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# THREE BELLOWS ACTUATION SYSTEM

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***Abstract:*** *In this paper, an actuation system whose operation is based on three bellows is introduced. After a brief presentation of the principle that underlies the conversion of pneumatic energy into controllable motion, through bellows, some representative examples of similar actuation systems are analyzed. An original experimental stand have been designed and tested. It is composed of a compressor and three servo-valves ensuring controlled pressures for three parallel bellows. The system can reach up to three degrees of freedom and is controlled by a PC through an interface.*
***Key words:*** *Bellows, actuators, pneumatic.*

## 1. INTRODUCTION

The actuators are components of mechatronics systems that can transform an input energy (electric, magnetic, thermal, chemical, pneumatic, and hydraulic) into a mechanical work [7]. They are based on well known physical and chemical phenomena to convert some form of energy into controllable motion as a response to control signals [1].

Linear actuators rely on mechanical interaction and are represented by cylinders and membranes. In addition, a new category is represented by linear or rotary actuators with flexible deformable elements – category that fits bellows actuators, too. In time many actuators based on elastic elements have been developed for various applications starting from paper and cellulose industries, oil extraction to biochemistry, biotechnologies, micro-sensors, machine building, aerospace, etc.

Bellows, called also corrugated tubular elements, are thin-walled shells of revolution, curled across the lateral surface deforming elastic under axial loads and accumulating mechanical energy. They can be used for sealing, pressure measurement or controllable motion [4].

This paper aims to design and develop an operated bellows actuators platform with three degree of freedom (DOF) with different options of corrugated items, and study of the state of tension and strain in corrugated tubes subjected to various tests, the final scope being to establish a precise method of motion control.

In case of bellows which are used as pressure transducers, the most important problems which arise are: manufacturing process, determining the relationship between the pressure inside the bellows and its free end displacement and the axial load in the tube walls [3].

## 2. ANALYSIS OF BELLOWS BASED ACTUATORS

In general, selection for bellows actuators construction based on metal corrugated tube is based on functional parameters, the environment, aesthetics and the economics aspects.

A few classical applications of bellows actuators that have different functions, various geometric shapes and sized are shown in fig. 1 where are presented some specimens of mechatronics actuators with different forms of energy converted into controlled motion in reply to a signal.

Bellows are sealed rooms embossed so that the pressure within the tube will be forced into a tendency to extend the tube which can be

configured and controlled with success in various poses.

For all types of actuators presented in the figure below [1], [5], [6], [7], [8] [9], and [10], the principle of operation is similar, only the structure and role of the components being different. Therefore, in fig. 1 a) is given a surgical tool who makes navigation within the body and to eliminate some unwanted tissue without affecting other tissues even when they are connected to each other.

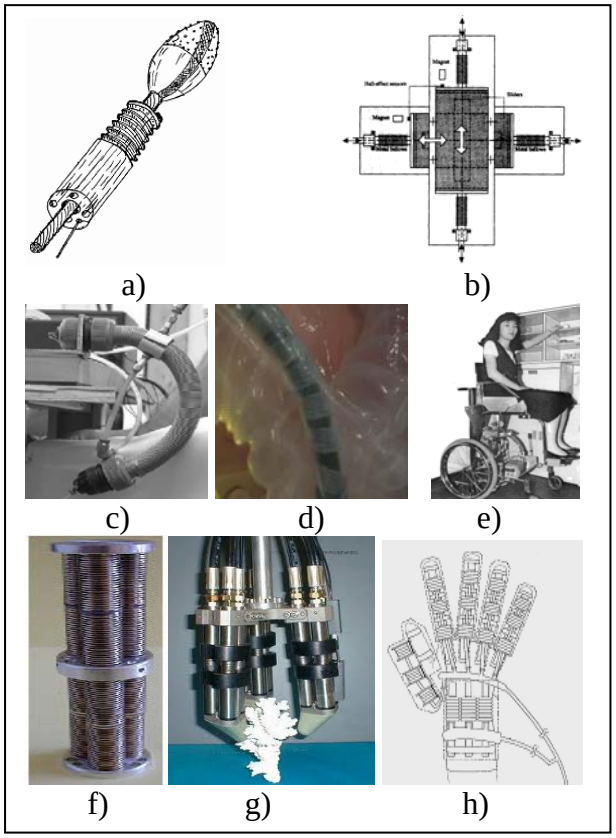


**Fig.1.** Examples of different bellows actuators

Another example of the movement generated by bellows deformation under the action of air pressure is that of fig. 1 b). Here is created a high precision device with two degrees of freedom (DOF) composed by combinations of metal bellows that can create axial, lateral and angular movements, also it can perform small fast and precise movements.

