Proceedings of the International MultiConference of Engineers and Computer Scientists 2011 Vol II,
IMECS 2011, March 16 - 18, 2011, Hong Kong

Pneumatic Muscle Actuated Gripper

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***Abstract*— The paper addresses the theoretical and experimental study of the operational behaviour of a fluidic driving system based on pneumatic muscles. A concrete application of pneumatic muscles is presented, namely two original non-anthropomorphic gripping systems with two jaws and integrated control system, developed by the authors. The presented solutions were selected upon analysis of several possible constructive variants, described in the paper, and represent an optimum as to both overall dimensions and performance. Further the operational performance of the gripper is analysed: response time, positioning precision, influence of various pneumatic components included by the circuit. Modelling and simulation of the dynamic behaviour of the pneumatic muscle are presented, together with the study of the influence of air feed pressure on the behaviour of the developed assembly. By adequate selection of working parameter values the optimum variant of the gripper is obtained.**

***Index Terms*— gripping system, pneumatic muscle**

I. Introduction

A robot is an important handling machine which roughly reproduces the human arm. In order to be effective, it also requires mechanical hands, which are generally referred to as grippers. These are also required on pick-and-place devices and a wide range of other automatic systems. In principle, there are two basic designs of grippers: those designed in the form of fingers and those which do not resemble fingers in any way. Thousands of individual patents can be found, each of which claiming to be able to solve a gripping problem more successfully than previously known. This demonstrates that the gripper has a key role in automatic handling [1].

The role of mechanical hands is to replace the human one. Studies to date have proved that if the gripping capacity of a 5-finger mechanical hand is considered 100%, then the gripping capacity of a 4-finger mechanical hand is of 99%, that of a 3-finger hand of 90% and that of a 2-finger hand, namely of a 2-jaw gripper is only of 40% [2]. The maximum number of motions to be conducted by a gripping system is six, as illustrated in Fig. 1, namely three translations and three rotations (pitch, twist yaw).

Manuscript received January 03, 2011; revised January 18, 2011.

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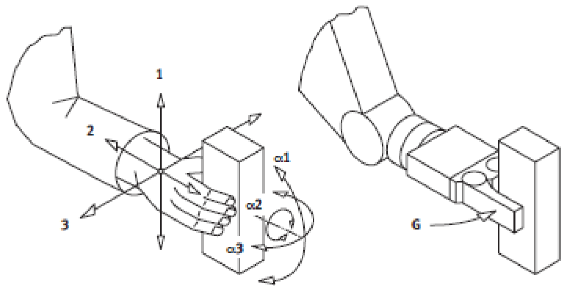

Fig. 1. Motions to be conducted by a gripping system

Several criteria need to be considered in classifying gripping systems. Thus, by the gripping modality of objects, the possible variants are by clamping, by vacuum, by suspension, by adhesion, electromagnetically etc. By the number of gripping points, grippers can achieve singular or multiple contact (anthropomorphic and tentacular grippers). The actuation of a gripping system can be electric, hydraulic, pneumatic or combined. The deployed actuation mechanisms can be articulated, with gears, cams, combined, screw-based, with threads, etc.

The gripper is an important component of a robot, its role being to link the manipulated object to an element of the guiding device. Most robot mounted gripping systems are two-jawed (two-fingered) and are used for both manipulation and assembling tasks. Two-jawed grippers are the most frequently used, due the simplicity of their object gripping configuration and mounting and deploying characteristics.

The gripper achieves its role by clamping, namely it grasps the object by means of mechanical contact forces, unlike other types of gripping systems that can be magnetic, vacuum-based, electro-static, etc.

There are many workpieces which can withstand the necessary gripping force without sustaining damage. But there are other workpieces which are for example polished, thin-walled, soft, brittle or super-finished and which can be damaged during gripping, especially by clamp-type grippers which impose a point loading (Fig. 2.). Point loading is the contact force per unit gripping area which results from clamp gripping. [1].

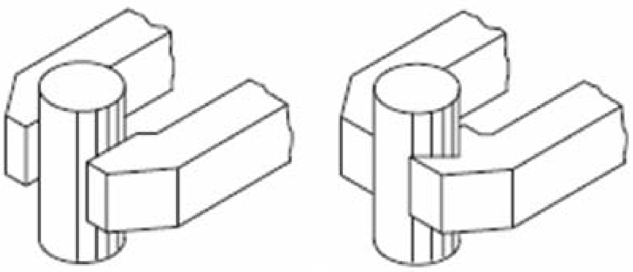

Fig.2. Types of point loading resulting from gripping

In industrial robotics the actuation of gripping mechanisms is achieved mechanically, electrically, hydraulically or pneumatically, by deploying linear or rotating motors. Electrical actuation is ensured by DC motors, step-by-step motors, all rotating, or, less frequently, by AC motors or linear motors. Combined actuation includes: electro-hydrostatic, electro-pneumatic or hydro-pneumatic solutions. For example, pneumo-hydraulic actuation has the advantage of rapid displacement of the driving cinematic elements, combined with safe clamping and a high end-of-stroke gripping force.

