2013 6th Summer School on Surgical Robotics

Soft Actuators for Surgical Tools/Robots

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My Background

- Bachelors in Mechanical Engineering in 2012 from Amrita University.

- Currently working as a Research Assistant in Indian Institute of Science, Bangalore, India.

Research Interests: Bio-Robotics, Actuators for Surgical or Medical Purpose.

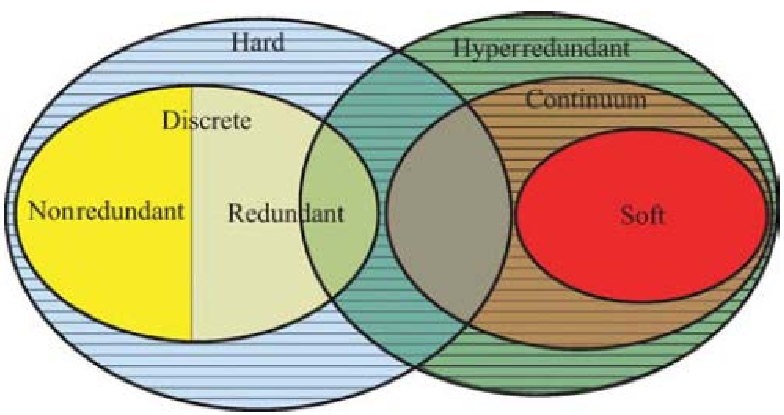
Outline

- Brief Introduction to Soft Actuators
- Pneumatic Actuators (Linear Actuator)
- Eccentric Actuators (Bending Actuators)
- Eccentric Bellow Actuator(Bending Actuator)

Soft Actuators

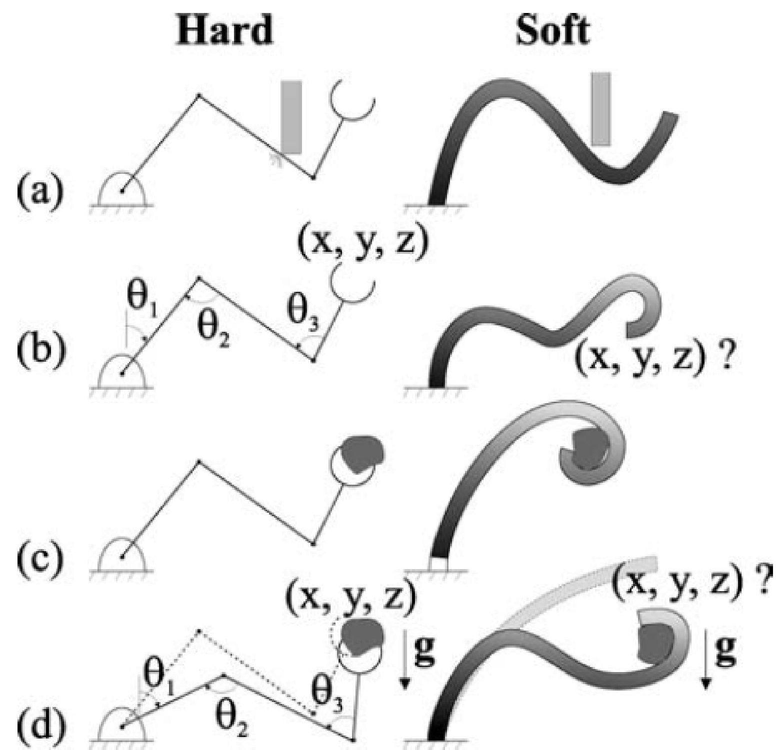
- Actuator

(electrical, hydraulic, Pneumatic……….)



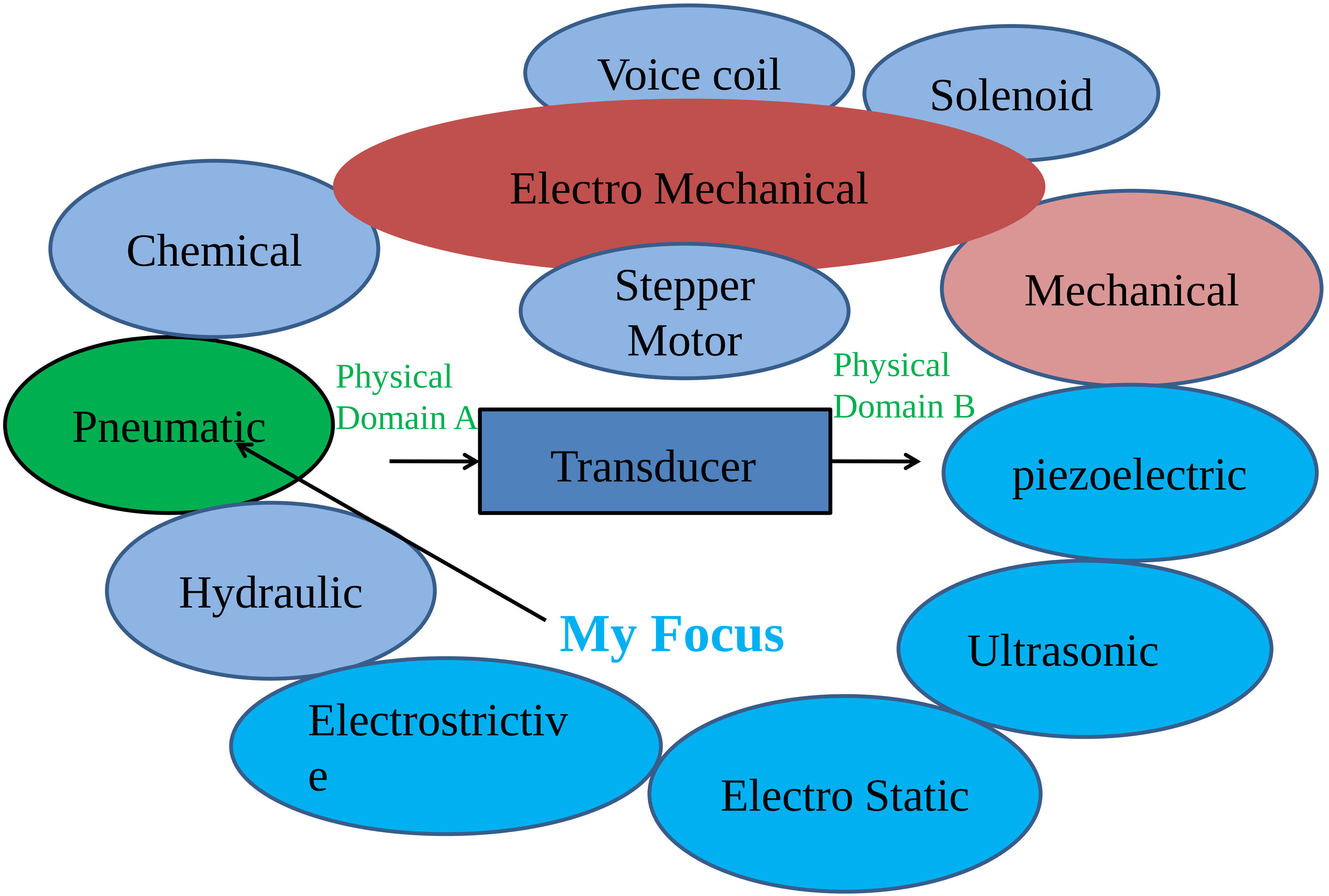
Classification of robots based on the Materials and DOF .Hatched area represents empty set

