Indian National Society for Aerospace and Related Mechanisms

BANGALORE CHAPTER

E-NEWSLETTER

Vol. 2, No. 3, August 2008

From the Editor

Dear Member,

This has been an interesting quarter wherein a good amount of interaction took place in the domain of smart materials, systems and mechanisms. This was made possible in the form of 5th International Conference on Smart Materials, Structures and Systems in July 2008 at IISc, Bangalore, supported by Institute of Smart Structures and Systems, ISRO and IISc. The conference brought into focus the significant developments in smart materials and systems in the form of plenary lectures, invited lectures, paper presentations and poster presentations. The conference covered the latest developments in MEMS, Nano devices, Shape Memory Alloy based systems, applications of smart materials and structures in the area of health monitoring of large systems, detailed analysis and simulations methodologies. Several of INSARM members had the opportunity to participate and contribute significantly to excellent organization and success of the conference by being chairman and members of several organizing committees, delegates, technical session chair, volunteers and the like.

It may be brought to your notice that this newsletter is intended to be a medium of information exchange regarding the state of the art developments and future directions in the area of mechanisms and related fields. The editorial committee welcomes your active participation in the form of technical articles and ideas which will definitely enhance the technical value of this e-newsletter.

With best regards,

Dr. R Ranganath
Chief Editor

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FROM INSARM BANGALORE CHAPTER

WISH YOU A HAPPY INDEPENDENCE DAY

Forthcoming conference/seminars

National Conference on Emerging Trends in Mechanical Engineering, ETIME 2008, At BMS college of Enggg., Bangalore on 28-29 August, 2008.
www.bmsce.ac.in

International Symposium on Measurements & Control in Robotics, ISMCR08 At NIMHANS Convention Centre, Bangalore, on 4-6 September 2008.
www.seminarindia.org

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ELECTROACTIVE POLYMER (EAP) ACTUATORS

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EAP Definition

EAP are polymer materials which change its size and shape when subjected to electric field, either to applied voltage or current.

Types of EAP

EAP are of two types; Ionic and Electronic.

Ionic EAP

This actuator has anode, cathode, electrolyte and a dielectric medium. The application of electric field produces potential difference. This results in variation of ion concentration near electrodes and thus produces bending. This actuator, due to presence of electrolyte, is called "Wet type" or Ionic Polymer Metal Composite (IPMC). Actuation voltage is 1V - 5V and the strain produced is around 20%.

Conductive Polymer (CP) is another variant in ionic type actuators made by suitable addition of doping material. When surrounded by an electrolyte, CP can expand or contract when ions migrate in and out of the polymer. Ion migration occurs when it is oxidized or reduced by an applied current.

Electronic EAP

These types of actuators based on electron concentrations at electrode, produces stretch in particular direction. This actuator, also called "Dry actuators", has anode, cathode and a dielectric medium. These types of actuators generally provide linear motion, i.e. tension/ compression actuation. The strain produced is reported maximum of the order of 216%. The prime disadvantage is the requirement of very high electric field (~100 V/ µm).

Operating Principle of Ionic EAP

Ionic EAP contains electrolytes that involve transport of ions/ molecules in response to an external electric field. The field controlled migration or diffusion of the ions/ molecules result in an internal stress distribution. These internal stress distributions can induce strains, like volume change, bending. Fig.1 depicts the principle of operation.

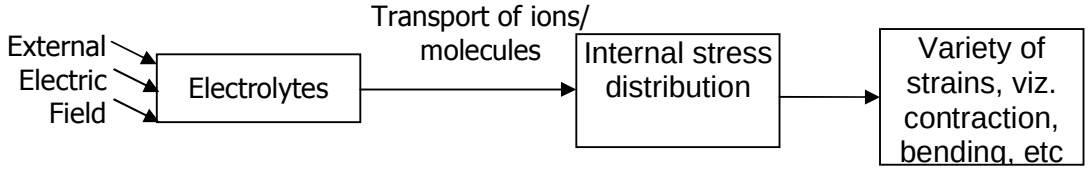

Fig.1 Flow chart of Ionic EAP function

Initial (straight) and excited (bent) configurations are shown in fig. 2a & 2b respectively.

