Journal of Mechatronics, Automation and Identification Technology
Vol. 2, No.3. pp. 10 – 14

Control and Testing of a New Soft Pneumatic Gripper with Optimised Design for Soft Robotics

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***Abstract*— The paper describes the design, control and testing of a new soft pneumatic gripper. As soft pneumatic actuators are an essential component of soft robotic systems it's important to develop a process cheaper and easy to produce. The developed gripper is made out of soft, stretchable silicon that is powered by air. Silicones are used in numerous engineering applications; in this case it extends under input pressure. Thus offering intrinsic advantages: robustness to uncertainty, easiness for manipulating a wider range of objects, easiness interactions with objects from static environment. Pressure is measured with the help of MPX4250AP pressure sensor. Results obtained present the feasibility and reliability of the proposed mechatronic system in actuating and controlling the silicone based soft pneumatic gripper to realize and conduct bending and grasping motions. During the research, it were obtained the qualitative measurements of the bending distance and pressure. The proposed electronic design is made to be low-cost, easy to replicate and can be integrated easily in any specific soft robotic system which requires pneumatic driving.**

***Keywords*— soft robotics; finger; mechatronics; control; design; actuators**

I. INTRODUCTION

Soft pneumatic actuators are an essential component of soft robotic systems [1][4][5]. Because, they are made of silicone the soft robotic grippers can resist to certain kinds of damage, such as physical impact or severe bending much better than their counterparts made from hard robotic structures (with about the same weight and size). Another contribution of the paper is the proposed, compact, low-cost, and easy to fabricate the manufacturing system and the associated control hardware for the actuation and control of the soft pneumatic gripper. It contains an Arduino board, relays, MPX4250AP pressure sensor, flex sensor which bends and flexes physically with motion device, electro-pneumatic valve, pressure valves, power supply, and pressure gauges.

The proposed system offers easiness of fabrication, low cost which provides an alternative to the expensive existing off-the-shell electro-pneumatic regulators available on the market. During the research, it were obtained the qualitative measurements of the bending distance and pressure.

The proposed silicone based soft robotic gripper can be highly customized, it's light-weight, and most of all inherent safety for numerous human interaction uses.

The proposed electronic design is made to be low-cost, easy to replicate and can be integrated easily in any specific soft robotic system which requires pneumatic driving. The second part presents the design of the new pneumatic soft robotic gripper. The third part presents the preparation and manufacturing part of the silicone rubber and fabrication details for the soft robotic gripper. The last part presents the testing details and control of the proposed soft robotic gripper.

II. DESIGN OBJECTIVES OF A NEW PNEUMATIC SOFT GRIPPER

In this section it will be discussed the objective design goals with respect to the design of the gripper and the manufacturing methods developed for construction of the new pneumatic soft gripper (See Fig. 1).

This paper is selected from the 4th International Conference and Workshop Mechatronics in Practice and Education, MECHEDU 2017, Subotica, 4-5. May. 2017.

Fig. 1. Proposed silicone based soft robotic gripper

A. *Setting the objective design goals*

It was designed the new pneumatic soft gripper taking into account the next following key objectives in consideration:

- Easiness to manufacturing and cheaper process to fabrication;
- Low-cost solution for control and interface with the existing hardware;
- Ability to grasp a wide range of objects (with focus on agriculture products).

For this it was developed and designed a gripper which consists in 4 individual soft fingers that can be inserted onto a pneumatic interface. The fingers are using the same identical design, thus offering a modularity interface for existing hardware, being easy to swap the fingers in a variety of configurations (2 finger design, 3 finger design, etc..). This is important for permitting faster manufacturing and possibility of more design iterations.

When designing each of the soft finger, it was taken into account:

- making a design in order to assure a constant curvature bending when not loaded;
- assuring a partially constant curvature bending when loaded;
- compliant and soft, to be made of silicone rubber.

The usage of air actuation was due to the most inherent advantages: it can provide fast inflation of the pneumatic finger (pressurized air provides low viscosity and moves fast), it's easy to control and measure it using pressure regulators and sensors and it's light in weight.

The factors like pre-grasp position, and object shape can influence and affect grasping. Having proposed this compliant gripper, grasp failure is less likely to occur with this design.