In fig. 1 c) is a manipulator of two balloons located in the middle of an elastomeric tube closed at both ends, separated by a sheet of steel, but attached at one of its ends and free at the other end. When one of the balloons is inflated, it will start to expand generating a force on the inside of the tube creating a bending moment of the device, and the piece of steel will take the form of the inflated tube wall.

A guiding mechanism in form of an endoscope used for inspecting the bowels is shown in fig. 1 d). Because the prototype is used in closed loop, will establish instability of the system and for increasing damping is added a rubber tube around the bellow. The new structure will have new reactions that is no longer oscillates and needs a higher pressure to have the same angle of the bending tube.

At corrugated tubes based on a metal hydrides presented in fig. 1 e), the active elements components are alloys with hydrogen absorbing which by heating increases pressure equilibrium of hydrogen, which is released. For high speeds by heating – cooling, these processes are performed by using Peltier elements. These actuators are used for rehabilitation robotics, equipment for patients transferring or medical elevators.

Pneumatic flexible configuration of a sphere is shown in fig. 1 f). It consists of three bellows arranged at an angle of $120^0$, the air being introduced independently in each tube, rotation of the sphere being carried out in the direction in which the pressure is lower.

Fig. 1 g) is represented by a clamping device that produce moments with a bending elastic arms located in parallel which together form the peaks of an equilateral triangle. It acts like a gripper and he can grab objects from different environments.

The fig. 1 h) represents the model of an orthesis, manufactured from several bellows which is used in medical recovery or replacement of a physiotherapist with exercises for joints of the fingers and wrist.

Because the bellows can be arranged in series and in parallel and at different angles, some assembly can be controlled by an infinite number of configurations and in different forms, each joint being controlled separately or in antagonist mode.

The advantages of the bellows are that there are no mechanical transmissions; the positioned element can be controlled in any direction with any speed, bellows are resistant against buckling and produce silent movements, with less vibration or shocks.

## 3. EXPERIMENTAL RESEARCH OF THE BELLOWS ACTUATION SYSTEM

### 3.1. Structure of the experimental stand

The mobile platform is actuated by three corrugated tubes disposed at $120^0$ as shown in fig. 2. Outer diameter of the bellows is 12.7 mm, inner diameter is 9.1 mm, natural length is 19 mm and wall thickness is 0.064 mm. It has 23 convolutions and is made from electrodeposited nickel alloy. These are controlled by three proportional pressure regulators, a compressor, an interface and a PC.

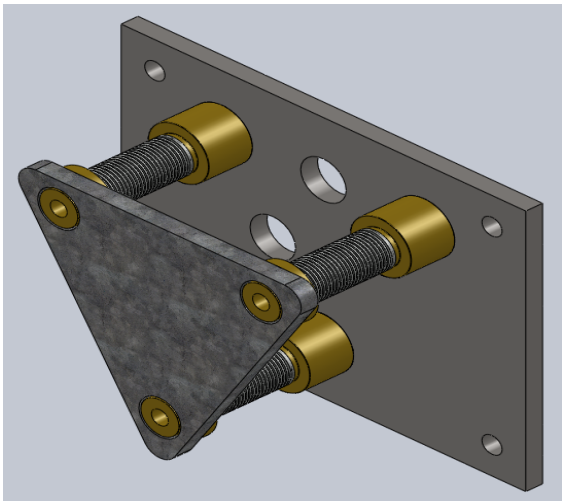

**Fig. 2.** Driven platform by three bellows

### 3.2. The functional scheme

First step is to prepare the entire installation as shown in fig. 3. A PC connects the interface to control the servo-valves. A compressor will feed into the three servo-valves by an intermediate element called pressure regulator to control the maximum pressure within the servo-valve. Bellows will be powered by means of hoses.

### 3.3. Control of the system

High-precision control of bellows is made using servo-valves connected to the compressor and controlled with the help of the PC through an interface. A great advantage of this interface is to use the various signals that you can implement the servo-valves such as sinusoidal signals form, rectangular, triangular or even a signal drawn by us.

