ICAEHT 2021

(Virtual Mode)

INDO-POLISH INTERNATIONAL CONFERENCE ON ADVANCES IN ENERGY HARVESTING TECHNOLOGY

BOOK OF ABSTRACTS

Edited by :

Dr. Pradeep V.Malaji

ICAEHT 2021

(Virtual Mode)

INDO-POLISH

INTERNATIONAL CONFERENCE ONADVANCES IN ENERGY HARVESTING TECHNOLOGY

Edited by
Edited by: Dr. Pradeep V.Malaji
ICAEHT-2021
BLDEA's V.P.Dr.P.G.Halakatti College of Engineering and Technology
Vijayapur-586 103, India

Book of Abstracts of International Conference on Advances in Energy Harvesting Technology, Virtual (Online) March 18 - 20, 2021

Sponsors

Forward
ICAEHT-2021

Welcome to International Conference on Advances in Energy Harvesting Technology ICAEHT2021 (virtual mode). The Conference adopts a timely theme, featuring workshop sessions and keynotes of broad interests and oral presentations covering recent advances in the rich spectrum of topics covered by Energy Harvesting, including new frontiers and challenges such as nonlinear dynamics, control, thermoelectric, triboelectric harvesters, materials and storage.

This conference is jointly organized by Department of Mechanical Engineering, BLDEACET, Vijayapur, India and Department of Automation, Lublin University of Technology, Poland in the frame of EHDIALOG, supported by the program of the Minister of Science and Higher Education in Poland under the project DIALOG 0019/DLG/2019/10 in the years 2019-2021. The conference is special because the conference is registration free for presenting authors to facilitate broad participation and features award of $ 100 for three best presentations by students for explaining their research in 3 minutes. The conference features 3 keynotes, 16 invited talks and 75 regular presentations in the following areas;

- Nonlinear effects in energy harvesting
- Triboelectric energy harvesting
- Energy harvesting, Structural Health Monitoring and Control
- Metamaterial/Metastructures for energy harvesting
- Multifunctional materials for energy harvesting
- Thermoelectric energy harvesting
- Ocean energy Harvesting
- Energy harvesting circuits
- Application of energy harvesting in biomedical
- Energy harvesting for IoT

The workshop sessions were invited from leading researchers in the energy harvesting field on the above topics. Total 12 different sessions are hosted. The success of ICAEHT 2021 depends largely on these session organizers and enthusiastic authors. Special praise is also deserved for committee members on organizing, advisory, steering and technical committees.

We gratefully acknowledge BLDEACET, India, VTU, India, Lublin University of Technology, Poland, EHDIALOG, Poland, AIMIL, India, Casper instruments, India for their sponsorship

Prof. Grzegorz Litak
Dr. Pradeep V Malaji
Dr. Piotr Wolszczak

ICAEHT 2021
March 2021

Brief Report

The conference received 96 abstracts (including invited talks) of which 91 abstracts were selected after review. 90 presentations were made during the conference. Participants from 22 nations (Fig. 1) presented their work during 3 days (Fig. 2).

