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CEHMS Get Involved.

Center for Energy Harvesting Materials and Systems

# The CEHMS Chronicle

## Energy Economics: Solar Energy

Once an energy source mainly adopted by the space industry, solar energy is now one of the principle renewable energy source choices within the United States.[1] And with 173,000 terawatts of energy production from the sun, daily ("10,000 times the world's total energy use"[1]), it is not surprising that the commercial demands for solar energy production are so high. This then begs the question: if solar energy is so abundant, why is it not used by everyone?

It may seem that the solar energy market has suddenly begun to take off in its popularity, the US having installed "85 percent more solar panels [in the first quarter of 2012] than the first quarter of [2011]… putting the country on track to be the fourth largest solar market in the world."[1] However, there are still marketing issues that must be addressed before solar energy can realistically begin to shine as a viable, preeminent energy source.

Picture courtesy of: The National Renewable Energy Laboratory

In today's marketable solar technology, we can run into many financial hurdles, or "soft costs"[1], making it more difficult to justify the transition into solar energy. Connecting solar panels to the power grid, costs of inspections, permitting and zoning; small businesses and homeowners may find such an expensive transition disenchanting.

There is, however, a bright side to this solar turn-off: the resources and efforts being expended towards producing more cost-effective solar prototypes. With the help of CEHMS and it's new University and industrial partners in India, the field of solar technology with soon see its widespread use come to fruition.

[1] http://energy.gov/articles/top-6-things-you-didnt-know-about-solar-energy

### Special points of interest:

- Don't forget to sign up for the 2013 Energy Harvesting Workshop, July 14-18 in Hannover, Germany!
- Next **IAB meeting** will take place in Hannover, Germany in July.

### Inside this issue:



## Technical Article: Piezoaeroelastic Energy Harvesting at CEHMS

**By Dr. Muhammad Hajj**

### Problem

**Aeroelastic vibrations are a common occurrence in aeronautical applications, civil structures and mechanical systems. In general, these vibrations are undesirable. On the other hand, they have been proposed as a means to harvest energy that can be used to operate low-power consumption devices, such as microelectromechanical systems, health monitoring sensors, wireless sensors, actuators or replacements for small batteries that have a finite life spans or would require hard and expensive maintenance. Of the different options, which include electromagnetic, electrostatic, and piezoelectric transduction, the piezoelectric one has received the widest consideration because of its capa-**

# Technical Article Cont.: Piezoaeroelastic Energy Harvesting at CEHMS

bility to harvest energy over a wide range of frequencies, its ease of application, and required volume.

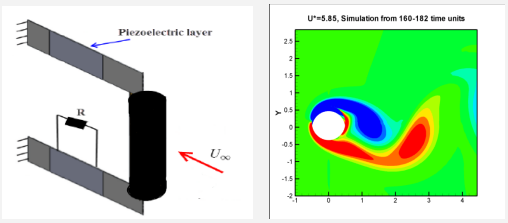
There are many challenges in designing efficient harvesters in terms of relevant power levels and high power and energy densities. These challenges are related to the nonlinearities associated with aeroelastic phenomena and the electromechanical coupling. At CEHMS, we have developed modelling and analysis capabilities of piezoelectric energy harvesting systems that can be used in their design and the optimization of their performance.

## Approach

Our group has considered different aeroelastic systems as possible candidates for energy harvesting. These include a wing undergoing limit cycle oscillations, vortex-induced vibrations of a circular cylinder and galloping structures. The approach in all of these applications has been to experimentally demonstrate the capability of energy harvesting, use the experimental results to validate a model representing the piezoaeroelastic energy harvester and use modern methods of nonlinear dynamics to analyze the system. This analysis is then used to optimize the performance of the system by varying its parameters.