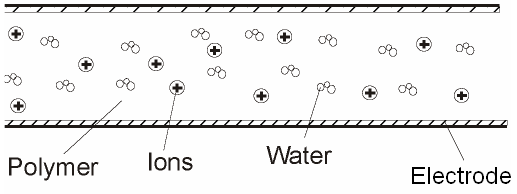

Fig. 2a Initial configuration

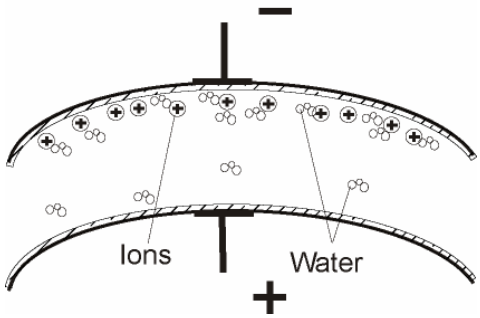

Fig. 2b Excited configuration

Operating Principle of Electronic EAP

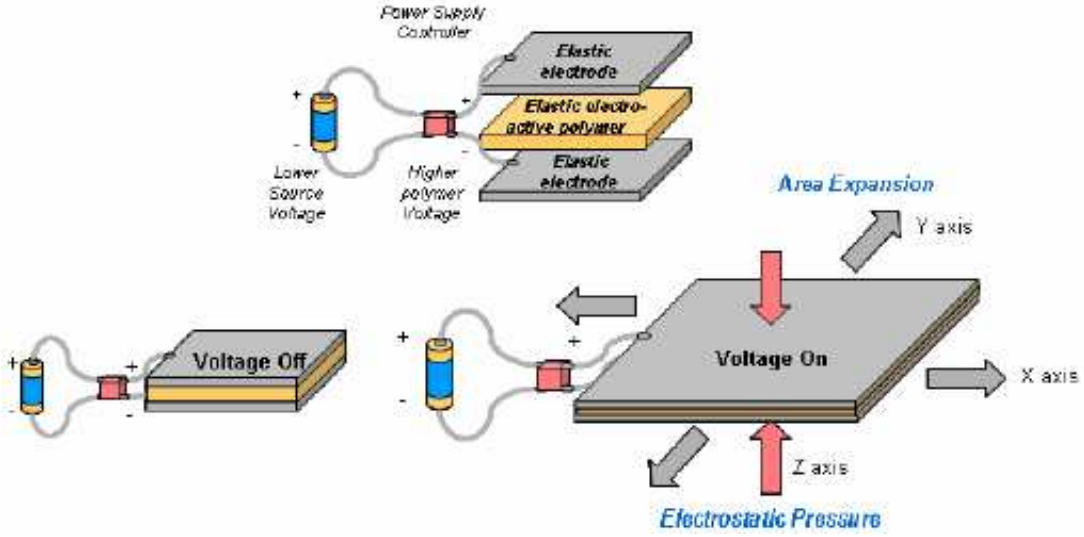

Fig.3 Electronic EAP construction and operation

Fundamentally, an insulating region sandwiched between two conductors is said to have capacitance C.

$$Q = CV \qquad \ldots 1$$

When top and bottom conductor are positive and negatively charged, an electric field is produced between the conductors and causes the conductive layers to experience an attractive force F between them, refer fig.3. If the conductors are held at a constant potential difference, then any movement 'δx', of the conductors relative to each other will cause a change in charge ' δQ'. Using principle of virtual work:

$$\delta W_E - F\delta x = V\,\delta Q \qquad \ldots 2$$

Where, δW_E is the change in electrostatic energy stored in the system. The change in charge is due to change in capacitance of the system, the differentiating equation 1 gives:

$$\delta Q = V\,\delta C \qquad \ldots 3$$

Also,

$$\delta W_E = \frac{V}{2}\,\delta Q = \frac{V^2}{2}\,\delta C \qquad \ldots 4$$

Substituting equation 4 into 2, gives

$$-F\delta x = \frac{V^2}{2}\delta C \quad \ldots 5$$

Parallel plate capacitance is givens as:

$$C = \frac{\varepsilon_0 A}{x} \quad \ldots 6$$

Where, A is the area of the parallel plates normal to the line of force, x is the thickness of the insulator and ε_0 is the permittivity of the free space.

Differentiating equation 6 substituting δC in equation 5 gives the attractive force experienced by the conductors:

$$F = \frac{V^2 \varepsilon_0 A}{2x^2} \quad \ldots 7$$

Advantages

1. Noiseless operation
2. Low metal concentration
3. Easy to build small devices
4. Stacking is possible

Disadvantages

1. Small power-weight ratio
2. The properties change in time
3. Need a wet environment
4. Force generated is small

Applications

Applications are very wide:

Diaphragms for pressure control, Positive displacement pumps, Linear actuated motors, toys, etc.

Space Applications

EAP actuators are attempted for on-orbit surface correction of inflatable antennas, haptic applications, sensing application, etc.

