Metrology for energy harvesting
European Metrology Research Programme

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Project news

Dr Mauro Zucca, and colleagues from the **Istituto Nazionale di Ricerca Metrologica**, (INRIM) have published research around a new approach to electromagnetic harvesting using the magnetostrictive properties of amorphous ribbons to generate an electromotive force upon time-varying stresses of vibrational origin.

The *paper* has been published in IEEE Transactions on Magnetics and describes a design composed of magnetothermally treated Fe-based amorphous ribbons which produced a power output around 20 uW / cm3 per unit volume (not yet optimized) of core material delivered into the load at 100 Hz.

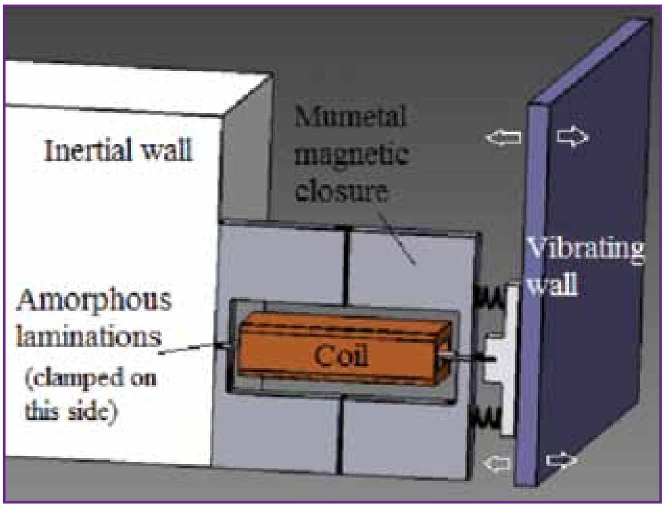

Figure 1. Scheme of the magnetostrictive harvester based on amorphous ribbons

The team presented the paper at this year's IEEE International Magnetics Conference (Intermag 2011), held in April in Taipei. Amongst the other presentations at the conference, Dr Zucca was particularly interested in research from Japan into *energy harvesting of magnetic power-line noise*.

Dr Zucca said: "It is interesting to note that since the article from Kurs and colleagues in *Science in 2007*, interest in the wireless transmission at distance of electrical power through strong coupled resonant circuits has constantly grown. As far as I know this paper from Japan is the first application to energy harvesting."

At the end of September researchers from **Physikalisch-Technische Bundesanstalt** presented on thermoelectric energy conversion at ECT2011, the *9th European Conference on Thermoelectrics* in Thessaloniki. There was a huge interest in their presentation (a poster from which can be viewed *here* and a four page paper will appear in a special volume of AIP Conference Proceedings).

The paper describes the methods to reach one important stopover of the project: the development of traceable and robust metrology to provide reliable property specifications for thermoelectric materials; in particular for Seebeck coefficients.

Dr Frank Edler and Dr Ernst Lenz from PTB report a real need for standard reference material for thermoelectrics in the temperature range 300 K to 900 K. As a result of their presentation the project is able to welcome new contacts from industry and academia, including researchers from Japan, Slovakia, Finland and Germany.

Dr Alexandre Bounouh and colleagues at the **National Physical Laboratory** (NPL) are preparing an abstract for submission to the *Conference on Precision Electromagnetic Measurements 2012* in Washington DC in July (see Upcoming Events). The paper looks at the development of a traceable measurement technique to determine both resonant frequency and damping parameter of MEMS based energy harvesters (EH) or more generally of micro and nano-electromechanical systems.

***Visit our blog at** http://emrp-metrology-for-enery-harvesting.blogspot.com*

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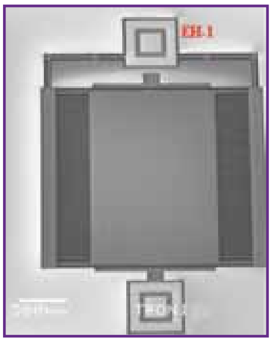

Figure 2a. MEMS based electrostatic EH

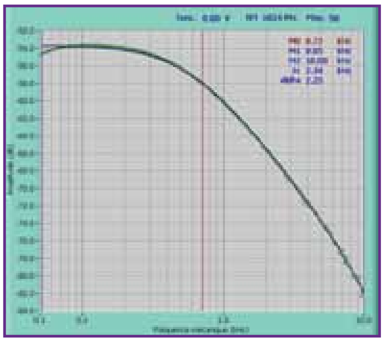

Figure 2b. Harmonic analysis of the MEMS output signal

The measurements are carried out through a distortion analysis of the output signal of the EH by sampling techniques using a digital voltmeter (DVM). The results are compared to values obtained with deep level transient spectroscopy (DLTS) measurements and finite elements computations performed with CoventorWare.