## Findings

1. The eccentricity and linear and nonlinear stiffness are important factors in determining the level of harvested power from wing-based piezoaerelastic systems. The effects of variations in the electrical load resistance on the flutter speed and pitch and plunge motions are negligible. On the other hand, these variations affect the output voltage and power.
2. When harvesting energy from vortex-induced vibrations, the load resistance influences the onset of the synchronization region and its characteristics. The nonlinearity associated with the vortex-induced oscillations results in a hardening behavior and hysteresis. The highest levels of harvested energy are associated with minimum displacement of the cylinder; a result that shows the need for the coupled analysis as performed in our investigations.
3. The galloping phenomenon of prismatic structures offers the capability to harvest energy over a wide range of operating parameters (particularly the speed). The load resistance affects the onset speed of galloping. Also, analysis of the coupled electro-mechanical problem shows that the highest power levels are accompanied by minimal structural displacement. This is due to the fact that the kinetic energy of the structure is transferred to electrical power.




Schematic of a piezoaeroelastic energy harvesting systém and results from numerical simulations.

## Selected Publications

A. Mehmood, A. Abdelkefi, M.R. Hajj, A.H. Nayfeh, I. Akhtar and A. Nuhait "Piezoelectric Energy Harvesting from Vortex-Induced Vibrations of Circular Cylinder, " *Journal of Sound and Vibration* (in press)

A. Abdelkefi, Z. Yan, M.R. Hajj "Modeling and nonlinear analysis of piezoelectric energy harvesting from transverse galloping," *Smart Materials and Structures*, 2013 doi:10.1088/0964-1726/22/2/025016.

A. Abdelkefi, M.R. Hajj, A.H. Nayfeh "Piezoelectric Energy Harvesting from Transverse Galloping Oscillations of Bluff Bodies," *Smart Materials and Structures* 2013 doi:10.1088/0964-1726/22/1/015014

A. Abdelkefi, M.R. Hajj, A.H. Nayfeh "Power Harvesting from Transverse Galloping of Square Cylinder," *Nonlinear Dynamics*, 2012, 70, 1355–1363, doi: 10.1007/s11071-012-0538-4

A. Abdelkefi, M.R. Hajj and A.H. Nayfeh "Phenomena and Modeling of Piezoelectric Energy Harvesting from Freely Oscillating Cylinders," *Nonlinear Dynamics*, 2012, 70, 1377–1388, doi: 10.1007/s11071-012-0540-x

A. Abdelkefi, A.H. Nayfeh, and M.R. Hajj "Enhancement of Power Harvesting from Piezoaeroelastic Systems," *Nonlinear Dynamics*, 2012, 68 (4), 531-540. doi: 10.1007/s11071-011-0234-9

A. Abdelkefi, A.H. Nayfeh, and M.R. Hajj "Design of Piezoaeroelastic Energy Harvesters," *Nonlinear Dynamics*, 2012, 68 (4), 519-530. doi: 10.1007/s11071-011-0233-x

A. Abdelkefi, A.H. Nayfeh, and M.R. Hajj "Modeling and Analysis of Piezoaeroelastic Energy Harvesters," *Nonlinear Dynamics*, 2012, 67(2), 925-939. doi: 10.1007/s11071-011-0035-1

# International Relations: The Korea Institute of Materials Science

Materials technology is a technology that creates new avenues in performance and service, which nearly all industries directly and indirectly rely upon History has shown that advanced materials and their application play a vital role in the foundation of industries and continue to carry on its impact on society.

The Korea Institute of Materials Science (KIMS) is confident that dedication to outstanding research and development, acting as the hub for interdisciplinary collaboration, authorizing test and evaluation, motivating national consortium ,will advance mankind and society. As a Korean government funded research institute, the object at KIMS is to comprehensively facilitate research and development, test and evaluate, and provide technical support related to materials technology in order to promote innovative technology and industrial development.