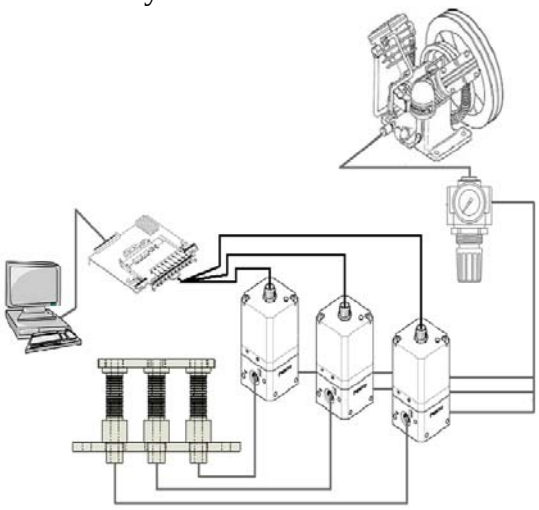

**Fig. 3.** The structure of the bellows actuation system

### 3.4. Simulation results

Our experiment begins by attaching the first bellow of the holster and controlling. That will perform the move only on the direction of the longitudinal axis, one of its ends being free. The next step involves a second bellow on the holster and shareholders of them in parallel, both being connected to each other with a metal plate. On the bellows was implemented a sinusoidal signal shifted with $180^0$ one toward each other, therefore the whole structure moves after a sinusoidal curve. The last phase is based on studying a complex structure with three bellows part controlling a triangular flange, as shown in fig. 2. After tests, it was observed that the results are very close in value, scope referring only to the sinusoidal signal. In fig 4 it can be observed the different parameters of the input systems and shifted sinusoidal signals for each bellow separately.

## 4. CONCLUSIONS, FUTURE WORK

The conclusions set out below will highlight the advantages and disadvantages of using bellows in mechatronics and other fields such as biomedical engineering and robotics. There are a large number of applications in which can be used corrugated tubes because they are very flexible, allow the extent of bending, turning or compression or even the combination of these movements. Another aspect is the diversity of

the number and the configurations of bellows which can be used, and also their use in parallel way as well in the antagonist way.

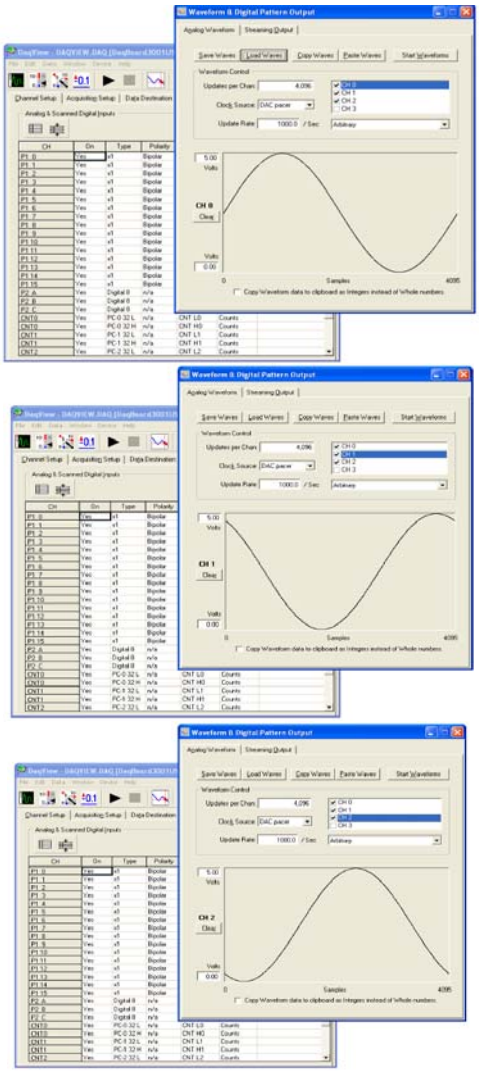

**Fig. 4.** The variation of the input signal

Concerning the developed platform, the bellows can be controlled very silent at pressures up to 10bar, and be racing up to 60mm. In the future we plan comparative analytical – numerical - experimental studies useful in design process of the actuation systems based on bellows.

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**Sistem de acţionare pe bază de trei silfoane**


*În această lucrare este introdus un sistem de acţionare a cărui principiu de operare este bazat pe trei silfoane. După o scurtă prezentare a principiului care stă la baza conversiei energiei pneumatice în mişcare controlată prin intermediul silfoanelor, sunt analizate câteva exemple reprezentative de actuatori similari. A fost proiectat şi testat un stand experimental original. Acesta este compus dintr-un compresor şi trei servo-valve care asigură controlul presiunii pentru cele trei silfoane dispuse în paralel. Sistemul are trei grade de libertate şi este controlat de un PC prin intermediul unei interfeţe.*



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