**Trivedi et al ,2008*

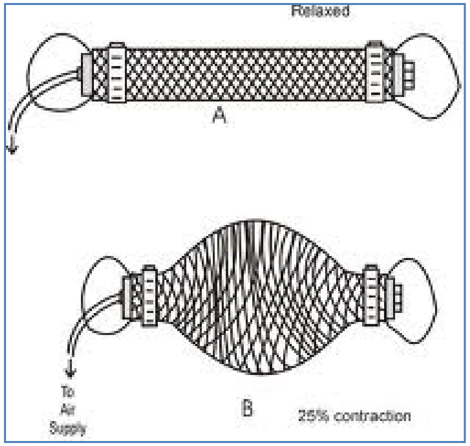


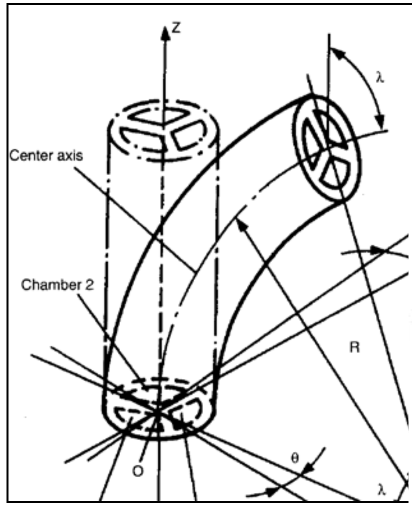
Capabilities of hard and soft robots (a) Dexterity (b) Positioning and sensing (c) Manipulation (d) Loading

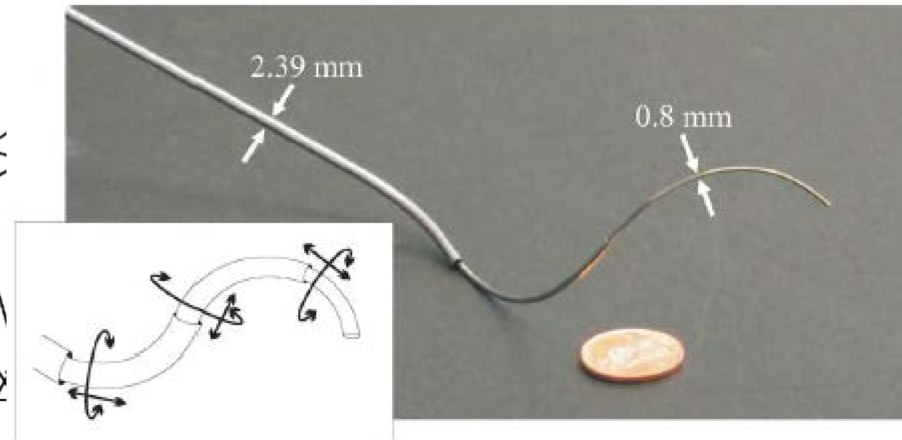
Actuation Principles



Available Soft Actuators





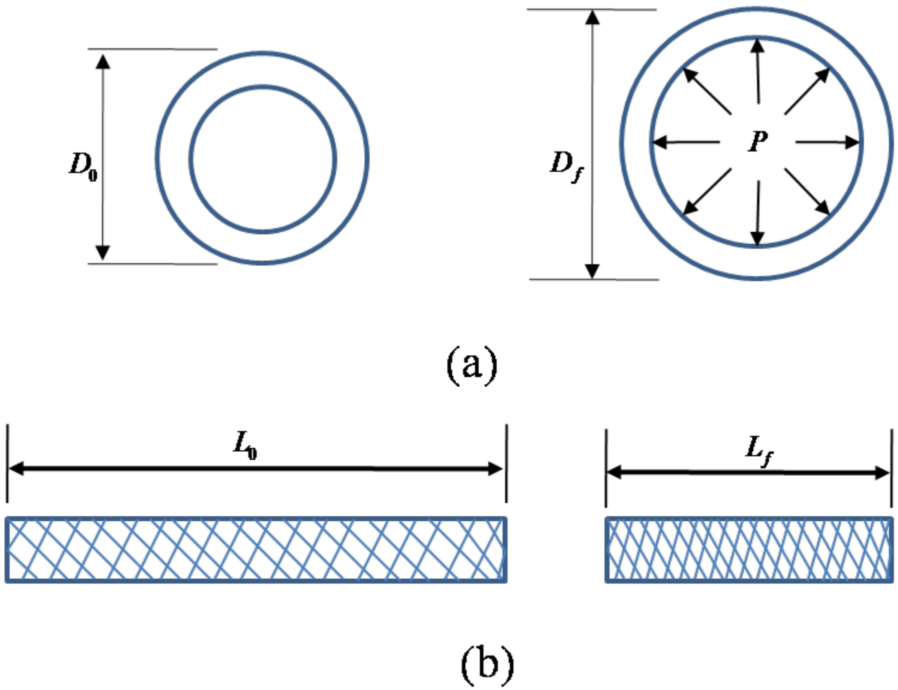


Suzumori et al - 2007

Robert J Webster et al III, 2009

Pneumatic Artificial Muscle, known as Mckibben Air Muscle---Refer Hanaford,1994,Tondu Lopez,2001 Yong Kwun Lee 1994.

