Artificial Muscle Construction Using Natural Rubber Latex in Thailand

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***Abstract*— This artificial muscle, also known as McKibben artificial muscle, is a pneumatic actuator which gives high force to weight ratio. The artificial muscle consists of the inner rubber tube, made from natural rubber latex in Thailand, and the braided outer sleeve. In this work, we studied the effects of change of diameter in artificial muscle, therefore three different diameters 15 mm, 20 mm, and 30 mm are made. All of them have the same length of 140 mm. The experiment was set up to collect the displacement data of the artificial muscle with various compressed air pressure. The results show that the 20 and 30 mm diameter of artificial muscles have similar tensile force but varied in percent of contraction. The movement of artificial muscle is soft which is similar to the human muscles therefore its application can be used as the actuator for the prosthetic appliances. The artificial muscles are then tested for driving the arm prostheses.**

I. Introduction

Thailand has been one of the worldwide exporting of natural rubber latex, however, its value of export is very minimal. This work try to make it worthwhile by using it as the artificial muscles. Pneumatic technology is capable of soft interactions and compliance [1]. The braided pneumatic actuator was invented by McKibben to help the movement of polio patients in 1950s. They are also called McKibben muscles or artificial muscles powerd by the compressed air [2], [3], [4], [5], [6]. Many researchers have improved this artificial muscles, for example, reinforcing with kevlar fiber [7], improving the characteristics of the muscles [8]. In recent studies, Klute has constructed lower limb protheses using artificial muscles to help patients to walk [9]. For the upper limb, people who have had high-level arm amputations have very limited manipulation abilities compared to people who have had lower level arm amputations. As a result, these people have difficulty in living without the help of prostheses [10].

II. Experimental Setup

A. Test Pieces

The artificial muscle consists of the inner rubber tube where the natural rubber latex through the valcanizing process has been used as shown in Figure 1. The rubber tube was made by dipping the mould into the rubber latex and dry at room temperature which is around 32 degree celsius in Thailand.

Fig. 1. **Rubber Tube**

The outer shell is the braided sleeve. The assembly of the artificial muscle is shown in Figure 2 where one side is the air inlet and the other side is the closed end. In this experiment, three different sizes in diameter of 15 mm, 20 mm, and 30 mm with the same length of 140 mm have been tested. The artificial muscle weighs about 200 gram.

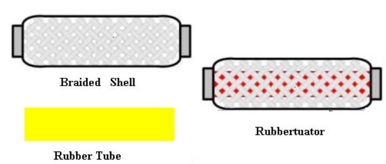

Fig. 2. **rubbertuator**

B. Test Platform

The test platform was designed to measure the lateral displacement when inflated. The tensile forces are calculated from the spring displacement where the spring constant is known. The components of the test platform are the spring which is fixed to the base, the cable connected from the end of the artificial muscle to the force sensor. The position encoder measured the displacement of the artificial muscle when inflated. The other end of the artificial muscle was the compressed air inlet. The set up is shown in Fig 3.

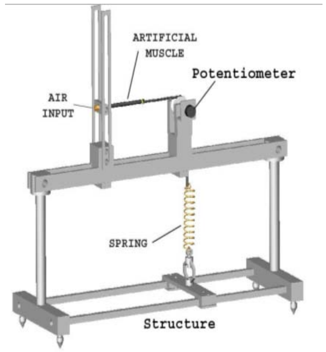

Fig. 3. **Tensile Test Platform**

To obtain the data, the control box was built with LTC1298 to convert analog to digital signal and LTC1661 to convert digital to analog signal. The computer interface was connected via parallel port to the computer shown in Figure 4. The computer sent the signal to the control unit then sent the voltage supply 0-10 volts to the pressure regulator valve which can vary the air pressure from 0-7 bar in corresponding to the voltage supply.

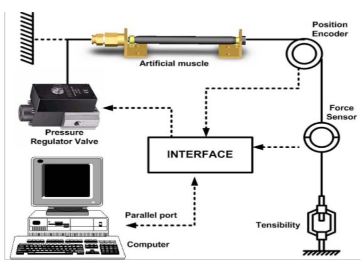

Fig. 4. **Computer Interface**

This experiment was done on the pressure of 1, 2, 3, and 4 bar. Because the artificial muscle will be broken when the compressed air pressure is high, we therefore inflated the artificial muscle at the maximum pressure of 4 bar.

