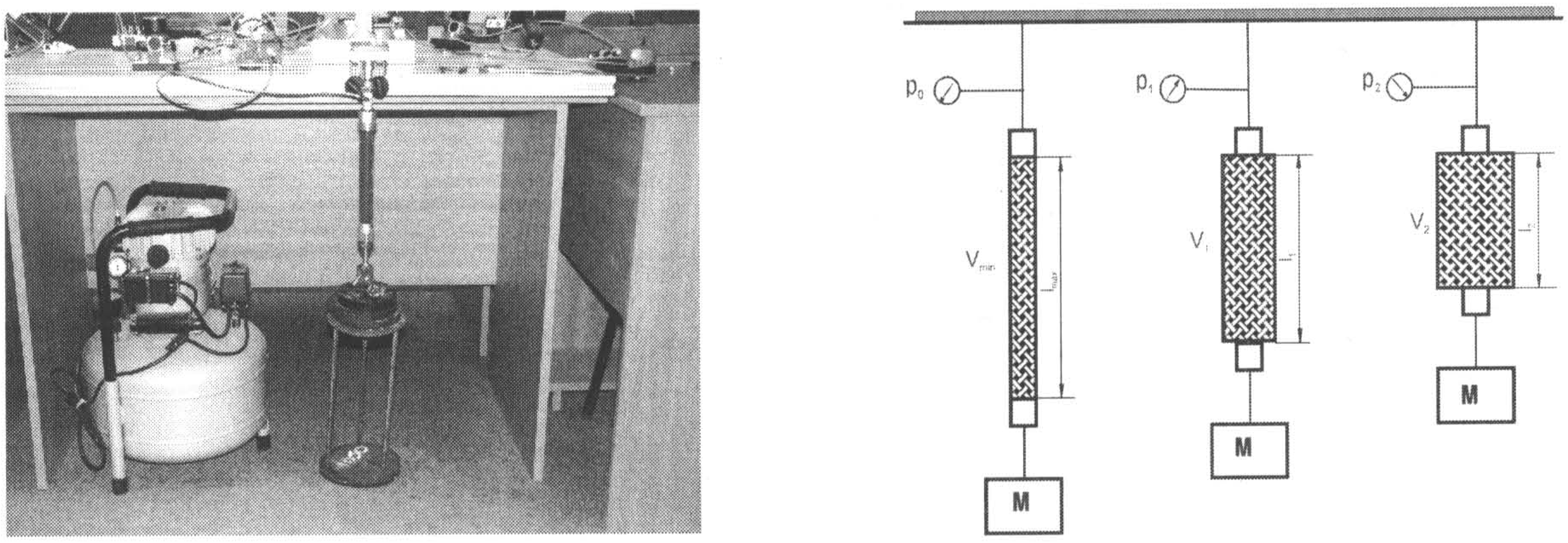

Fig.3 *Loading with constant load of the pneumatic muscle.*

A stand was build following the model from fig.2 by using the pneumatic equipment available in the pneumatics laboratory. The pressure in the muscles has been carried out with two manual pressure controllers and the values of the pressure could be followed at two digital pressure sensors fig.4.

