Evaluation of Fluidic Muscles for a Walking Machine Driver

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***Abstract* – The paper outlines the research on and choice of pneumatic muscles for setting walking robots in motion. Typical for walking robots is the need for appropriate correlation between weight and performance power. Presented are the results from simulation and experimental investigations of pneumatic muscles developed by the FESTO Company. A choice based on pre-given parameters for the creation of leg prototypes for a 6-leg-robot is made. In order to reduce weight and meet requirements two muscle types are investigated. Shown are the simulation and experimental investigations.**

***Keywords* - walking robots, actors, fluid muscles, mechatronics.**

I. Introduction

Most research works described in the literature and dealing with walking mobile robots use electric motors as drivers. In recent years efforts in the field of designing such robots are focused on achieving a maximal proximity with the biomechanics of living species. In literature, 3 kinds of artificial muscles have been described: electrochemical, fluid [3] and mechanical [4]. Many researches dealing with biologically motivated robots are based on the *Carausius Morosus* (stick insect). Efforts are aimed at a maximal resemblance with the nature's model. Presently the application of fluid muscles provides for achieving elastics similar to that of biological muscles and power matching the one of electric drivers. Further, it allows the setting of a configuration whose geometry and proportions are in conformity with the natural specimen and in favor of achieving a maximum reproduction. These ideas are implied in order to create the model of a walking mobile robot driven by fluid muscles.

II. Model Description

During the model's development and since fluid muscles can generate only one- dimensional forces, for the motioning of one segment were used two muscles, following the principal of antagonism – the force of the concentric contraction (constricting) always opposes the force of the eccentric contraction (extension). While a muscle contracts and rotates the joint, the other expands and thus the necessary position of the segment is settled. The leg-model created in conformity with the above principle is built of three segments (Fig. 1).

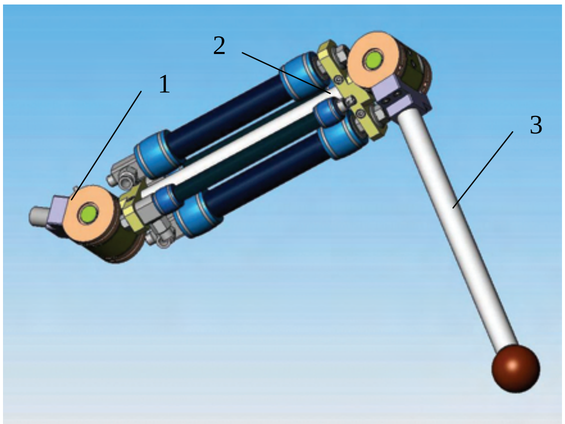

Fig.1 Model leg for a six-legged mobile robot

Based on afore planned weight and geometrical parameters, following parameters are determined: 2 – maximal load = 600N and step S = 13 mm, while for segments 1 and 3 the maximum load = 210N, the step S = 13 mm.

III. Setting the Parameters for the Fluid Muscle

In order to define sizes for the pneumatic muscles, which would satisfy the above mentioned requirements the simulation program developed by FESTO and known as MuscleSim-2.0.1.6. is applied.

The first task of the simulation was to fix a minimal size for the muscle under provision of the necessary load and step. For this it was purposeful to use the following muscle types: DMSP 20 for segment 2 and DMSP 10 for segments 1 and 3.