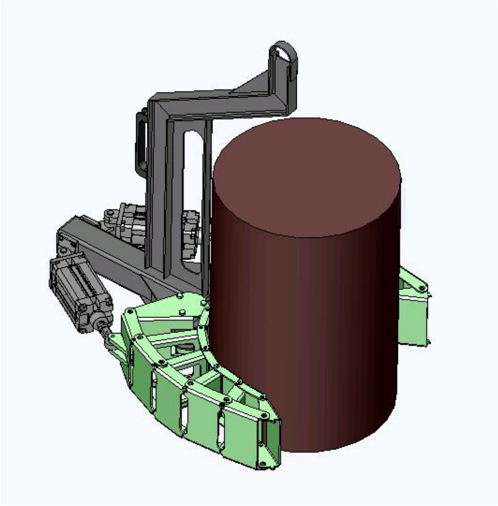
Miniaturized Pneumatic Artificial Muscle for Surgical Applications (MPAM)

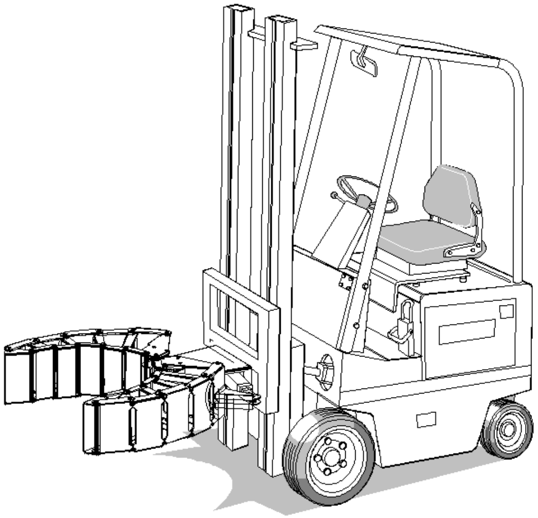


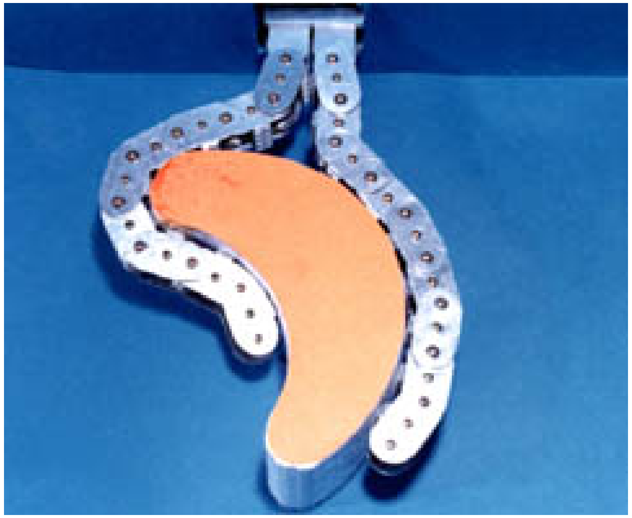
(a) Cross sectional view of Silicone Tube before pressuring and after pressurizing (b) Behavior of the braided sleeve before contraction and after contraction

Shanthanu.C, Aditya.K and Ashitava Ghosal

EARLIER DEVELOPED – HARD GRIPPERS

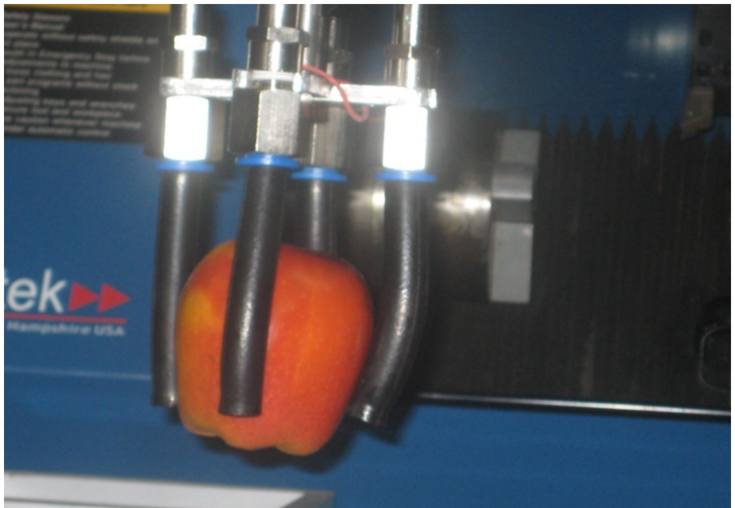






Eccentric Actuator

ROBOTIC GRIPPER

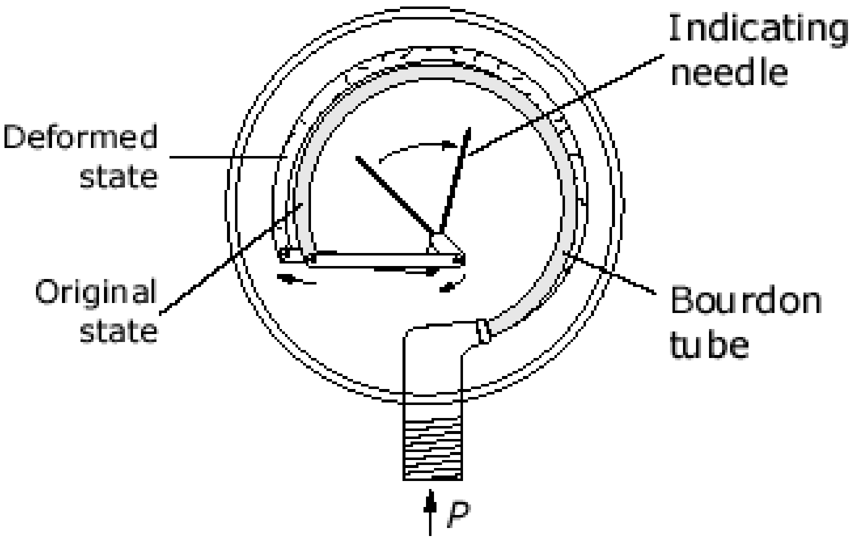


Aditya.K, Sai Dinesh Ganesha Udupa, Pramod Sreedharan 2010-2012

HOW IT WORKS

Bourdon tube

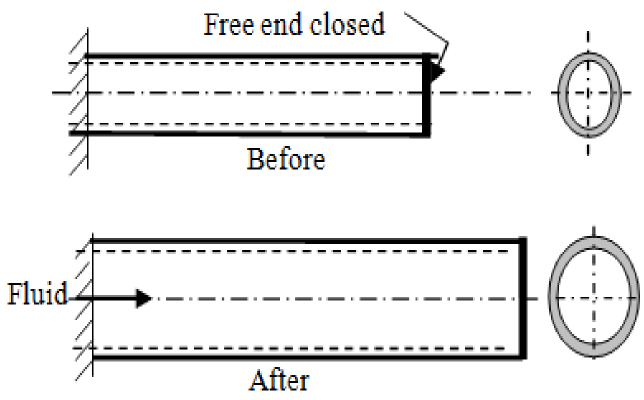
It is initially curved having a cross section either flat or elliptical or oval, under internal pressure will try to straighten up