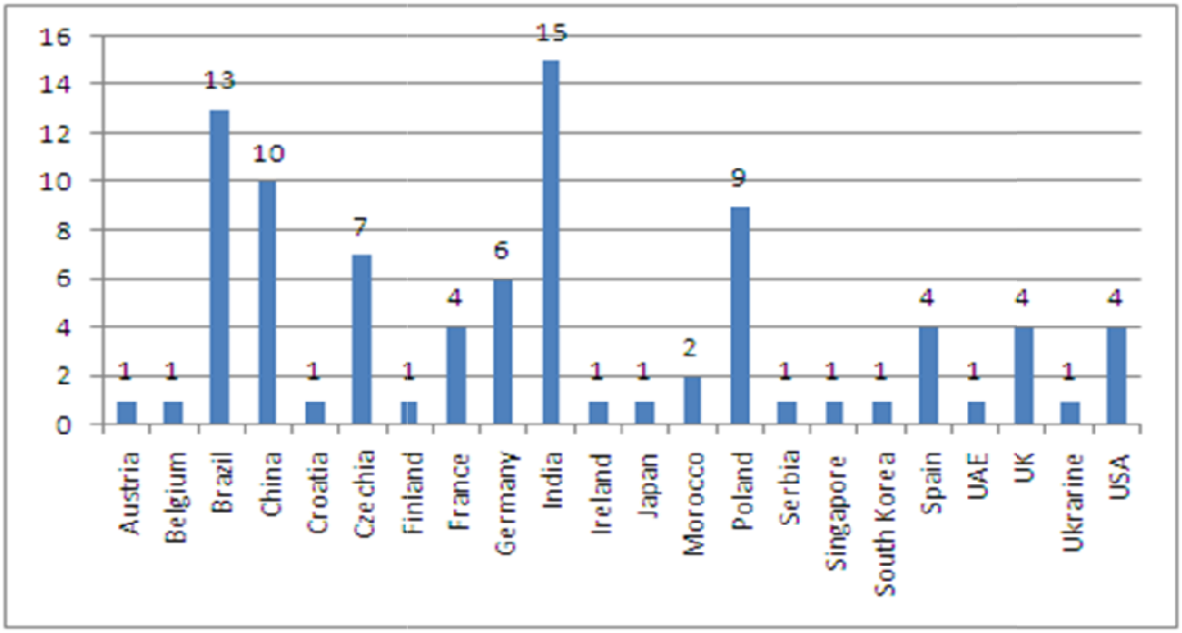


Figure 1. Nation wise participation

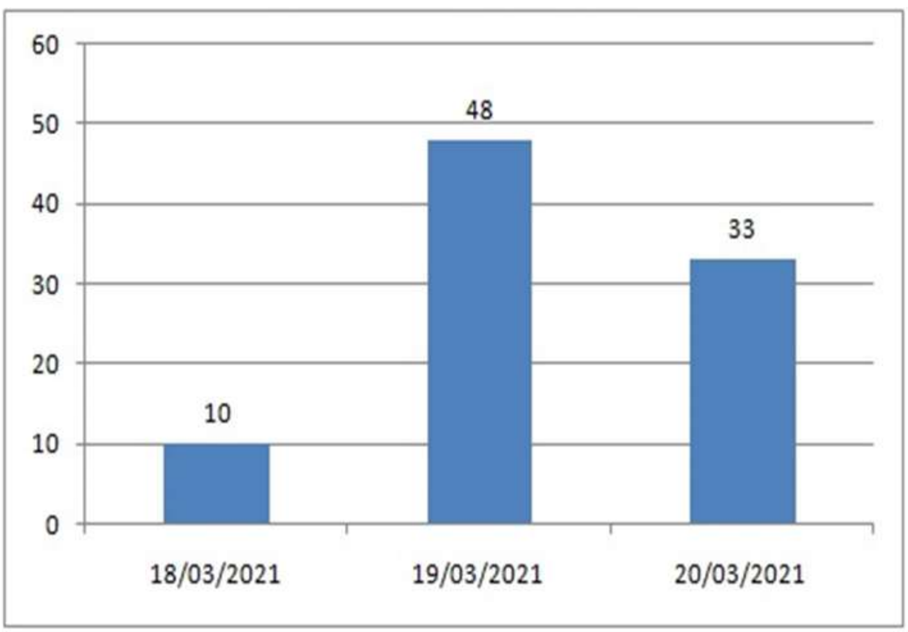
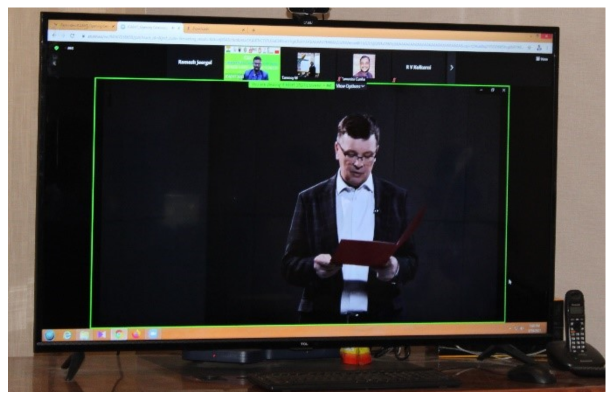
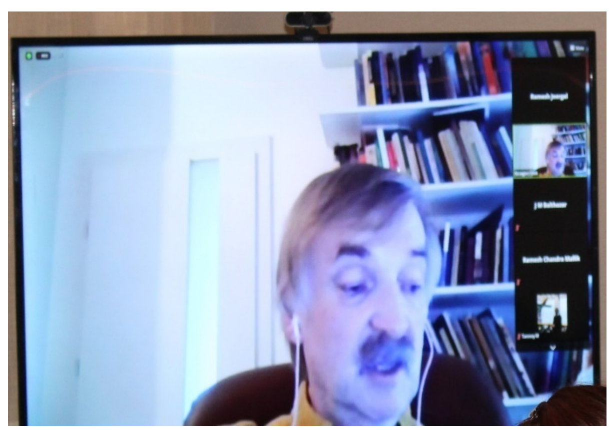