The Functional Ceramics Group in KIMS, a highly active research team established in 2005, conducts in-depth researches on various functional ceramics technologies, surpassing the limit of conventional materials. Eight research staff and approximately ten research assistants/ students work diligently within this group. All research staffs have Ph.D degrees in various research areas such as piezoelectrics, multiferroics, catalysts, fuel cells, biomaterials, and applied physics. Their current research topics include:

- Development and evaluation of low temperature processed large-area electrolyte/ electrode film for SOFC application.
- Research on composition development and thick film fabrication process of lead-based/lead-free piezoelectric materials and temperature sensitive NTC thin film materials for multi-functional sensor applications.
- Development of the biocompatibility improved functional biomedical coatings.
- High-efficiency photo- and gas-catalyst for noxious gas reduction.
- Solid electrolyte thin/ thick films for all solid state Lithium ion batteries.
- Magnetoelectric composites and multiferroic materials for energy or sensor applications.
- Magnetocaloric materials for low/room temperature refrigerating machine without refrigerant.

Very recently, the KIMS Functional Ceramics Group developed a large area (100 x 65 $cm^2$) ceramic thick film coating technique by so called aerosol-deposition (AD). The AD can deposit various nano crystalline ceramic films (oxide, nitride, and carbide) with very high deposition rate (> 1 μm/min) at room temperature. Presently, the group is concentrating this novel process to adapt above listed research topics. They published more than 90 research articles and 30 patents on this technique since their establishment.

For more information on KIMS, please go to:

http://www.kims.re.kr

KIMS Logo

# Student Profile: Cary Baur

One of the University of Texas at Dallas's ingenious and accomplished students, Cary Baur has been an essential part of The Center for Energy Harvesting Materials and Systems for the past several years. Working closely with Dr. Dennis W. Smith, Cary has dedicated his time to enhancing "piezoelectricity in PVDF through the addition of carbon nanoparticles", an endeavor which has resulted in "2x enhancement in current material, an exciting breakthrough" made possible by CEHMS funding and interest. When asked about his experiences with CEHMS and how working with an I/UCRC has impacted his career, Cary noted that he "[has [ had the opportunity to collaborate with complimentary scientists to develop technology that would otherwise be impossible, and I have met with many industrial CEHMS members that have showed interest in my work… I was able to meet many people that are working in the same field as I am. As a result, new collaborations are developing that would not have been possible without [CEHMS]".

Cary Baur

# CEHMS Annoumces Inventor Award Winner: Walter Herrmann

It all started in 1961 with a big bang when the young electrician Walter Herrmann watched his newly developed ultrasonic generator blow up in his face. He had previously set up his own company without any equity capital, hardened machine parts in his wife's kitchen, and turned the living room into a design office. Once he had perfected his low-voltage machine generator, there was finally an alternative to the failure-prone and low-performance ultrasonic generators which needed up to 10,000 Volts. After initially only using the generator for ultrasonic cleaning, Walter Herrmann rapidly discovered new markets for ultrasound and he started building machines in Karlsbad-Ittersbach that could be used to weld plastic parts. These were later joined by machines for sealing plastic packaging and, in the 1990s, for laminating and embossing nonwovens, which are used for products such as filters and diapers, reflecting the diversity of ultrasound.

The company has always been innovative; Herrmann Ultraschall is a technology leader in its field. It has very few serious competitors because its technology is very complex. Through his inventions and patents, Walter Herrmann has been a major force behind the development of ultrasonic joining technology and his work has brought him numerous awards and accolades. The last was the ZIM-Solo innovation prize from the German Federal Ministry of Economics and Technology in 2010. The company donated the prize money to its two partner schools, Werkrealschule Langensteinbach and the Albert-Schweitzer-Schule Waldbronn. After all, Herrmann has already joined the competition to recruit the engineers of the future. This makes the Chamber of Commerce and Industry's initiative "Wirtschaft macht Schule", which links schools and industrial partners, a key HR marketing tool.

Walter Herrmann

Son Thomas Herrmann manages the company with Arnold Schneider, ensuring that Herrmann Ultraschall remains in the family. Herrmann's daughter, Sabine Herrmann-Brauss, also works in the company's finance division. "The future looks good; the company has plenty of potential for growth," says Thomas Herrmann. Today, Walter Herrmann still attends strategy meetings, but is delighted to have more time for hunting, his great passion. His best technical ideas have come to him in the hide. The beauty, peace and quiet of nature have always kept him in touch with reality.