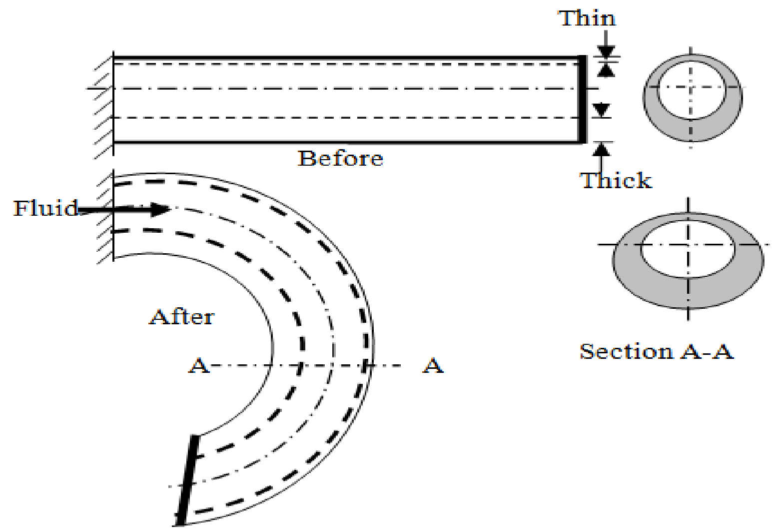
Anti-Bourdon Tube principle

A straight asymmetric (eccentric) tube with circular cross section under the application of pressure will become curved and elliptic in cross section.

ILLUSTRATION OF PRINCIPLE



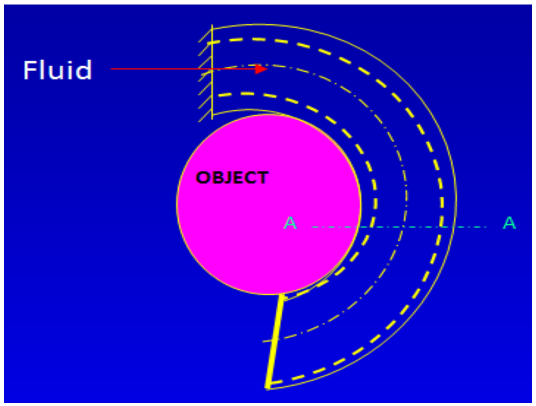
- Symmetric synthetic tube subjected to internal fluid pressure.
- Elongation of tube occurs due to internal pressure.

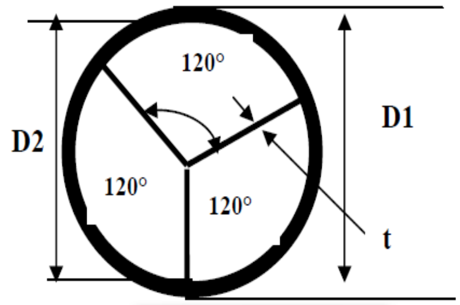


- Bending of Flexible Micro Actuator under the application of internal pressure.
- Differential expansion of thicker and thinner side leads to bending of FMA.

Mould used for Manufacturing Asymmetric Actuator

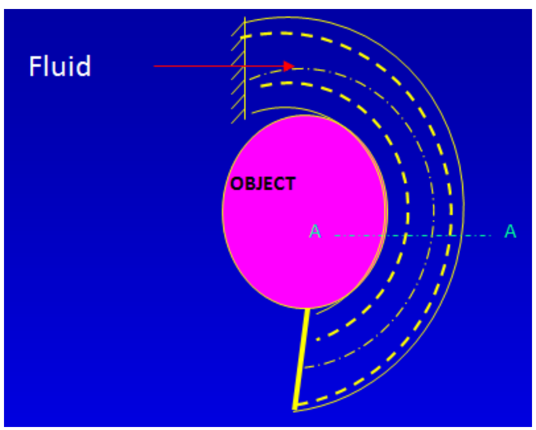
Robotic Gripper Design Based on an Asymmetric (Eccentric) Rubber Tube Actuator

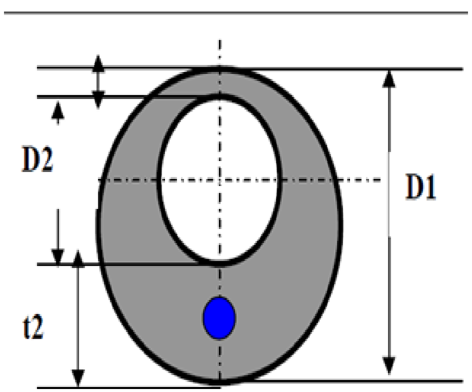




Section A-A

PRIOR ART- **K. Suzumori**





Section A-A

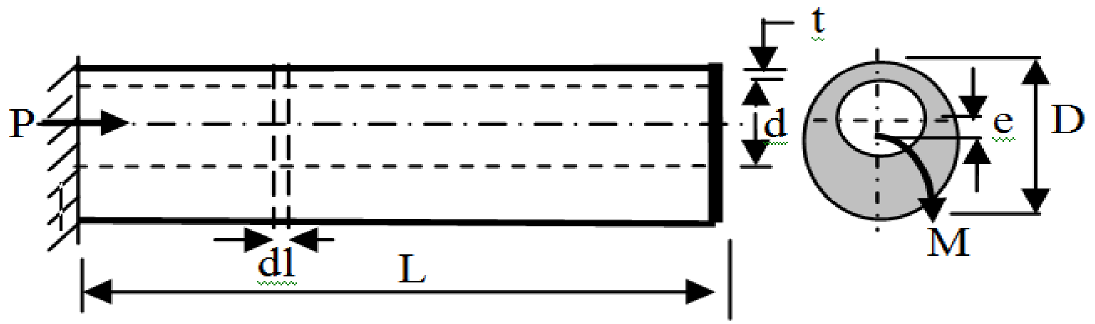
NEW ART – **Our Contribution**

Materials : Neoprene, Nitrile, Silicone, rubber ….