III. PREPARATION OF THE SILICONE RUBBER

The ZA22 MOULD is a brand of silicone rubber used for molding which is made by ZHERMACK INDUSTRIAL (Italy). The silicone comes under the form of two bottles, containing Part A and Part B. Both parts, Part A and B are liquids and when mixing together they form silicone rubber and solidify (about 2-3 hours at room temperature).

According to the producer safety manual, the materials are non-toxic. However, it should be avoided repeated or prolonged exposure to the unmixed materials because they can cause irritation for skin.

When the two parts were combined, it was needed to evenly mix and to stir forcefully to break up the beads. The material is very viscous so it had to flow slowly (see Fig. 4). The silicone rubber are capable of working in environments with the temperature having a wider range, additionally they are also water resistance.

Fig. 2. Preparation of the silicone rubber mixture (Part A and Part B)

Fig. 3. Preparation of the silicone rubber finger, adding the reinforcement mesh

Fig. 4. Obtained silicone based soft finger

After 4 hours at room temperature it became solid. The actuator is made of silicone rubber and forms a closed air chamber that inflates when air is started.

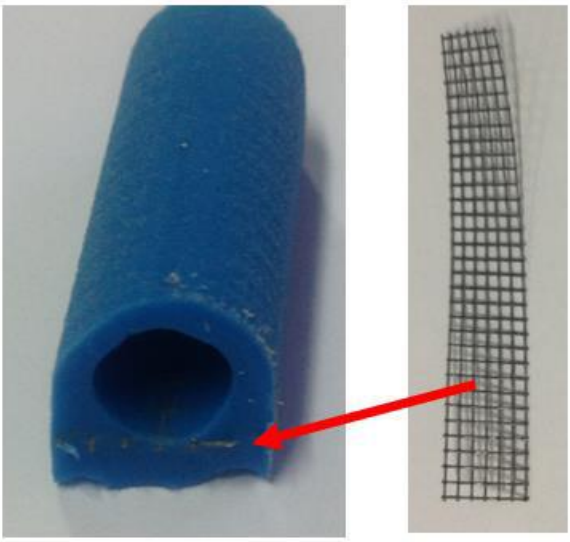

Fig. 5. Cross-section of the silicone rubber soft finger, it can be noticed the reinforcement mesh

IV. TESTING OF THE SILICONE RUBBER

A. *Flex sensor data*

In the next table are presented the main features of the flex sensor, both electrical and mechanical specifications [2].

TABLE I Electrical and mechanical specifications

Electrical Specifications
-Flat Resistance: 25K Ohms
-Resistance Tolerance: ±30%
-Bend Resistance Range: 45K to 125K Ohms (depending on bend radius)
-Power Rating: 0.50 Watts continuous. 1 Watt Peak
Mechanical Specifications
-Life Cycle: >1 million
-Height: 0.43mm (0.017")
-Temperature Range: -35°C to +80°C

In the next figure it's presented the principle of working for the flex sensor (see Fig. 6).

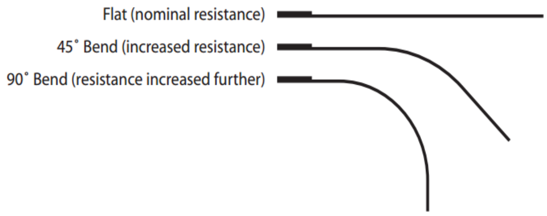

Fig. 6. How it works principle for flex sensor [22]

Fig. 7. Flex sensor used for the test soft robotic finger

B. *Pressure sensor*

The MPX4250A series piezoresistive transducer is a stateof- the-art monolithic silicon pressure sensor designed for a wide range of applications, particularly for the one which uses a microcontroller or microprocessor with A/D inputs [3].

Fig. 8. Pressure sensor MPX4250AP

Features:

- 1.5% Maximum Error Over 0° to 85°C
- Specifically Designed for Intake Manifold Absolute
- Pressure Sensing in Engine Control Systems
- Patented Silicon Shear Stress Strain Gauge
- Temperature Compensated Over -40° to +125°C

- Offers Reduction in Weight and Volume Compared to Existing Hybrid Modules
- Durable Epoxy Unibody Element or Thermoplastic Small Outline, Surface Mount Package

C. *Control*

Control of the movement of the soft gripper is another important parameter that characterize performance. The soft finger follows a quasi linear relationship between bending motion and pressure [6].