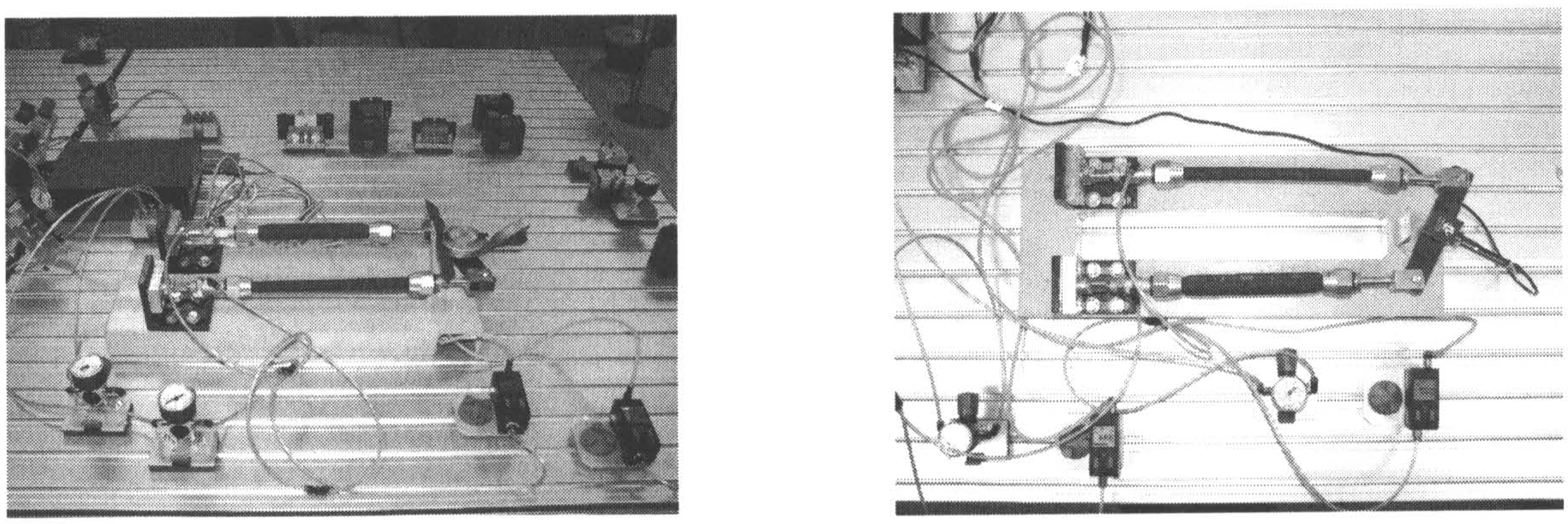

Fig.4 *Experimental stand with two pneumatic muscles and lever*

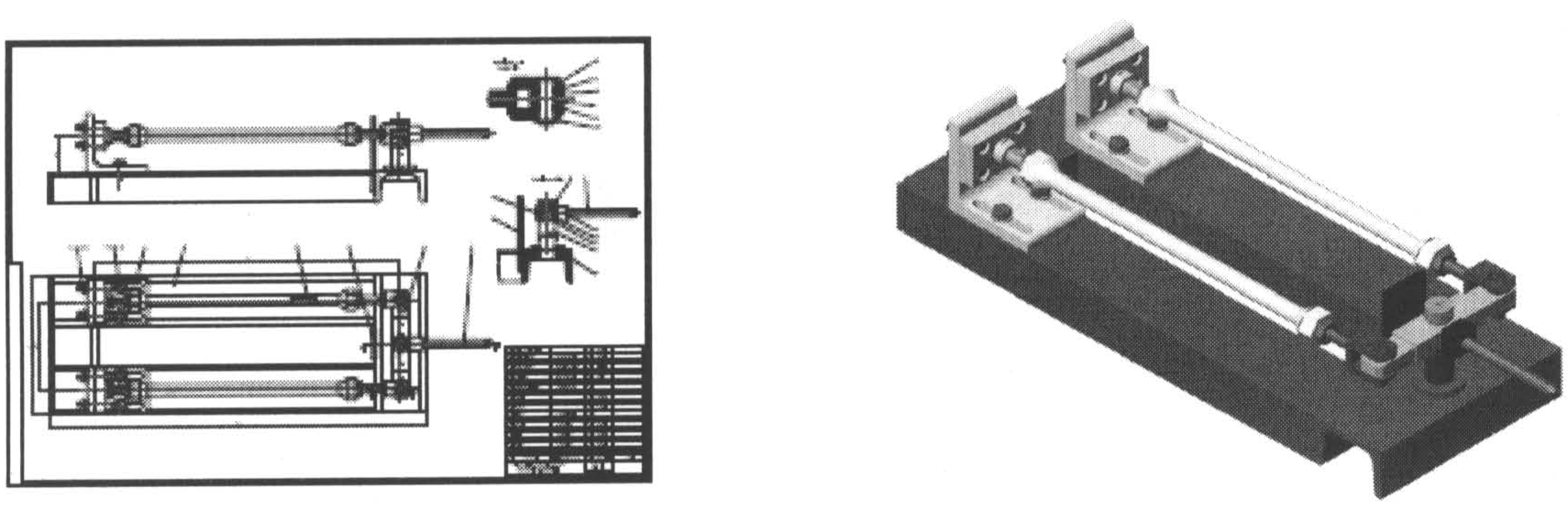

Fig.5 *2D and 3D construction of the experimental stand*

An electronic trecker of type *InterSense InertiaCube3* and a mechanic interpolator with a precision of 5' have been used for recording the angular deviations of the lever. One has also used: an air supply, an air preparatory unit and a voltage source.

4. EXPERIMENTAL DATA

When the pressures p_1 and p_2 are equal, the lever has a neutral position ($\theta=0$). While maintaining the average pressure p_m =ct., pressure "transfers" have been made with increments Δp=0.5 bar between the two muscles, each time recording the angular deviation. The tests have been made while running idle, without applying any external load. Some of the results of the measurements are centralized in Tab.1.