MODELLING

By Euler's Formulae

$$\frac{EI\,\frac{d^2y}{dx^2}}{\left[1+\left(\frac{d^2y}{dx^2}\right)^2\right]^{3/2}} = PAe = M$$



Shows parameters considered of formulation

Substituting, $\frac{dy}{dx} = v$

We have,

$$\frac{EI\ v'}{[1+\ (v)^2]^{3/2}} = PAe$$

Let $V = \tan\theta$

$$dv = (\sec^2\theta)\, d\,\theta$$

Substituting $EI\,\frac{(\sec^2\theta)\,d\,\theta}{[\sec^2\theta]^{3/2}} = PAedx$

Integrating $EI\ \sin\theta = PAex + K$

MATHEMATICAL MODELLING

Applying the boundary condition, at x=0, θ =0 and hence K=0,

$$\theta = \sin^{-1}\{\frac{CPAe\ x}{EI}\}$$

where ,C is an empirical constant which compensates the dynamic effect of bending of FMA and the value of C is 1.48.

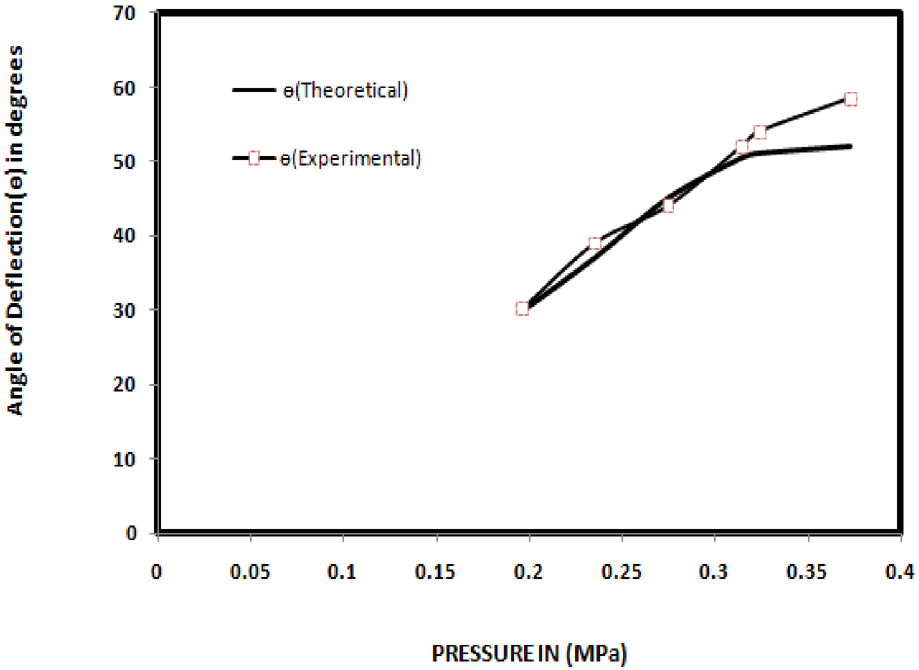
Radius of curvature

$$R = \frac{EI}{CPAe}$$

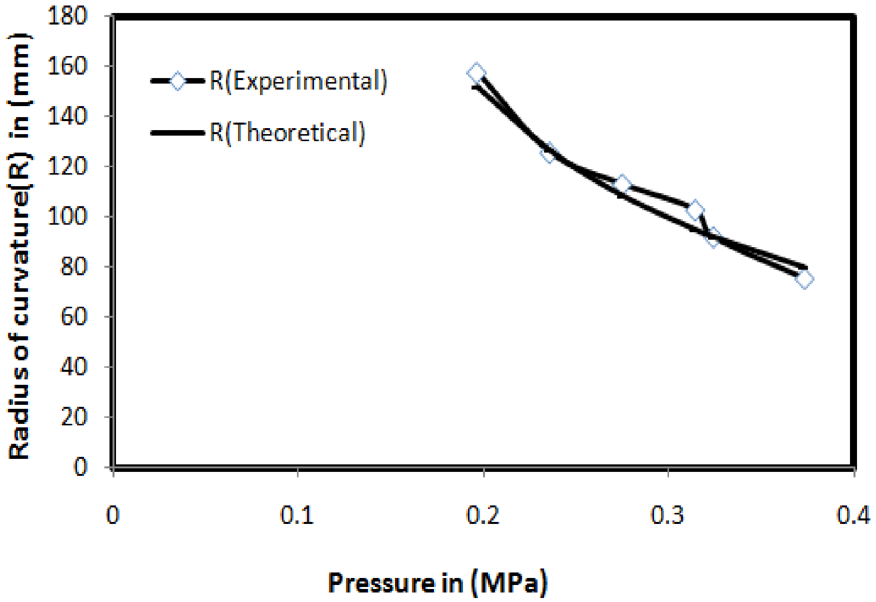
Experiments using FMA

c) P=0.35 MPa

THEORETICAL AND EXPERIMENTAL VERIFICATIONS



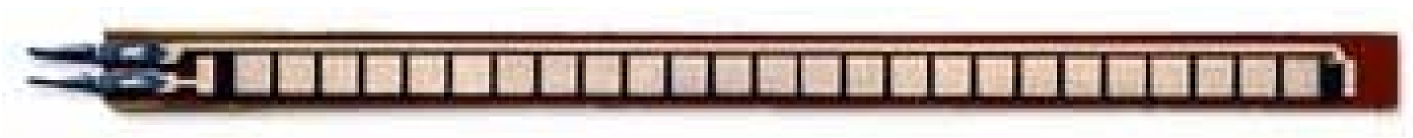
Comparison of theoretical and experimental data for angle of deflection Vs pressure.



