2013 10th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI)
October 31-November 2, 2013 / Ramada Plaza Jeju Hotel, Jeju, Korea

Low Cost Flexible Robot Manipulator for Pick and Place Tasks

Gustavo Kato[1], Diego Onchi[2] and Monica Abarca[2]
[1] Department of Engineering, Pontificia Universidad Católica del Perú, Lima, Perú
(Tel : +51-1-6262000 ext.4748; E-mail: gkato@pucp.edu.pe)
[2] School of Science and Engineering, Pontificia Universidad Católica del Perú, Lima, Perú
(Tel : +51-1-6262000 ext.4748; E-mail: eiji.onchi@pucp.pe, monica.abarca@pucp.pe)

Abstract – The present study reports a novel concept for flexible robot manipulators focusing in low cost construction. The proposed flexible robot arm was designed for pick and place applications of light weight products. The robot arm is actuated by the use of two DC motors and one stepping motor. And a wire connected to the stepping motor is used for controlling the bending position of the flexible link. The vibration of the end tip of the flexible link is reduced by the action of the pulling wire. Preliminary experimental results regarding the flexible link are presented.

Keywords – flexible, robot arm, design, pick and place

1. Introduction

The study of flexible robot manipulators began more than forty years ago [1]. Flexible manipulators compared with rigid manipulators are lighter, made with cheaper materials, and have lower energy consumption [2, 3]. On the other hand, the flexible manipulators are difficult to model and control. Many studies regarding the control of flexible link robot manipulators have been made by simulation [3-5] and by experimentation [6-10]. The main focus on the flexible manipulator studies has been the control of the vibration at the end tip of the flexible link [6-8, 10, 11]. The present study shows a novel model of flexible robot arm focused on low cost. It is expected that this flexible robot arm will have future applications for pick and place tasks. The proposed flexible robot arm uses a wire mechanism to partially control the vibration generated by the flexible link.

2. Concept of the flexible robot arm

The flexible robot arm is actuated by the use of two DC motors with reduction gearboxes for the rotary joints and one stepping motor is used for pulling the wire that bends the flexible link. The proposed flexible robot arm model is shown in Fig.1. The first joint allows the arm to rotate on the horizontal plane and the second joint allows the arm to move on the vertical plane. The flexible link consists of two parallel bars of silicon attached by the use of three supports. The first support (S_1) attaches the two bars at the end of the link, the second support (S_2) is located at the middle of the link, and the third support (S_3) attach the two bars to the rigid part of the link. A nylon wire is used to bend the flexible link and two pulleys are used to guide the wire in the rigid part of the second link.

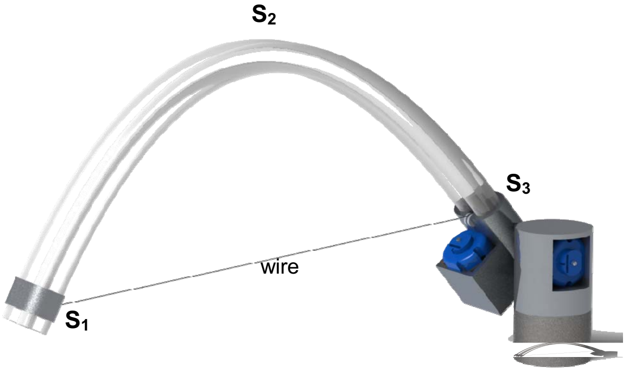

Fig. 1. Flexible robot manipulator model.

Figure 2 shows the upper view and side view diagrams of the flexible robot arm concept.

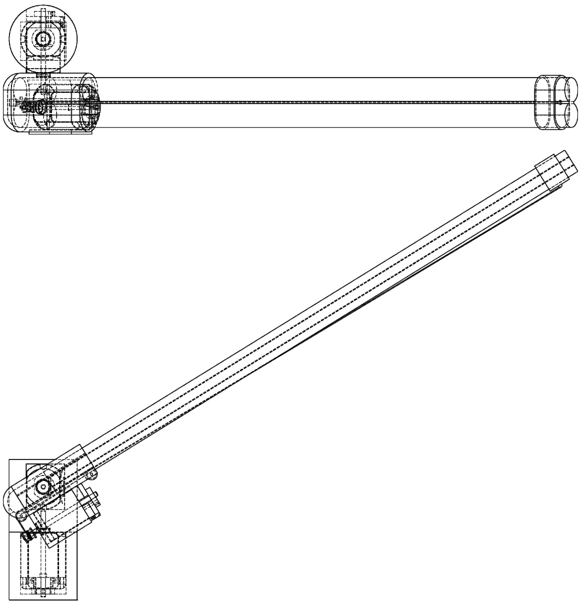

Fig. 2. Diagrams of the flexible robot manipulator model.