A simulation tool of a magnetostrictive harvester has been developed at **Istituto Nazionale di Ricerca Metrologica**. Stress or strain time-behaviour up to 64 harmonic components constitutes the direct input for the model, allowing a particular high resolution of the mechanical excitation. The model is based on a physical approach taking into account the non-linear material behaviour, including hysteresis, and implements a 2D finite element procedure together with a coupled electrical circuit.

A prototype of the magnetostrictive generator has been set-up to validate the software. By assigning an accurate reconstruction of the force input (at least 32 harmonic components) to the software, it is able to reconstruct the waveform of the voltage and the strain with a maximum discrepancy, attributable solely to the peak values, not exceeding 7%. The software can be particularly useful for the design of a harvester and for the optimization of dimensional parameters.

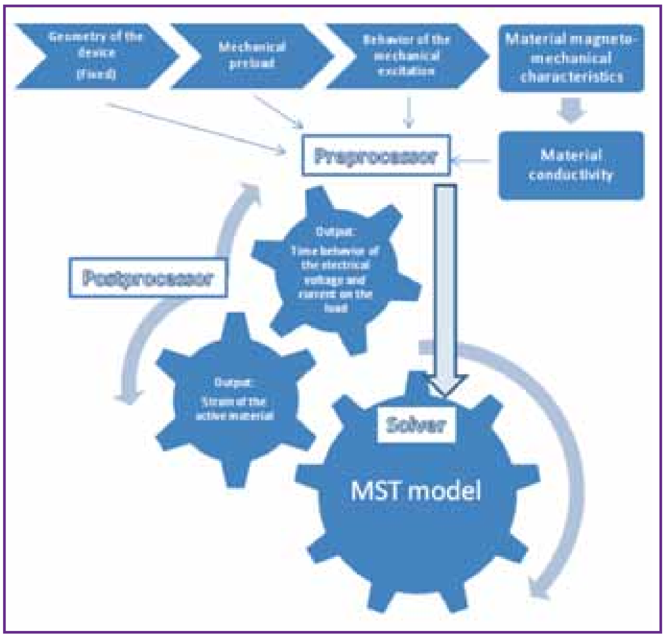

Figure 3. The software modules developed at INRIM

Upcoming events

IEEE-MEMS2012
29 Jan – 2 Feb
Paris

DPG-Frühjahrstagung 2012
25-30 March
Berlin

Printed Electronics and Photovoltaics Europe 2012
3-4 April
Berlin

ICMOVPE-XVI
20-25 May 2012
Busan, Korea

Energy Harvesting & Storage Europe 2012
15-16 May
Berlin

View from industry:

Sami Hakulinen, Metso Automation

Metso is a global supplier of sustainable technology and services for the mining, construction, power generation, automation, recycling and the pulp and paper industries. It has about 29,000 employees in more than 50 countries.

Metso's automation professionals specialize in process industry flow control solutions, automation and information management systems and applications, and life cycle services. Main products include for example control valves, automation systems, quality control systems and measurement solutions.

Sami Hakulinen works within Metso Automation in the production of intelligent positioners for control- and on/off valves, used mostly in refineries and paper mills.

What do you do at Metso?

Our customers come to us with all kinds of challenges. In some cases we design and build whole new factories from DCS systems down to field devices for optimised performance. Whilst for others we are retrofitting new devices on top of existing infrastructure. In either case our clients are looking for a solution which they can install and forget about, leaving the equipment to operate without any concerns over reliability.

There is a lot of demand for advance diagnostics within field devices to monitor the quality and reliability of the process control devices and predict defunctionality of the system. To do this we install intelligent devices that are fitted alongside the process control devices. These can measure anything from stresses and response times, to leakage across the process pipeline and pressures to calculate load factors.