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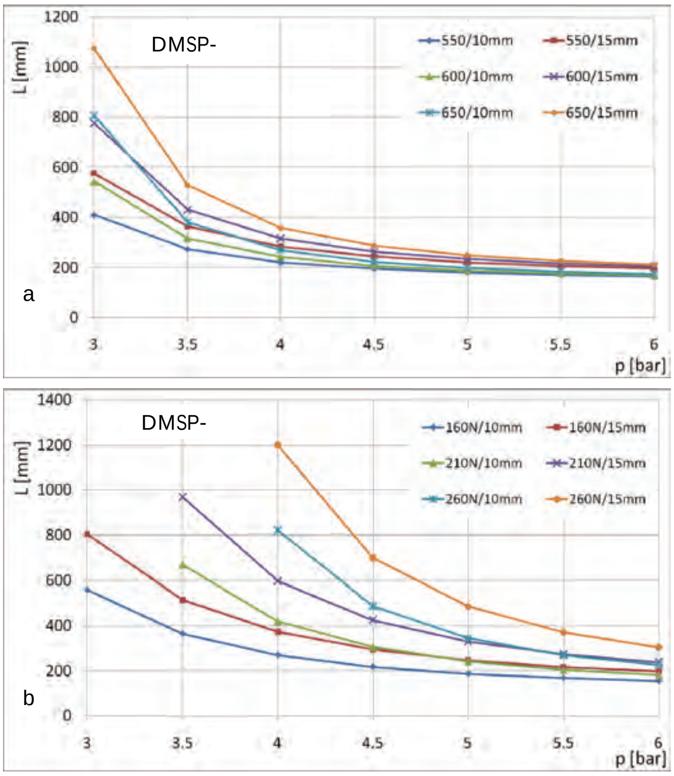

Fig. 2 Simulation results with FESTO –MuscleSim-2.0.1.
a- muscle type DMSP 20, b-muscle type DMSP 10.

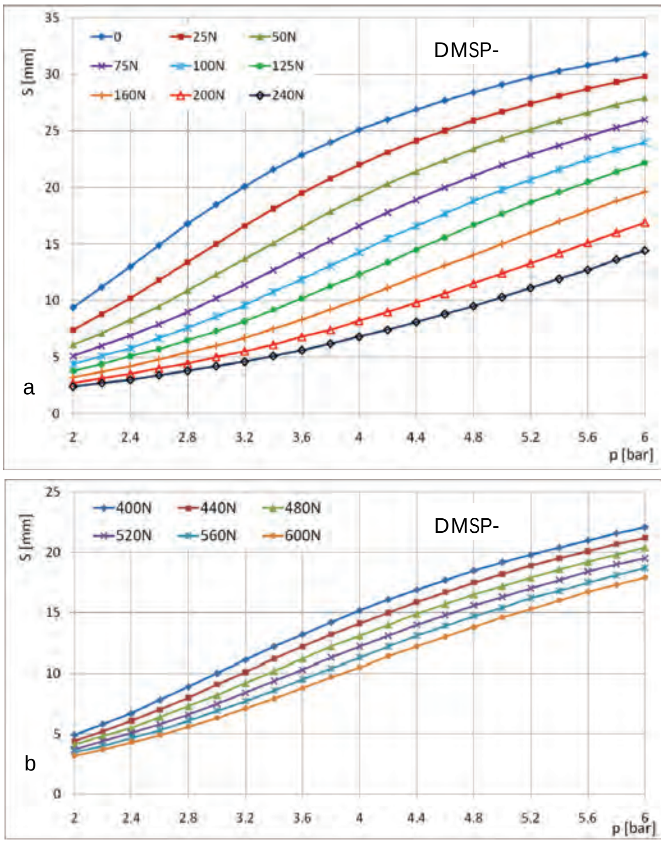

Fig. 3 Simulation results with FESTO –MuscleSim-2.0.1.
a-muscle type DMSP 10, b-muscle type DMSP 20.

The results obtained for both muscle types can be seen on Fig. 2. From the curves describing muscle types DMSP 20 (Fig.2a) and DMSP 10 (Fig. 2b) becomes obvious that in the case of work pressures ranging from 4 to 6 bar the optimal length L is between 200 and 250 mm.

Based on the obtained results and in accordance with the fixed proportion the muscles chosen to bring the three segments in motion have a length L = 210mm.