2.1 Flexible material

The physical characteristics of the flexible material used are shown in Table 1. The flexible silicon cylinder bar has a length of 271 mm, a diameter of 11 mm, and weights 26.5 grams.

Table 1 Physical characteristics of the silicon bar.

Density	1.2 gr/cm3
Traction resitance	80-90 kg/cm2
Shear resistance	20 -50 kg/cm2
Ductility	250%
Compression	3.60%

Preliminary experiments were made to determine the behavior of the silicon bar. The first experiment was made to calculate the required force for bending the silicon bar to a fixed distance. The bar has one of its tip fixed at a point so it can only rotate and a force (F) is applied to the other tip until the distance between the tips reaches the required distance (d). Fig. 3 shows the diagram of the experiment and Table 2 shows the experimental results.

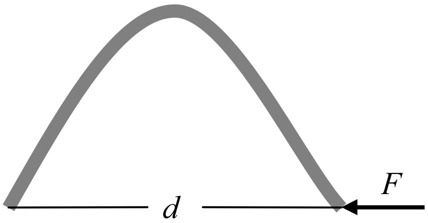

Fig. 3. Diagrams of the preliminary experiment.

Table 2 Experimental results of the preliminary experiment.

d (mm)	F (N)
50	2.41
100	2.25
150	1.62
200	1.47
250	1.41

The second preliminary experiment was made to show in a graph the position of the flexible bar when the bar is flexed. Fig. 4 and Table 3 show the maximum heights reached by the bar for different distances.

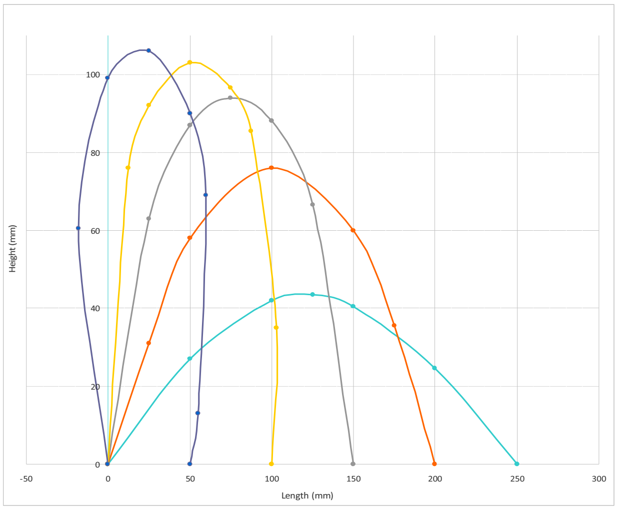

Fig. 4. Positions of the flexible bar when flexed.

Table 3 Maximum height of the bended bar.

d (mm)	hmax (mm)
50	106
100	103
150	94
200	76
250	43

From the preliminary results it is assured that for the minimum value of d (50mm) the required force to keep the bar in position is 2.41N and the bended bar reaches the maximum height of 106mm. It is observed that the silicon bar always reach the maximum height at middle of the bar.

2.2 Actuators

The design considers two DC motors with reduction gearboxes are used for actuating the robot links. The proposed task of the flexible robot is the pick and place of products. For this reason, the DC motors that actuate de links do not need to lock the position of the links during the movements of the robot. A stepping motor is considered for pulling the nylon wire to control the position of the end tip because the position of the rotor can be locked. The positions of the motors have been proposed focused in the reduction of the motor torques by keeping the centers of gravity close to the axis of the motors.

2.3 Structure and supports

The material considered in the design for the main structure and the motor supports is aluminium. Aluminium is a low cost, light weight and easy to machine material.

3. Experimental results of the non-actuated prototype of the flexible link

A non-actuated prototype was constructed and experiments were performed to evaluate the performance of the flexible link when carrying weights at different pulled distances of the wire (L). Fig. 5 shows the detail of the parameters measured during the experiments (h,d).

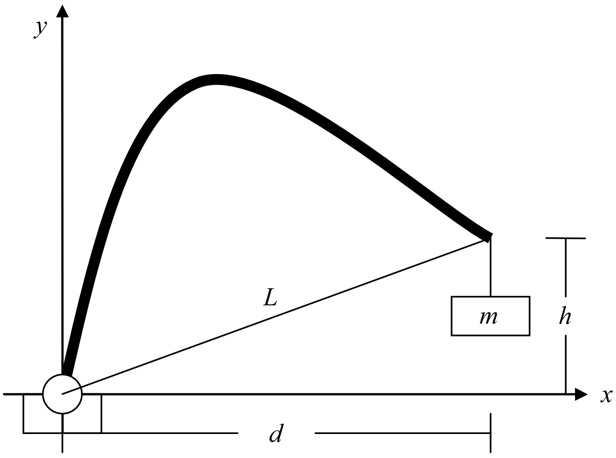

Fig. 5. Detail of the measured parameters.