When did you first come across energy harvesting technology and what were your initial thoughts?

It was around 2008 or 2009, probably at an exhibition. Straight away I thought it was an exciting idea.

At the time there was a lot of talk around the use of wireless technology in the process engineering industry. We knew our customers were concerned about the maintenance load involved in changing batteries for wireless devices. Therefore there was a strong interest in harvesting technology.

Soon after we started to contact some providers to see how their products could work in the environments we operate in.

What were your initial concerns?

The problem for us is we are not developing measurement instruments; rather we focus on the production of process control assemblies with smart field devices. The energy demand for our field devices are so much higher than for transmitters which are more commonly talked about as an application.

I felt the devices on the market lacked the capability needed to power wireless systems for control uses. I would say even today energy harvesting solutions are not at the level required for real process control.

Are there any areas where you think application is more likely?

It's hard to say exactly how it might be used. There may be applications for long distance wireless systems like in oil pipelines or wellheads but this is not my particular area of expertise.

Within the mining side of our business, big machines like crushers contain many moving parts and are constantly vibrating. Here the environment is not suitable for delicate wiring. There are lots of stones being processed which could potentially cut through the cables so wireless monitoring devices might be a really good idea. I also imagine it would be easier to retrofit extra measurement devices retrospectively if they were powered wirelessly.

Have Metso conducted any research into energy harvesting?

We have looked into thermal energy recovery for powering our devices and vibrating systems as well. We have also conducted some research into wireless energy transfer.

Whilst the thermoelectric generators (TEGs) seem to be the most promising, there are still significant challenges around energy output. Low power sensors might work fine with the energy available but the field devices within our process control systems require between 50- 100 mW, and yet from our trials we haven't achieved that much power from energy harvesting.

As a result for the field device case the temperature difference for these TEG elements needs to be continuously around 50 Celsius which is unrealistic at present. Developers might need to look at new ways to maintain this temperature difference for higher energy demand applications like ours – potentially in the design of more effective cooling systems.

Have you encountered any other problems with energy harvesting devices?

Neither us, nor our customers know the conditions these harvesters would sit in and therefore what sort of power output they could provide. The vibration side is particularly challenging in this respect – we know the field devices are always vibrating, but we don't know the frequency or the amplitude of these vibrations and they probably vary in every position.

In order to make this feasible, we would like to be able to harvest all possible energy sources, vibration and temperature together, at the same time.

Do you see any further problems which could hold back adoption of energy harvesting with your business sector?

The operating environment could be quite challenging for these devices, especially for the cooler models I have seen. There could be a lot of dirt in sites and the devices may be handled very roughly. This might affect their long term reliability.

Price is another consideration. At present there is no obvious financial justification for making the switch over because the price of energy harvesting solutions should not exceed the price of battery based equivalents, unless their maintenance free lifetime exceeds significantly the lifetimes of the battery based solutions.

Are there any areas within energy harvesting that you would like to see further research?

The one interesting questions is the interface between the field device and whatever powers it, in particular how to utilise this energy and what type of energy storage you need. This is key as the optimum position for harvesting energy isn't always going to be where you want to evaluate or monitor your equipment and the brown out times for the energy sources are also not known.

The best possible solution would be a harvester embedded in the device which measures or monitors the same thing that powers the device, but this is not always the case. You are always going to need cables when the harvester is separated in space from what it powers and the last thing we need is extra cables.

How do you see the health of the energy harvesting market going forward?

If you think of the move towards greener energy technology, then you would suspect energy harvesting is far more likely to grow than decline.

At present it is mainly targeted towards wireless solutions and there seems to be a lot of support and interest in this technology. If developers can prove energy harvesting as the solution for wireless monitoring then it has a good chance. There may also be applications as a complement, rather than simply a replacement for wire-based systems if the output of the existing solution is particular low.

How do you see the important of metrology in the future of energy harvesting technology?

It's key. If manufactures are providing devices, and companies like ours are developing process incorporating these devices into their systems, it's vital that we know what we are getting.

***We welcome feedback, opinion and suggested articles. Please send your comments to** markys.cain@npl.co.uk **and** james@proofcommunication.com*

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