Table 1 *Experimental results*

Nr. crt	i	$p_m=(p_{1,i}+p_{2,i})/2$ [bar]	$\Delta p_i=(p_{1,i}-p_{2,i})/2$ [bar]	$p_{1,i}$ [bar]	$l_{1,i}$ [mm]	$p_{2,i}$ [bar]	$l_{2,i}$ [mm]	θ_i [rad]	k
1.	0	3,5	0	3,5	178	3,5	170	0	0,000
2.	1		0,5	4,0	172	3,0	175	0,084	0,588
3.	2		1	4,5	168	2,5	180	0,167	0,584
4.	3		1,5	5,0	164	2,0	185	0,250	0,583
5.	4		2	5,5	158	1,5	190	0,328	0,574
6.	5		2,5	6,0	154	1,0	194	0,395	0,553
7.	6		3	6,5	152	0,5	197	0,453	0,528
8.	7		3,5	7,0	150	0	200	0,513	0,513
9.	6		3	6,5	150	0,5	197	0,465	0,542
10.	5		2,5	6,0	152	1,0	195	0,431	0,603
11.	4		2	5,5	155	1,5	192	0,367	0,643
12.	3		1,5	5,0	159	2,0	189	0,270	0,630
13.	2		1	4,5	162	2,5	186	0,175	0,612
14.	1		0,5	4,0	167	3,0	182	0,088	0,616
15.	0		0	3,5	172	3,5	178	0,039	0,000

The results have confirmed that, in conditions of balance, (when $\ddot{\theta}=0$) and in absence of an exterior load, the angular position of the lever is determined of the values of the pressures from inside the two muscles: p_1 and p_2 , by a relation like [3]:

$$\theta = k\frac{p_1 - p_2}{p_1 + p_2} \tag{1}$$

where k is a constant of the joint that has been determined by calculus. The small differences recorded can be perfectly explained taking into consideration the availability of adjusting the pressure and the reduced possibilities of initial stress of the muscles.

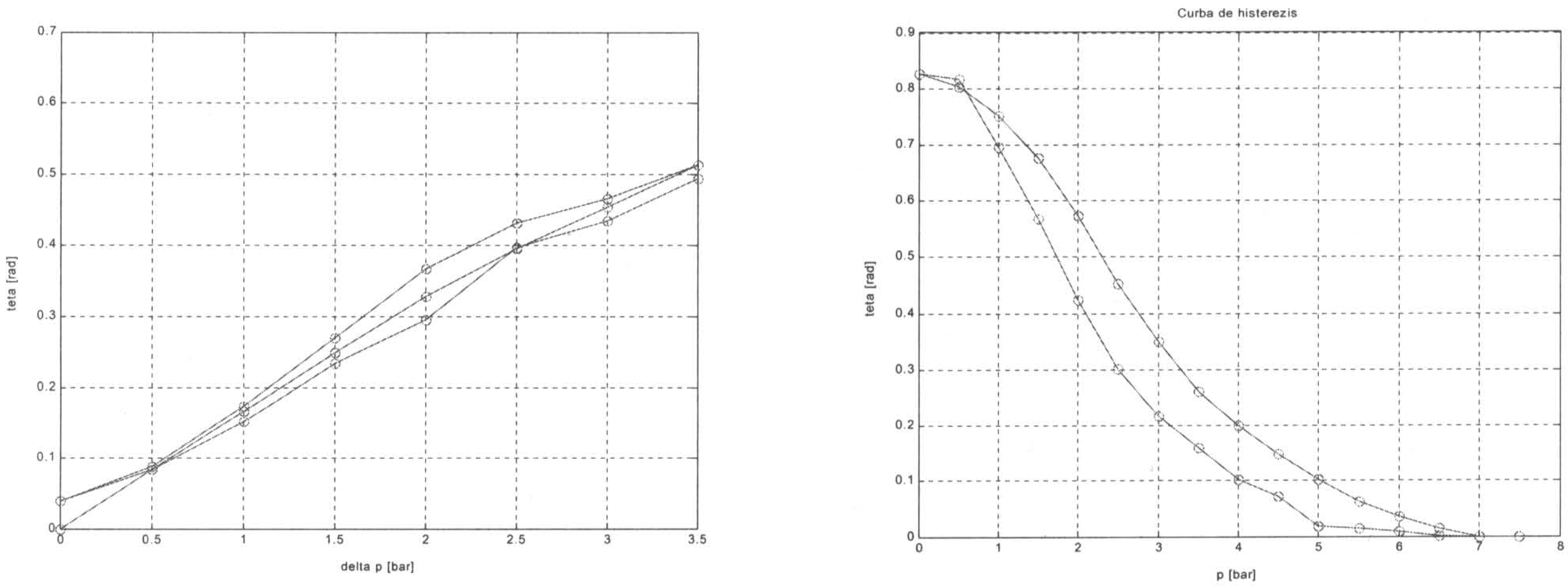

Fig.6 *Plots of rotation angle vs. pressure and difference of pressure*

5. CONCLUSIONS

- A pair of muscles that work antagonistically can be used for the mobilization of a joint in rotation movement.
- The angular position is strictly determined by the values of the pressures p_1 and p_2 from the two muscles as well as by the geometrical characteristics of the connecting element.
- The difference of pressures p_1 - p_2 controls the angular amplitude of the joint while the sum of pressures p_1 + p_2 dictate the stiffness of the articulations in position of balance.

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