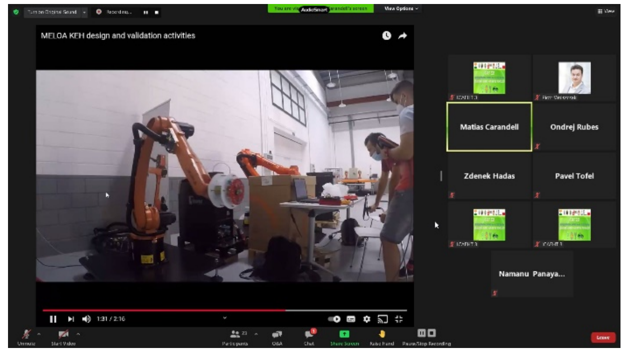
Figure 2. Day wise Presentation

An industry-academia panel discussion was held on March 19, 2021. The panel discussed regarding application, challenges to bring energy harvesting technology from lab to land, industry academia collaboration and funding opportunities from various national/international sources were discussed. Dr. Shaikh Faruque Ali, IIT Madras Chaired the session with following panelists.
Tomasz Szewczyk, Sitaniec Technology, Poland
Przemysław Łagód, Cubetech, Poland
Łukasz Kurzępa LBR lab, Poland
Tomasz Korbiel, AGH University of Technology, Poland
Grzegorz Litak, Lublin University of Technology, Poland
J. AroutChelvane,DMRL-DRDO,India
D. D. Ebenezer, Adjunct Faculty, CUSAT, Kochi, Retired Director (Systems), NPOL, India
Aravindan Ramalingam, FTD solutions,Singapore





Photos: Conference opening ceremony



Photos: Conference sessions

Winners of Explain your research in 3 minutes (award of $ 100 sponsored by EHDIALOG)

Total 11 videos were received from students which were reviewed by 3 experts. 4 best presentations were selected for award based on scores given by experts.

Student Name	University	Topic
EDUARDOABUHAMAD PETROCINO	UNESP SÃO PAULO STATE UNIVERSITY, BRAZIL	REDUCTION OF THE SOMMERFELD EFFECT ON A NON-IDEAL SYSTEM WITH ELECTROMAGNETIC INTERACTION
JOAO PEDRO NORENBERG	SAO PAULO STATE UNIVERSITY, BRAZIL	EXPLORING THE BEHAVIOR OF A BISTABLE ENERGY HARVESTER VIA GLOBAL SENSITIVITY ANALYSIS
SANYUKTA GHOSH	IISC, BANGALORE, INDIA	ENHANCEMENT OF THERMOELECTRIC PROPERTIES OF CO4SB12 VIA COMBINED STRATEGY OF FILLING THE VOIDS AND NANOCOMPOSITES
LUCAS MACHADO	HERIOT WATT UNIVERSITY, UK	PIEZOELECTRIC ENERGY HARVESTING FOR ELECTRONIC GADGETS

Prof. Grzegorz Litak
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Dr. Piotr Wolszczak

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Ramesh Malladi, BLDEACET, India

Sl No	Name of the session	Organizers
01	Multi-functional materials for energy harvesting and sensing	Yang Bai, University of Oulu, Finland, *Email:* yang.bai@oulu.fi Chris Bowen, University of Bath, UK, *Email:* msscrb@bath.ac.uk
02	Thermoelectric energy harvesting **(**Materials & modeling, Device Development & Testing, Systems Design & Applications**)**	Ramesh Chandra Mallik, IISc, Bangalore, *Email:* rcmallik@iisc.ac.in
03	On emergent nonlinear energy transfer vibrating problems and phenomena	J M Balthazar, UNESP-UniversidadeEstadualPaulista, Bauru-SP, Brasil and UniversidadeTecnológica Federal do Paraná, Ponta Grossa, PR, Brasil, *Email: jmbaltha@gmail.com*
04	Rotational and Multi-directional vibration energy harvesting for smart sensing	Shengxi Zhou, Northwestern Polytechnical University, China, *Email:* zhoushengxi@nwpu.edu.cn Wenbin Huang, Chongqing University, China, *Email:* whuang@cqu.edu.cn
05	Nonlinear effects in energy harvesting	Krzysztof Kucab, University of Rzeszów, Poland; *Email: kkucab@ur.edu.pl* Mohamed Belhaq, University Hassan II – Casablanca, Morocco, *Email:* mbelhaq@yahoo.fr
06	Electrical interfaces for efficient energy harvesting	Prof. MickaëlLallart, Univ. Lyon, INSA-Lyon, LGEF EA 682, F-69621, France, *Email:* mickael.lallart@insa-lyon.fr
07	Energy harvesting & vibration control in mechanical systems	Krzysztof Kecik, Lublin University of Technology, Poland, Email: k.kecik@pollub.pl Marek Borowiec, Lublin University of Technology, Poland, Email: m.borowiec@pollub.pl
08	Energy Harvesting for Structural Health Monitoring	FavourOkosun, Dynamical Systems and Risk Laboratory, School of Mechanical and Materials Engineering, University College Dublin, Ireland, Email: favour.okosun@ucdconnect.ie Vikram Pakrashi, Dynamical Systems and Risk Laboratory, School of Mechanical and Materials Engineering, University College Dublin, Ireland, Email: vikram.pakrashi@ucd.ie