In most cases the actuation of gripping systems is ensured by electric motors. Pneumatic drives have been generally avoided because of control and compliance related problems. Over the last years, however, certain advantages of this type of actuation, like the compactness of the driving elements, the favourable power to weight ratio, low costs, easy maintenance, and clean working environment have made pneumatic drives increasingly attractive and have led to their more frequent utilization in robotics.

Recent research conducted at the Transilvania University of Braşov has revealed the advantages of using pneumatic muscles in robotics. An example for such application is presented in this paper, namely a gripping system designed for robot arms.

II. Applications of Pneumatic Muscles

The utilisation of membranes in the structure of pneumatic actuating elements has known a continued development, particularly in the field of industrial robots.

The utilisation of fluidic muscles for various industrial applications is still in its early stages, because of the relative novelty of these components. More recent achievements related to the deployment of fluidic muscles are those of the IAT of Bremen University, the IAI of Karlsruhe University, the Technical University of Berlin, as well as the Transilvania University of Brasov, Romania. Thus a well-known concept is the LeRoS-F developed in cooperation by the IAT Bremen and the IAI Karlsruhe, which involves a modular system consisting of normalised subassemblies and elements. These components facilitate a more rapid assembly and deployment of light, multi-sensor robots. The actuating elements are based on a new principle: each actuating element consists of two plastic sheets welded such as to allow air or liquid feed by a control channel. A number of various technical applications have already been achieved based on this solution, like for example an endoscope system or an artificial hand (Fig. 3) [4], [6], [7].

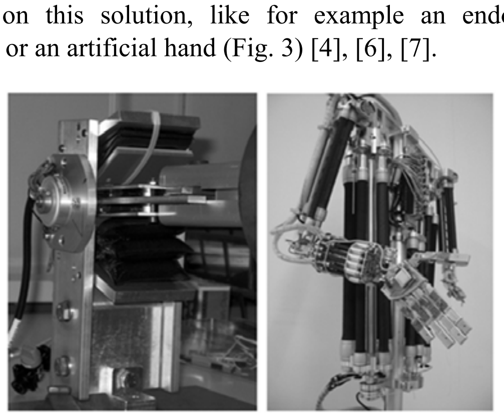

Fig. 3. Examples of applications of fluidic muscles

The Technical University of Berlin has designed and developed a pneumatic muscle actuated humanoid robot called ZAR (Zwei-Arm-Roboter, that is two-arm robots), currently having reached version 5. Fig. 3. shows some representative structures achieved with fluidic muscles.

Currently at the Transilvania University of Braşov research is being carried out concerning the behaviour of pneumatic muscles, resulting in proposed solutions for their utilisation in non-anthropomorphic gripper systems and manipulators to be mounted on wheelchairs for locomotion disabled persons. The paper presents the results of the research as well as one of the possible applications in the construction of non-anthropomorphic grippers.

III. Constructive Variants of Gripping Systems

Below two variants of non-anthropomorphic grippers are presented as applications of pneumatic muscles, designed and developed by the members of the research team. The driving element of the first constructive variant (Fig. 4) is a proportional 5/3 valve. The jaws achieve a linear stroke of 5 mm and develop a 50N force.

It can be noticed that the same casing includes both the actuating elements of the two gripper fingers and the control valve of the pneumatic valve. This yields a light and compact structure, easily placed within a robotised system.

A second constructive solution includes a pneumatic muscle actuating two rotating fingers. While the structure is slightly longer, it is similarly light as the previous one (Fig. 5).