Comparison of various smart materials

The following table gives a overall functional excitation and response comparison between three common smart material actuators, namely *EAP, Shape Memory Alloys (SMA) and Piezoelectric Ceramics (PC)*

Property	EAP	SMA	PC
Actuation strain	>200%	<8%	0.1 – 0.3%
Force (Mpa)	0.1 – 40	200	30 – 40
Reaction speed	µsec to min	msec to min	µsec to sec
Density (g/cc)	1 – 2.5	5 – 6	6 – 8
Drive voltage	Ionic EAP: 1 – 7 V Electronic EAP: 10-150 V/µm	5 V	50 – 800 V
Consumed power	m-Watts	Watts	Watts

Effective Mechanism Modeling with MechKernel/KinSys

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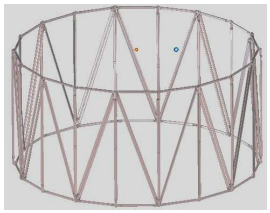
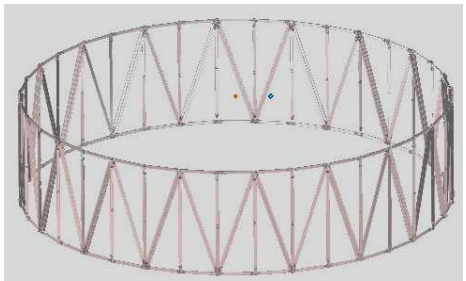
MechKernel is a library for modeling and analysis of planar linkage mechanisms developed in the Department of Mechanical Engineering, Indian Institute of Science, Bangalore. The distinctive feature of MechKernel is closed form kinematic analysis of planar mechanisms consisting of revolute, prismatic and pin-in-slot type of joints, which covers a wide variety of practical mechanisms including many used in space applications, using the so-called concept of automated *modular kinematics*. Describing links with key kinematic features on it such as the location of a pin/hole or line of action of a slider, and joints with mere adjacency among the links, MechKernel can compose the configuration, velocity and acceleration analysis of any mechanism closed form including many traditionally classified complex mechanism. Programs developed using it has been used in diverse applications such as mechanism simulation with realistic geometry of links, automatic generation of interference free mechanisms, mechanism synthesis applications, including an innovative application in tolerance analysis of MMIC packages in an ISRO sponsored project from SAC Ahmedabad. The main library was developed in a project sponsored by DST and is available for distribution for further collaborative development.



A class of spatial mechanisms can be found in practice, which is actually a combination of similar planar mechanisms arranged symmetrical about an axis. Similarly there are complex planar mechanisms which are again a combination of similar mechanisms arranged symmetrically on a plane. The kinematic analysis of these mechanisms can be done by analyzing one of the constituent planar mechanisms and the systematic transformations of this mechanism give the kinematic state of other mechanisms. These special type of mechanisms are referred to as *pseudo spatial mechanisms* or patterning of mechanisms. If the whole mechanism is considered at a time for analysis, obviously it results in huge number of constraint equations and solving them would require huge computational effort. In pseudo-spatial paradigm, once the basic mechanism is analyzed, the



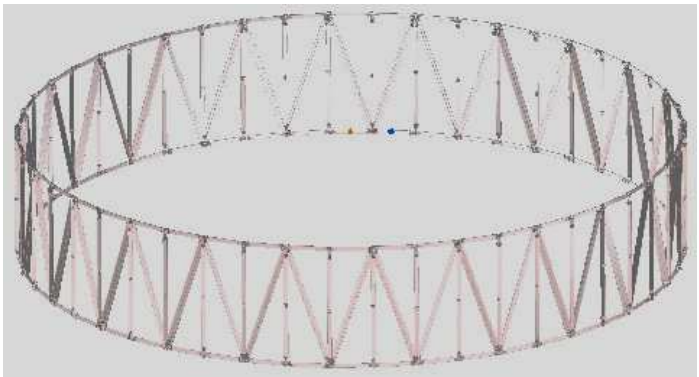


Figure 1: Translated and successively reflected special pseudo-spatial arrangements of a basic bay mechanism to obtain 18, 36 and 48 bay antennas.

required transformation is applied to determine all other mechanisms. The concept of pseudo-spatial mechanisms gives a modeling convenience, fast simulations and also an easy method for association of realistic geometries to all links. KinSys is a program developed in an STC project, in collaboration with SMG/ISAC, using MechKernel and pseudo-spatial modeling scheme to analyze this special kind of spatial mechanisms which are found in typical umbrella structures and rim trusses used in deployable antenna mechanisms. Examples of mechanisms modeled using KinSys are illustrated in the Figure-1 and Figure-2.