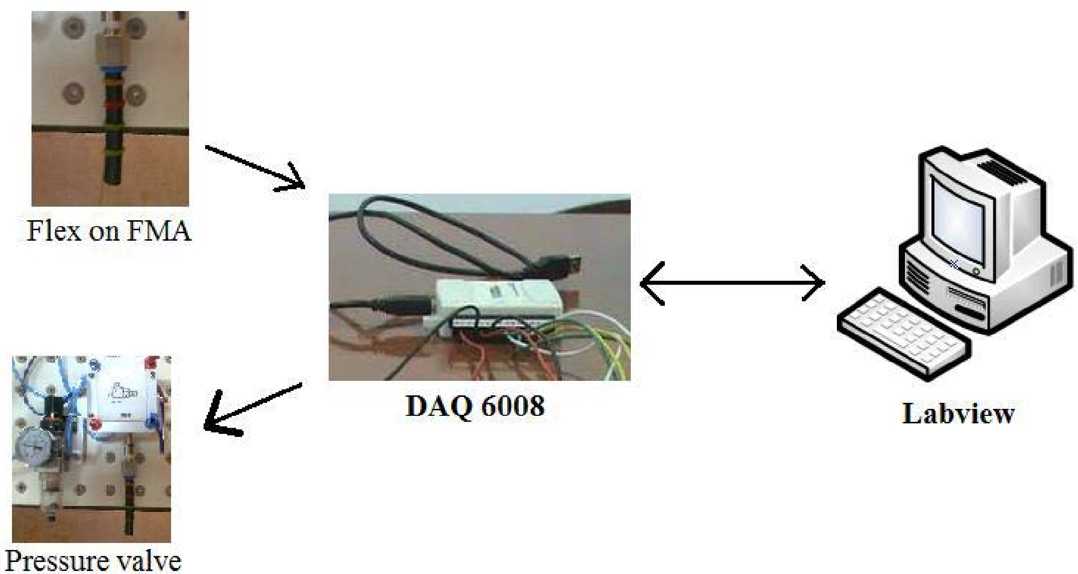
Comparison of theoretical and experimental data for radius of curvature Vs pressure.

Sensor Mounting for Controlling Pressure

- Sensor used for the detection of the bending angle is FLEX RESISTOR.

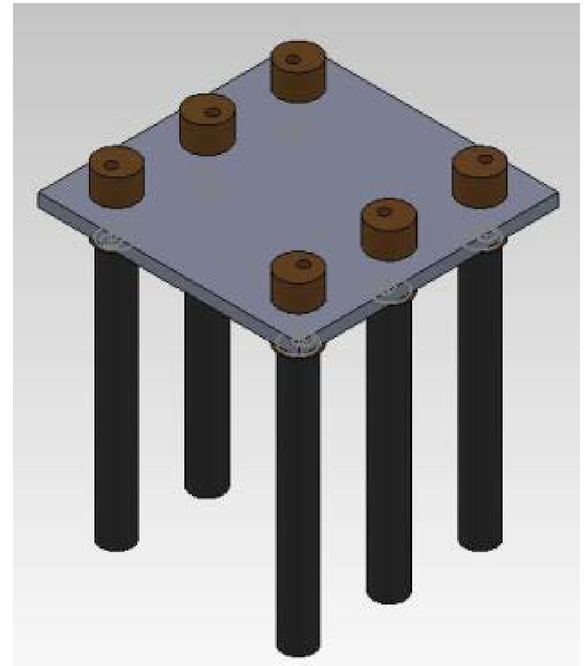


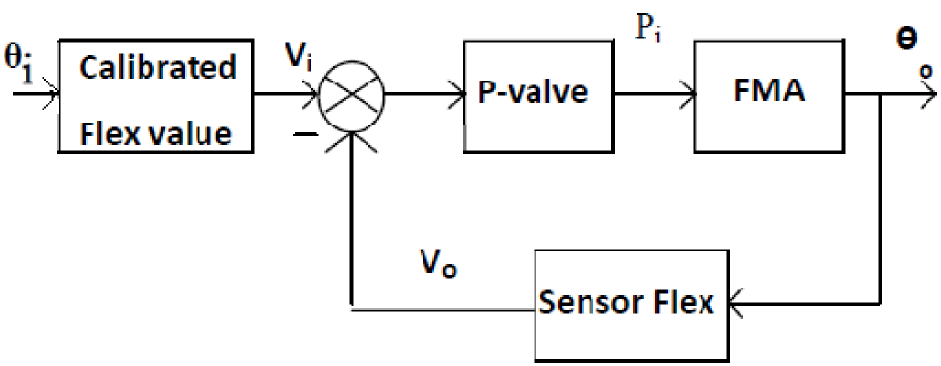
- Carbon resistive elements within a thin flexible substrate, inside the flex sensor is responsible for the change in the resistance with respect to bending.