The flexible link is fixed at 90° from the x axis and different weights are attached at the tip of the link. And the final position of the tip is described by the values of d and h. The first experiment was made without pulling the nylon wire. The results are presented in Table 4 and Fig. 6.

Table 4 Experimental results of the non actuated prototype

m(g)	d(cm)	h(cm)
0	3.2	24.2
50	12.1	21.2
70	16.8	16.3
90	20.6	7.7
100	20.2	4.7
120	20.0	0.8

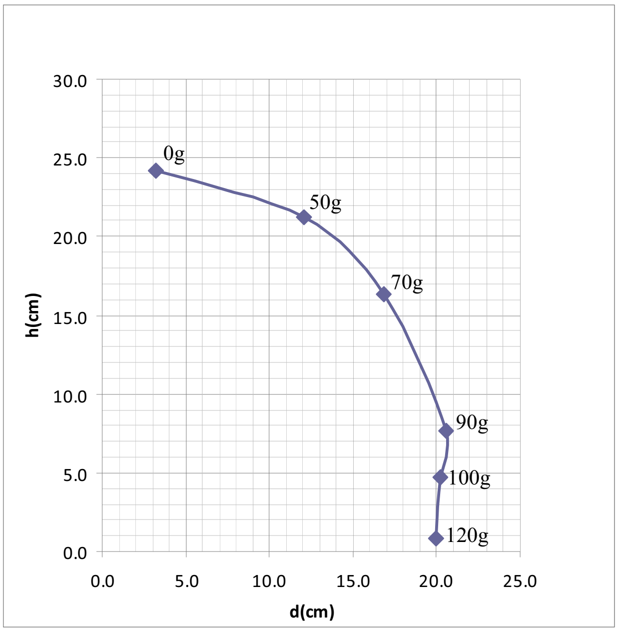

Fig. 6. Positions of the flexible link tip for different weights without pulling the wire.

The second experiment was made fixing the nylon wire at different distances (L). Fig. 7 shows the experimental results. From left to right the figure shows the results for the different values of L (5, 10, 15, 20) in centimeters and from top to bottom the results for different values of m (0, 50, 70, 90, 100, 120) in grams.

4. Experimental results of the actuated prototype

An actuated prototype was constructed to test the performance of the system by the use of two DC motors with encoders, a motor driver and an Arduino Uno as control system. Two pieces of polycarbonate were 3D printed to attach the silicon bars to the actuators and to attach the two silicon bars at the tip. Figure 8 shows the experimental prototype. For testing the performance of the system, the flexible arm had to move an object from one point to another in one axis. Two different weights were tested and the task had to be performed moving the object forwards and backwards.

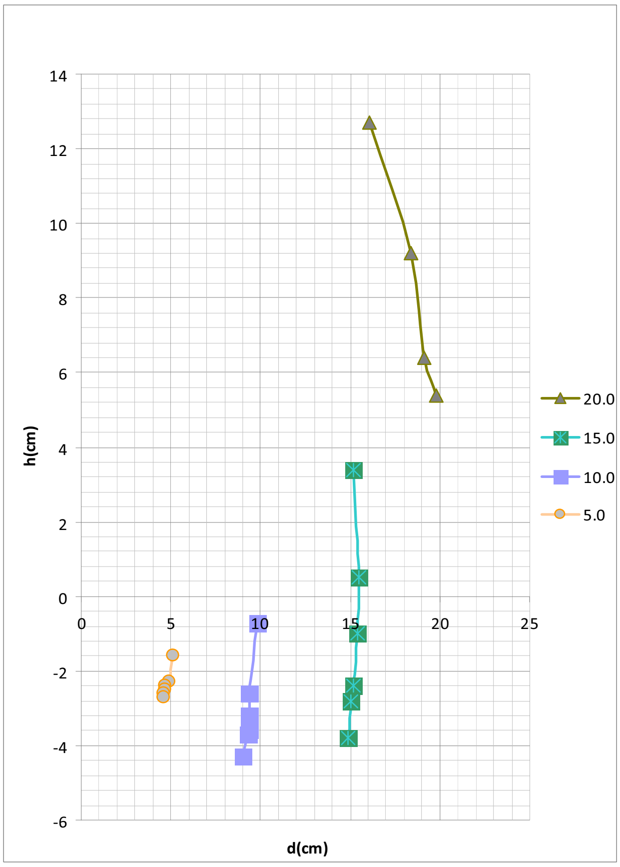

Fig. 7. Positions of the flexible link tip for different weights and different wire lengths.