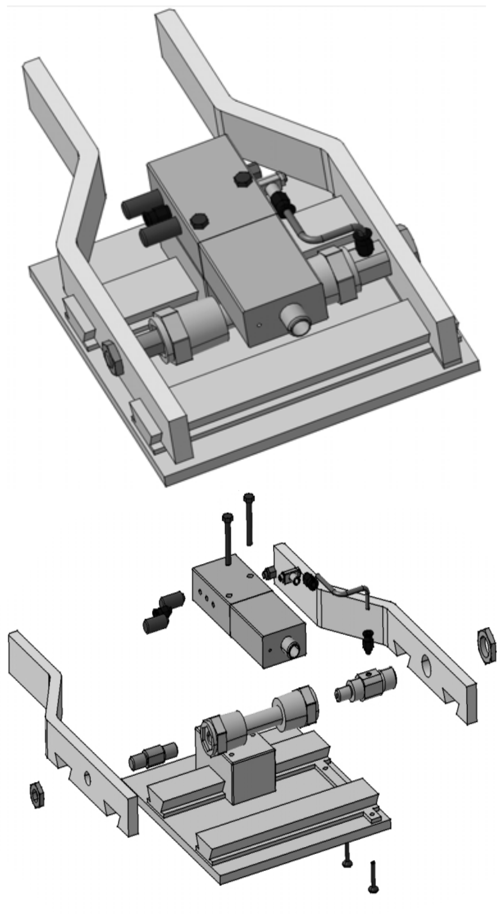

Fig. 4. Constructive variant with a transversally mounted muscle

ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

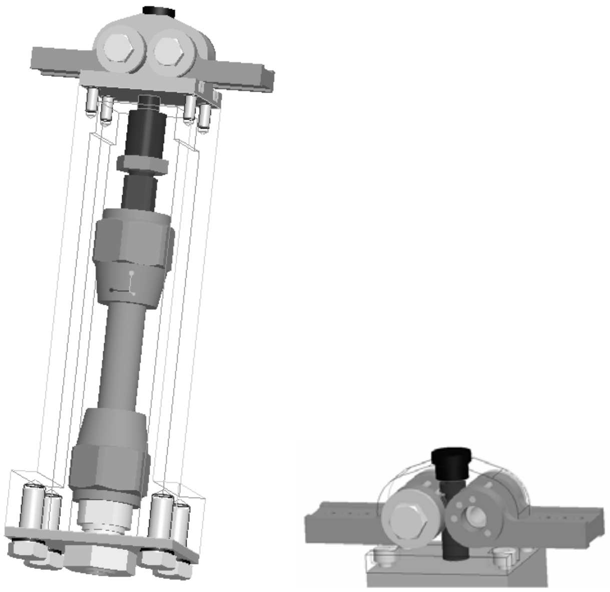

Fig. 5. Constructive variant with rotating fingers

The same type of pneumatic muscle was used for both variants, namely of 10 mm diameter and 40 mm length, manufactured by Festo of Germany. The characteristics of this muscle are presented in Fig. 6.

The dynamic behaviour of the pneumatic muscle can be described by means of the ProPneu programme, developed by Festo. Fig. 7 illustrates the changes in position of the free end of the pneumatic muscle while being fed compressed air, as well as the time related variation of speed and acceleration.

IV. Experimental Research Concerning the Behaviour of Pneumatic Muscles Used for Grippers

Conducted research was aimed at establishing the response times of a pneumatic muscle charged at different pressures. The response times of the pneumatic muscle in inflation and deflation, respectively, are established by analysing the graphs from the Fig. 8.