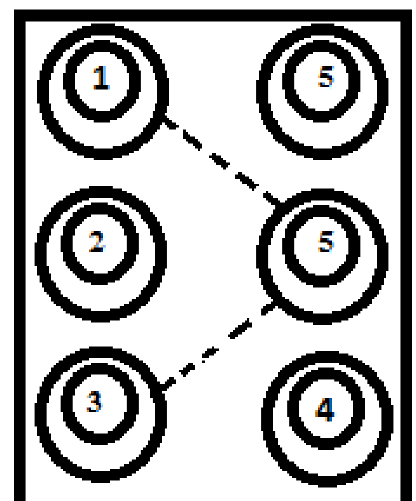


Source: imagesco.com/sensors/flex-sensor.html

Walking Robot using Eccentric Actuator

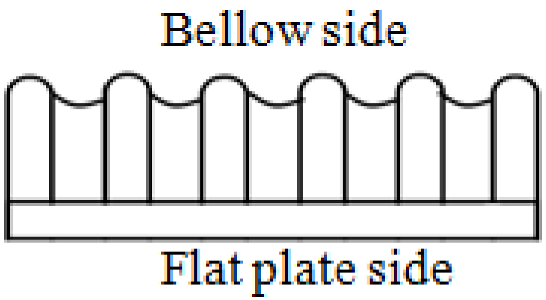


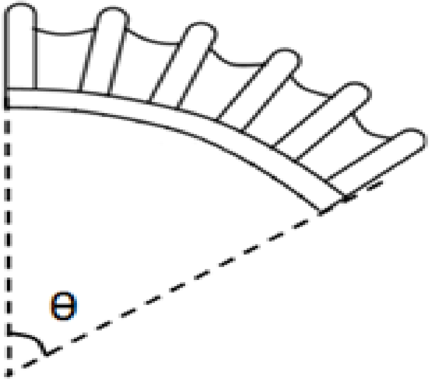




Control for the Walking robot

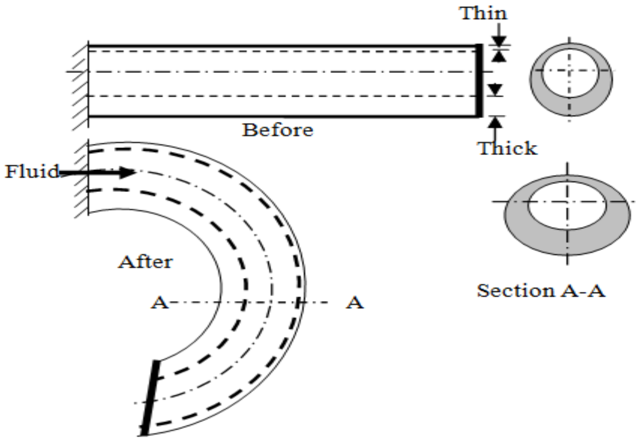
Pneumatic Asymmetric Bellows

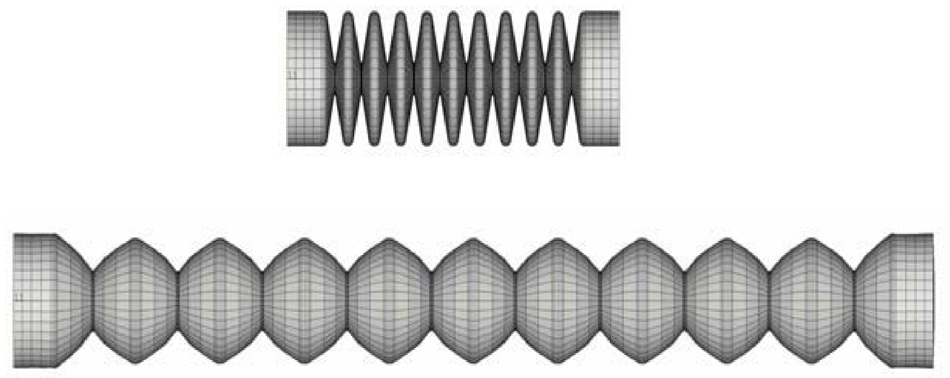




Asymmetric Bellow Flexible Pneumatic Actuator (FPA) subjected to internal pressure (a) Before (b) After

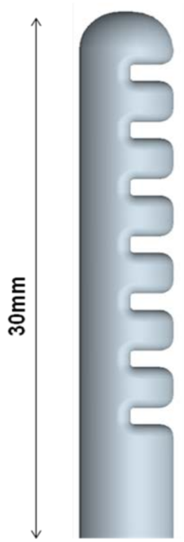
Our Actuator

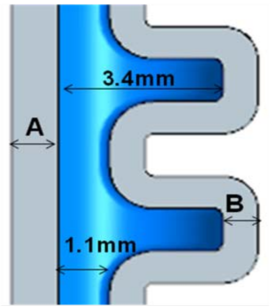




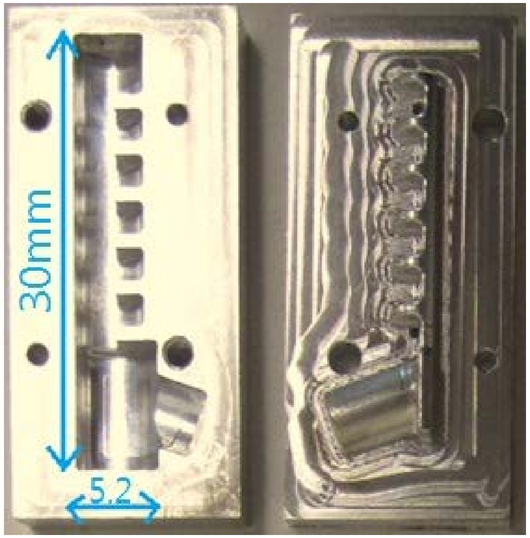
Bellow Actuator

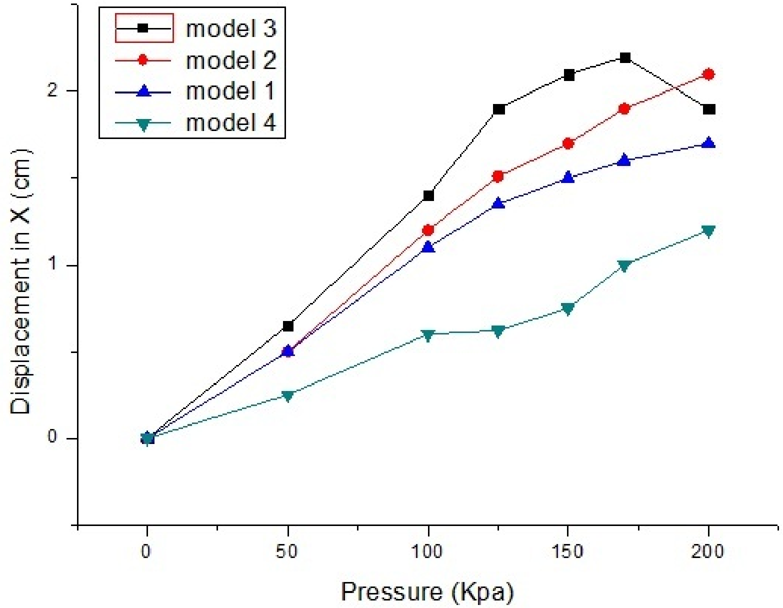
Our Actuator



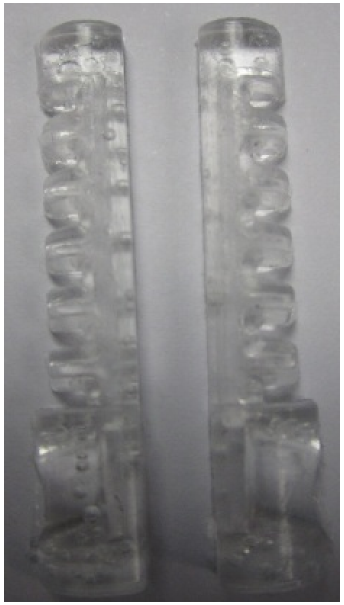


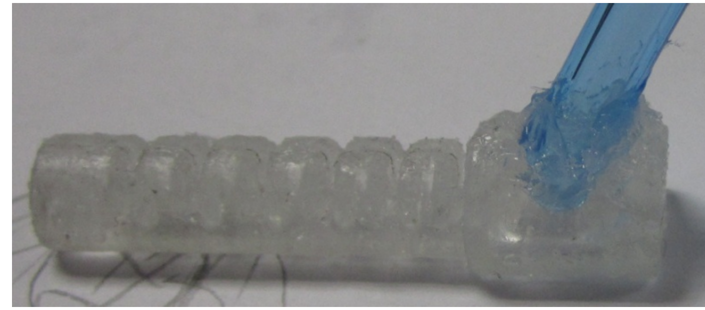
	A [mm]	B [mm]
Model 1	0.7	0.7
Model 2	0.9	0.7
Model 3	1	0.7
Model 4	1.5	0.7