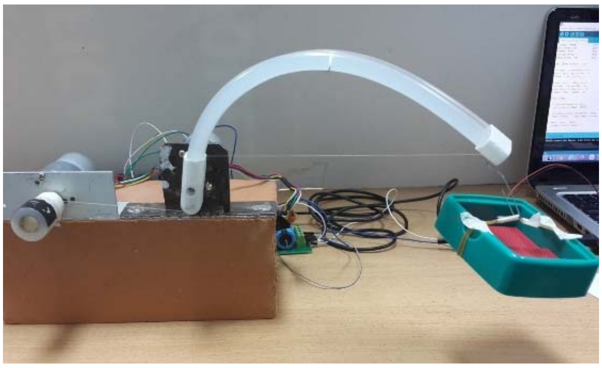

Fig. 8. Picture of the experimental prototype

4.1 Forward moving experiments

In these experiments, the object had to be moved forward changing its position from d =10cm to d =20cm and the time required for this motion was measured. The experiments were repeated five times and were made for two different weights of 25gr and 50gr. The experimental results of the experiments are shown in table 5. The average time for the 25gr object was 9.4s and for the 50gr object was 10.7s.

Table 5 Experimental results of the forward moving experiments

	25gr	***50gr***
1	9.4s	10.5s
2	9.5s	10.7s
3	9.2s	10.7s
4	9.5s	10.8s
5	9.3s	10.7s

4.2 Backward moving experiments

In these experiments, the object had to be moved backwards changing its position from d =20cm to d =10cm and the time required for this motion was measured. The experiments were repeated five times and were made for two different weights of 25gr and 50gr. The experimental results of the experiments are shown in table 6. The average time for the 25gr object was 7.1s and for the 50gr object was 7.9s.

Table 6 Experimental results of the backward moving experiments

	25gr	***50gr***
1	7.1	7.9
2	7.1	7.9
3	7.1	7.8
4	7.0	8.0
5	7.1	7.8

4. Conclusions

A novel flexible robot arm design is proposed and the experimentations were made to verify the usability of a silicon bar as flexible link. The design proposes a lightweight robot for pick and place work and the required components have been described. The experimental results show that the flexible silicon link is able to hold more than two times its own weight. The nylon wire is able to control the bending of the flexible link and to damp the vibrations generated by the movement. It is also clearly seen by the experimental results that the backward movement of the objects using the flexible robot arm is faster than the forward movement.

References

[1] J. Malzahn, A. Phung and T. Bertram, “A Multi-Link-Flexible Robot Arm Catching Thrown Balls”, Proceedings of the 7th Conference on Robotics, pp. 411-416, 2012.

[2] V. Etxebarria, A. Sanz and I. Lizarraga, “Control of a Lightweight Flexible Robotic Arm Using Sliding Modes”, International Journal of Advanced Robotic Systems, Vol.2, No.2, pp. 103-110, 2005.

[3] H. Pota, “A Prototype Flexible Robot Arm – An Interdisciplinary Undergraduate Project”, IEEE Transactions on Education, Vol.35, No.1, pp. 83-89, 1992.

[4] P. Sooraksa and G. Chen, “Mathematical Modeling of a Flexible Robot Arm”, Proceedings of the IEEE International Conference on Control Applications, Transactions on Robotics and Automation, pp. 960-964, 1996.

[5] M. Arteaga, B. Siciliano, “On Tracking Control of Flexible Robot Arms”, IEEE Transactions on Automatic Control, Vol.45, No.3, pp. 520-527, 2000.

[6] W. Wang, S. Lu and C. Hsu, “Experiments on Position Control of a One-Link Flexible Robot Arm”, IEEE Transactions on Robotics and Automation, Vol.5, No.3, pp. 373-377, 1989.

[7] K. Hillsley and S. Yurkovich, “Vibration Control of a Two-Link Flexible Robot Arm”, Proceedings of the IEEE International Conference on Robotics and Automation, pp. 2121-2126, 1991.

[8] B. Samanta, “Active Control of Flexible Robot Arms Using the Concept of Intelligent Structures”, Proceedings of the IEEE International Workshop on Robots and Systems (IROS), pp. 941-947, 1990.

[9] Z. Luo, N. Kitamura and B. Guo, “Shear Force Feedback Control of Flexible Robot Arms”, IEEE Transactions on Robotics and Automation, Vol.11, No.5, pp. 760-765, 1995.

[10] R. Wai and M. Lee, “Intelligent Optimal Control of Single-Link Flexible Robot Arm”, IEEE Transactions on Industrial Electronics”, Vol.51, No.1, pp. 201-220, 2004.

[11] Ö. Morgül, “On the Boundary Control of a Flexible Robot Arm”, Proceedings of the IEEE Conference on Decision and Control”, pp. 3856-3857, 2001.