The aim in this section is to determine and measure the degree of bending of the soft finger by monitoring its pressure. The objective is to get a method to allow predicting the movement and bending by monitoring its pressure. Control in the context of this paper, we use open loop control for the soft robotic grippe. An external compressor supplies pressurized air and industrial grade solenoid valves attached to the supply tubing control inflation and deflation of the soft robotic gripper. The control system was used to run back scripted sequences of valve actuations (MATLAB interface with ARDUINO). Fig. 9 presents the correlation between pressure and bending for 3 cycles (inflation/deflation) of the soft robotics finger.

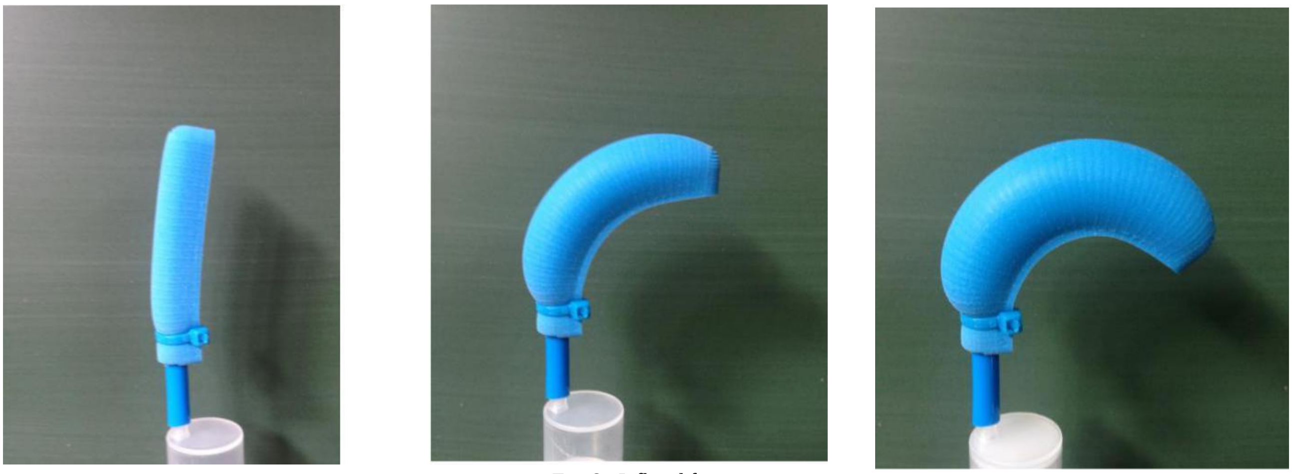

Fig. 8. Inflated finger

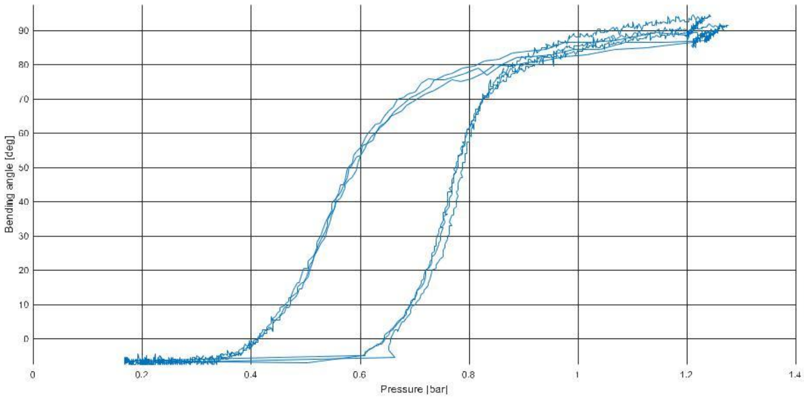

Fig. 9. Correlation between pressure and bending for 3 cycles of the soft robotics finger

Fig. 10. Testbed setup

CONCLUSION

The work presents a fast prototyping and development process for soft robotics pneumatic gripper with an approach based on very simple control using open-source electronic prototyping platform (Arduino board). We believe that this novel way of manufacturing soft robotic grippers can lead to simple, low-cost, effective end-effectors for robotic grasping manipulation. Handling fragile objects process — like fruits, which is difficult for conventional hard robot grippers can be improved and replaced with the new proposed soft robotic gripper.

ACKNOWLEDGMENT

The work received hardware support during developing and testing phases from the company SC JVD CompAir SRL.

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