The pneumatic diagram shows the artificial muscle connected via the 3/2 way pneumatic valve by FESTO is shown in Figure 5. The artificial muscle functions like the single acting pneumatic cylinder where the same port of the compressed air in and out.

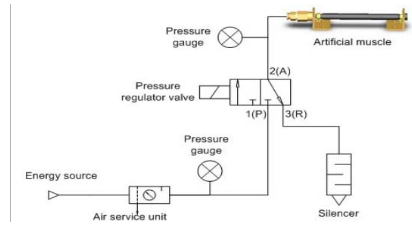

Fig. 5. **Pneumatic Diagram**

III. Results

Figure 6 shows the force versus the percent of contraction of the 15 mm diameter artificial muscle. The compressed air pressure of 2, 3, and 4 bar have been tested with the actuator where the maximum of tensile force is about 110 N. The experiment was performed by increasing the weight at the end of artificial muscle and suppy the constant compressed air pressure of 1, 2, 3, and 4 bar. Due to the very small displacement at pressure of 1 bar, this line does not appear in this graph.

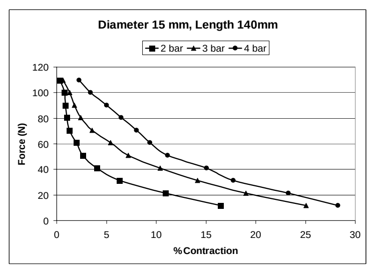

Fig. 6. **Force vs. Percent contraction of artificial muscle**

Figure 7 shows the force versus the percent of contraction of the 20 mm diameter artificial muscle. The maximum tensile force is at 160 N with small percent of contraction. This size however has about 30 percent of contraction at the pressure of 4 bar which is more than the 15 mm diameter size of artificial muscle.

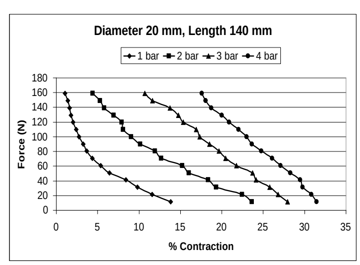

Fig. 7. **Force vs. Percent contraction of artificial muscle**

The percent contraction of the 30 mm diameter is maximum compared to the other two at 30 percent at air pressure 4 bar. The tensile force however is about the same as the 20 mm diameter size at 160 N. The results show that larger diameter gives more percent contraction and more tensile force. From the three graphs It can also predict the similar trend where the more percent of contraction, the less of the tensile force.

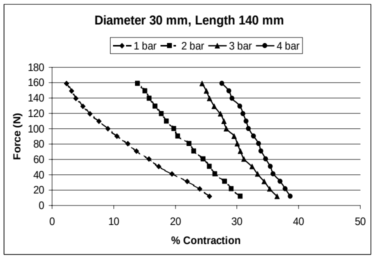

Fig. 8. **Force vs. Percent contraction of artificial muscle**

IV. Application

A. Arm Prostheses

Generally, prosthetic arms are built with electric motors, where the movements are far from natural. The motors are also more suitable for heavy mechanical systems engineering. This prosthetic arm is constructed for patients who lost forearm but still have the upper arm. The design of the prosthetic arm was inspired by the human arm muscular system which consists of two groups of muscles: flexor and extensor groups. These pairs of muscles are also attached in opposing pairs to the aluminum flat bar similar to humerus bone in human as shown in Figure 9.

Fig. 9. **Prosthetic arm actuated by artificial muscles**

V. Conclusions

The simple artificial muscle using the natural rubber latex in Thailand was developed. The evaluation results of the artificial muscle are as follows:

- The response of an artificial muscle was smooth and worked great.
- The force per weight ratio of the artificial muscle was excellent at the maximum ratio of 800 (using maximum tensile force at 160 N and the weight of the artificial muscle at 200 gram).
- The characteristic shows the relation between the force and displacement was similar in different size of diameter.
- This artificial muscle is possible to be the actuators for the prostheses because of its soft motion and inexpensive.
- The working cycle of this artificial muscle was however limited to 10,000 cycles and it needs to be improved for the future use in prostheses or robot applications.

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