With the second task a definition of the working range and the motion reserves of the selected muscles aligned with the given loads and pressures were sought. The preformed simulation studied the case of a constantly charged muscle, which functioning mode came at closest to the principle of the antagonistic muscle couple. During research the pressure was set at p = 2…6 bar and loads were in the range from 0 to 240N for muscle DMSP 10 (Fig. 3a) and from 400 to 600N for muscle DMSP 20 (Fig. 3b). The loads for muscle DMSP 10 start at “zero” in order to make a comparison with the experimental research. The resulting graphs prove that the chosen muscles cover the intended step of 13 mm within the zone of working loads and pressures.

Fig. 4 Experimental test-rig

IV. Experimental research

To validate the muscles parameters achieved through simulation an experimental research was conducted. The practical test-rig is shown on Fig. 4.

Object of the experiment was a muscle of the type DMSP10 with a 210mm length, which was functioning under constant load. The research was done both in static and dynamic modes. The static mode in fact repeated the simulation conditions. The background of the experiments granted possibilities for changing the loads in the range 0 to 125N. In the dynamic mode equal loads were applied and provisions for a cyclic contracting of the muscle with a 1Hz frequency were made. The dynamic mode experiment had t o check the carrying out of intended motions in circumstances matching the even pace of a walking robot. The test results in a static mode are shown on Fig. 5 and those in dynamic mode – on Fig. 6.

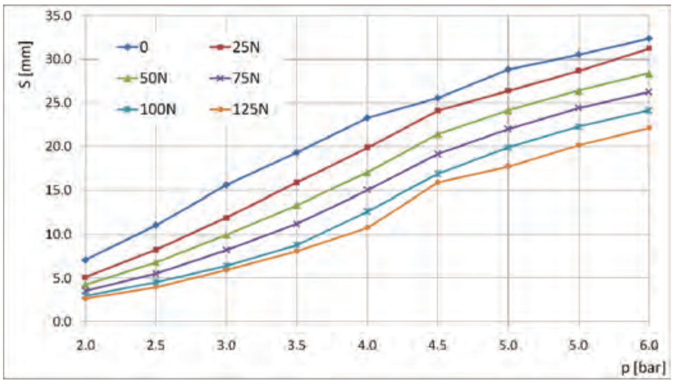

Fig. 5 Experimental results-static mode

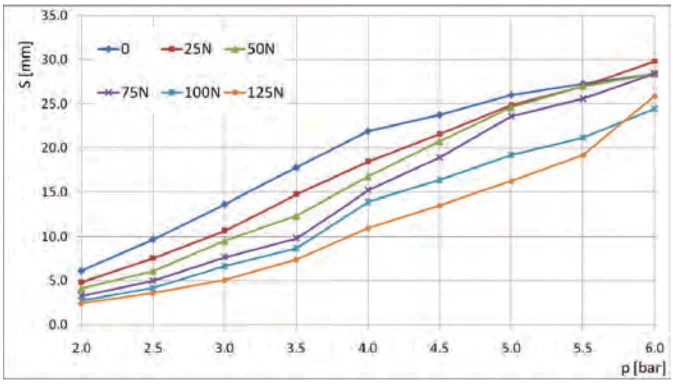

Fig. 6 Experimental results-dynamic mode

CONCLUSION

The paper offers an approach towards the choice of fluidic muscles with predetermined parameters aimed at setting in motion a mobile walking robot. This choice requires the solving of two major problems:

- A preliminary determination of the minimal muscle size with respect to the necessary load and pace – the test provided as a result sizes in the range from 200 mm to 250 mm for both muscle types (DMSP 10 and DMSP 20)
- Definition of the working zone and the motion reserves of muscles with lengths for both muscle types matching the intended loads and pressures.

Both the simulation and tests were done with regard to the specifics of the fluidic muscle's antagonistic function mode. The experimental results confirm the correlation types provided by the simulation with value differences regarded as negligible. The experiment executed in dynamic mode where the fluidic muscle features didn't change significantly give a solid reason to believe that the chosen muscles will be functional in the intended antagonistic operation mode.

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