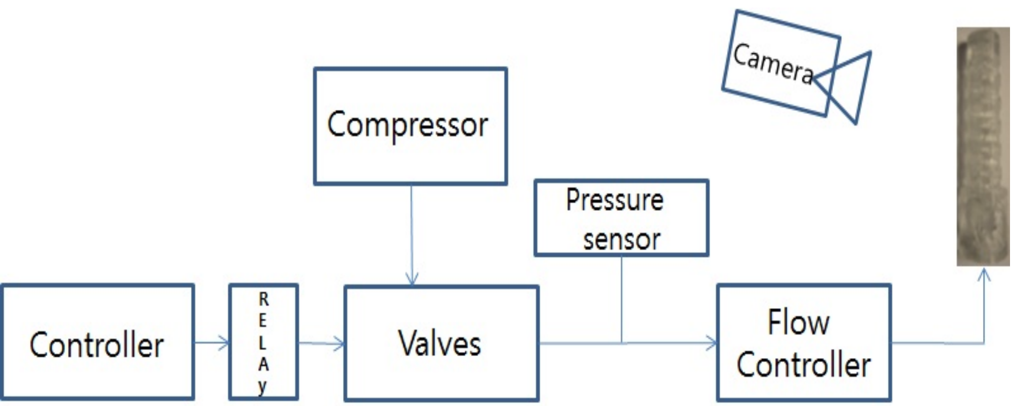




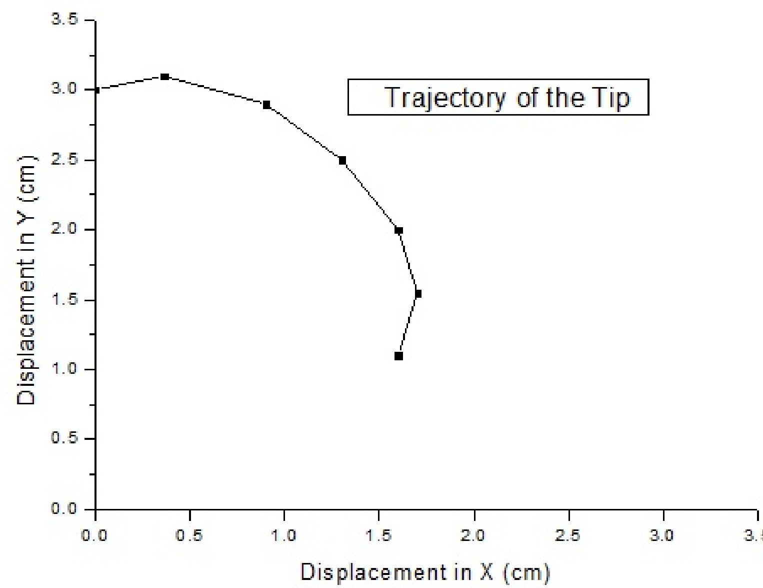
Displacement of FPA in X direction





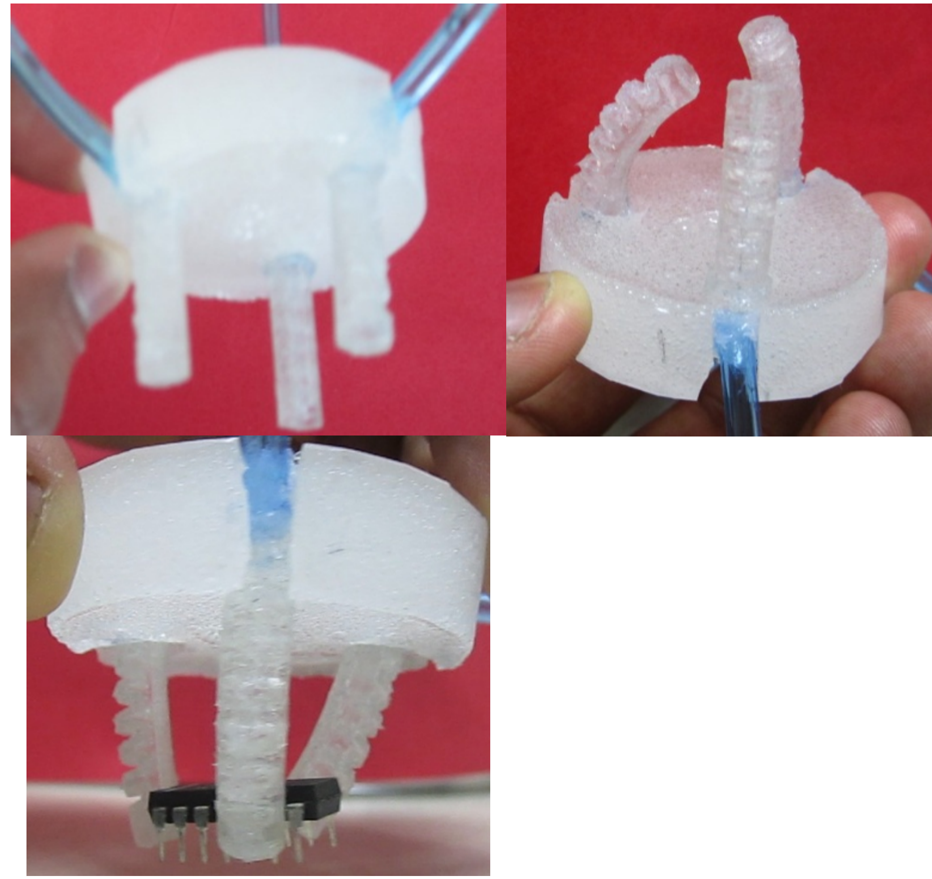


Experimental setup for the control of FPA



Trajectory of the Tip with each 30 [KPa] starting from 0 [Kpa]

Experiments with the developed Asymmetric Bellow



Acknowledgments

- Professor Ashitava Ghosal (IISc) for giving great technical guidance & support in to work on Pneumatic Actuators.
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- Present Robotics lab and M2D2 lab members in IISc and many more………….

Thank You!!!