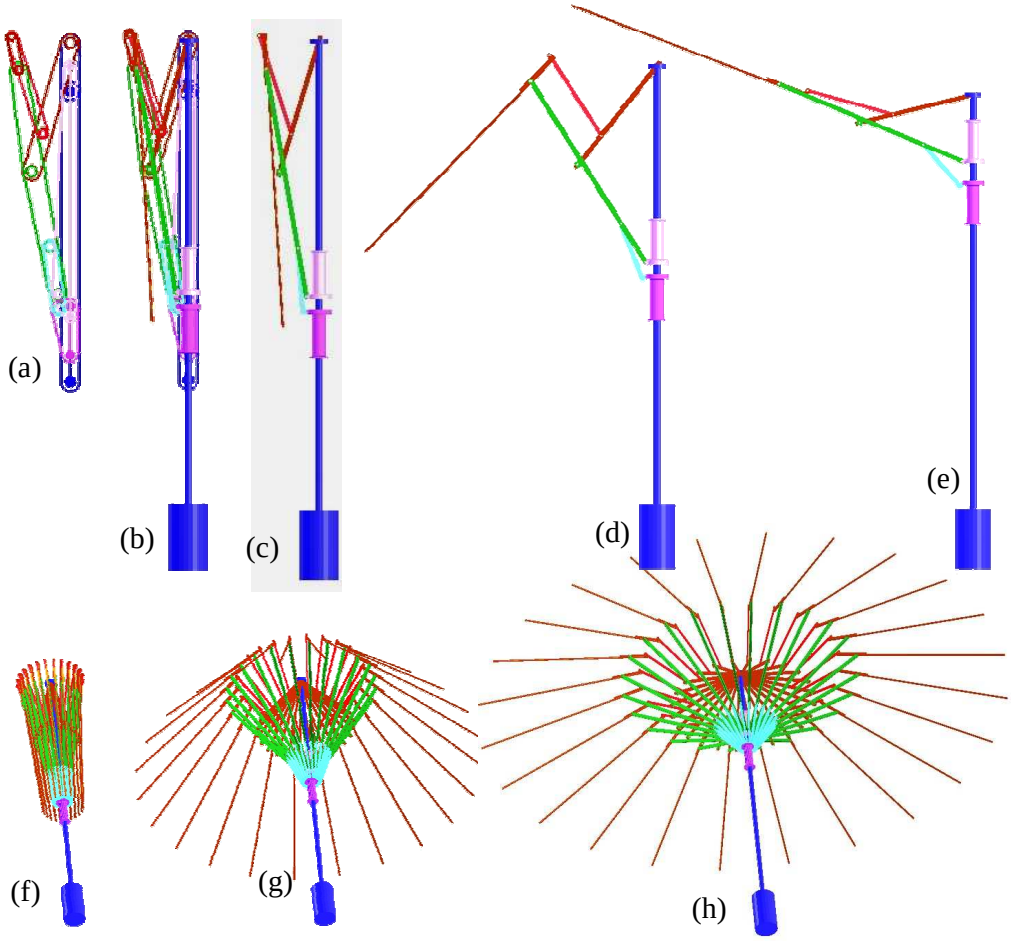


Figure 2: KinSys pseudo-spatial model of a double-folded umbrella as an axi-symmetric arrangement of planar slider-crank based mechanisms. (a) kinematic structure of the mechanism with two sliders (b) kinematic structure and geometry superimposed (c) one mechanism in folded configuration (d), (e) mechanism in different stages of deployment, (f)-(h) the pseudo-spatial model of the mechanism with 24 instances in axi-symmetric arrangement about y-axis with 30^{o} angle between two successive instances in different stages of deployment.

Forthcoming conference/seminars (Continued from page 1)

NAFEMS – INDIA Workshop on Finite Element Modeling for Engineering Analysis: Theory; Benchmarks; Case studies
At J.N. Tata Auditorium, IISc, Bangalore
On 23-24 September 2008
www.edafindia.org/nafems-workshop

International Conference on Trends in Product Life Cycle, Modelling, Simulation and Synthesis PLMSS-2008
At NAL, Bangalore, on17-19 November 2008
www.nal.res.in/nal50/plmss08
www.cpdm.iisc.ernet.in/plmss08

International Conference on Advances in Armament Technology
At ARDE, Pune, on 20-22 November 2008.
www.icaat.in

22nd National Convention of Aerospace engineers on '**Present Status and Technological Challenges of Indian Aerospace Programme**'
At Ranchi, on 27-29 November 2008.
www.ieijsc.netfirms.com

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