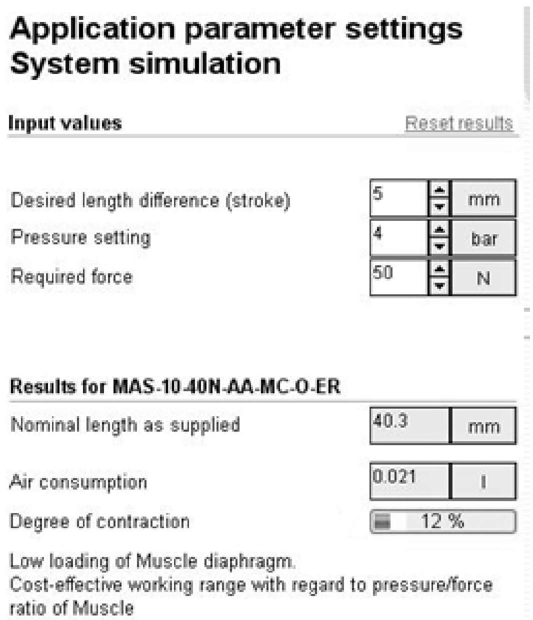

Fig. 6. Characteristics of the utilized pneumatic muscle

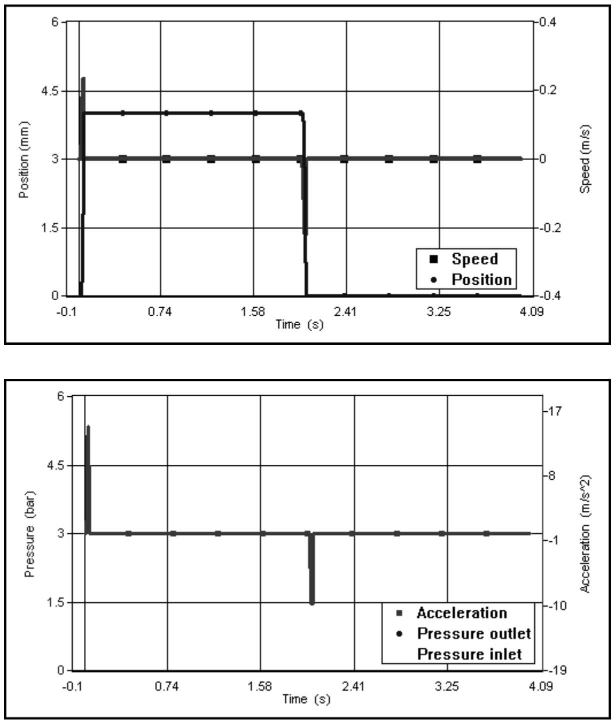

Fig. 7. Characteristic diagrams

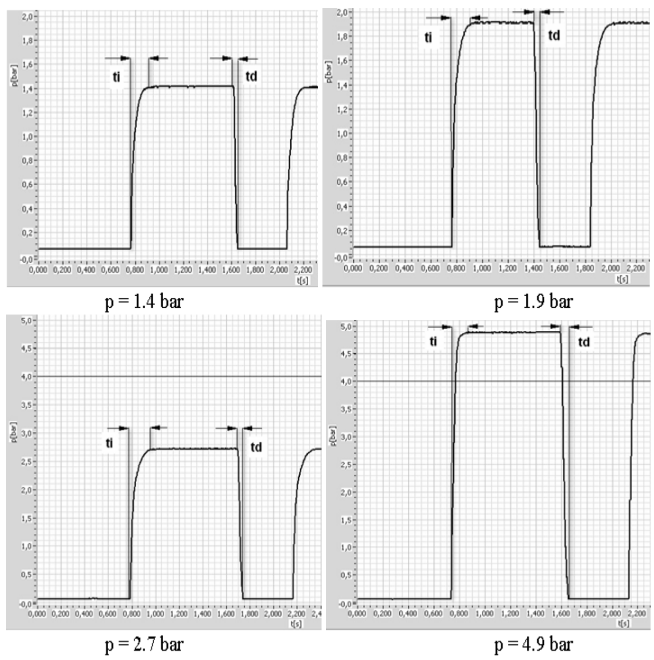

Fig.8. Response times of the pneumatic muscle

Table 1 centralises the measured data of the response times of the pneumatic muscle while inflating and deflating, respectively, and Fig. 9 shows the graph illustrating the variation of these two times vs. the feed pressure.

TABLE 1
VALUES OF THE INFLATION/DEFLATION TIMES FOR THE TESTED MUSCLE

Working pressure [bar]	Inflation time [s]	Deflation time [s]
4,9	0,134	0,068
2,7	0,173	0,050
1,9	0,176	0,047
1,4	0,176	0,042

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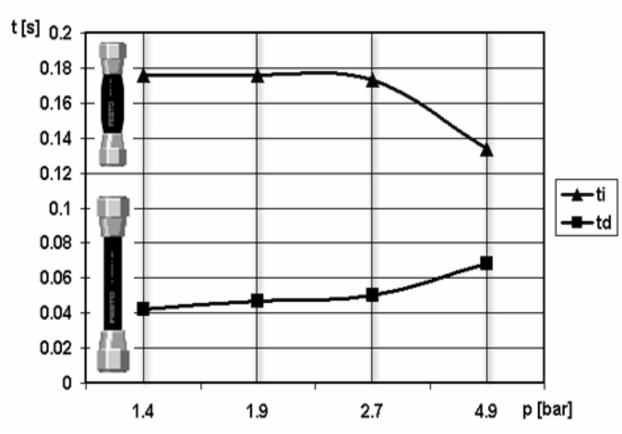

Fig. 9. Variation of the inflation/deflation times for the tested muscle

As can be noticed, the sum of the inflation-deflation time of a pneumatic muscle is of about 0.2 seconds, hence the conclusion that these actuating elements can be used at a maximum frequency of 5 cycles per second (5 Hz).

V. Conclusion

The utilisation of pneumatic muscles for the actuation of mechanical systems knows an increasingly larger development in industry. In this context in-depth research concerning the performances and behaviour of pneumatic muscle is called for.

In addition to the analysis of the main variants of gripping systems used in industrial robotics, the paper presents a series of constructive solutions of gripping systems with jaws, actuated by pneumatic muscles. Further experimental results obtained by the testing of the gripping systems were presented, with an emphasis on the inflation/deflation times of the pneumatic muscle that yielded data concerning their maximum achievable utilisation frequency.

Two constructive solutions of non-anthropomorphic grippers were presented, their main advantages being their small weight and easily adaptable manipulation systems.

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ISBN: 978-988-19251-2-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)