09	Energy Harvesting from Flow Induced Vibrations	Daniil Yurchenko, Heriot-Watt university, UK, Email: D.Yurchenko@hw.ac.uk Junlei Wang, Zhengzhou University, china, Email: jlwang@zzu.edu.cn
10	Vibration energy harvesting applications for wireless sensing and condition monitoring	ZdenekHadas, BRNO UNIVERSITY OF TECHNOLOGY, Czech Republic, Email: hadas@fme.vutbr.cz
11	New trends and tools for energy harvesting using smart materials and systems	Americo Cunha, Rio de Janeiro State University, Brazil, Email:americo.cunha@uerj.br Marcelo Savi, Federal University of Rio de Janeiro, Brazil, Email: savi@mecanica.coppe.ufrj.br Paulo SérgioVaroto, University of São Paulo, Brazil, Email: varoto@sc.usp.br Samuel da Silva, São Paulo State University, Brazil, Email: samuel.silva13@unesp.br
12	Materials and Devices for Energy Harvesting	Prof. Dr.-Ing. Olfa Kanoun, Chemnitz University of Technology, Email:olfa.kanoun@etit.tu-chemnitz.de Dr.-Ing. Sonia Bradai, Chemnitz University of Technology, Email: sonia.bradai@etit.tu-chemnitz.de Dr.-Ing. Slim Naifar, Chemnitz University of Technology, Email: slim.naifar@etit.tu-chemnitz.de

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Materials and Devices for Energy Harvesting

New trends and tools for energy harvesting using smart materials and systems

Nonlinear effects in energy harvesting

Thermoelectric energy harvesting,

Vibration energy harvesting applications for wireless sensing and condition monitoring

ELECTRICAL INTERFACES FOR EFFICIENT ENERGY HARVESTING

1. A unified nonlinear circuit combining piezoelectric and electromagnetic transducers

Giulia Lombardi*, Mickaël Lallart*
Univ. Lyon, INSA Lyon, LGEF, EA682, F 6 9621, VILLEURBANNE, FRANCE
giulia.lombardi@insa-lyon.fr

Abstract. With the aim of using as much as electro active parts as possible in the same electronic interface, the purpose of this work is to propose a hybrid nonlinear circuit combining piezoelectric and electromagnetic harvesting systems for significantly increasing the final output power while ensuring a relative independence to the load. The resulting technique, called Synchronous Electric Charge and Induced Current Extraction (SECICE) has been developed taking into consideration the Synchronous Electric Charge Extraction (SECE) and the Synchronous Magnetic Flux Extraction (SMFE) schemes, initially developed for the sole use with piezoelectric and electromagnetic transducers, respectively.

2. Analysis and Improvement of Self-powered P-SSHI Circuit for Piezoelectric EnergyHarvesting Eliminating the Effect of the Second Inversion

Hongsheng LIU*, **Bin ZHANG***
**School of Mechanical, Electrical & Information Engineering, Shandong University, Weihai, Shandong, China* liuhongsheng96@mail.sdu.edu.cn

Abstract. Piezoelectric energy harvesting (PEH) technology is considered a most promising method to power the wireless sensor nodes. Existing research has proven that the parallel synchronized switch harvesting on inductor(P-SSHI) interface circuit can significantly increase energy harvesting capability by several times compared to the standard energy harvesting (SEH) interface circuit. A new self-powered parallel synchronized switch harvesting on inductor (NSP-PSSHI) interface circuit is proposed, which adopts a new type of peak detection switching circuit to replace the synchronous switch in the P- SSHI circuit. The 'second inversion' phenomenon which is a side effect of the existing SP-PSSHI circuit, can be effectively eliminated. By analyzing the cause and the influence of this phenomenon, the energy flow and harvesting power of NSP- PSSHI circuit are studied. Experiments on the SEH, SP-PSSHI and NSP-PSSHI circuits show that the NSP-PSSHI circuit can effectively reduce the 'second inversion' influence, and the maximum harvesting power is 2.91 times of the SEH circuit.

Invited Talk

3. Resonant frequency tuning of piezoelectric energy harvesters thanks to electricalinterfaces

Adrien Morel[*], Gaël Pillonnet[*] and Adrien Badel[**]
[*]*Univ. Grenoble Alpes, CEA, LETI, F-38000 Grenoble, France*
[**]*Univ. Savoie Mont-Blanc, SYMME, F-74000 Annecy, France,* adrien.morel@cea.fr

Abstract. In this presentation, we describe electrical interfaces able to tune the resonant frequency of piezoelectric energy harvesters, thanks to the inverse piezoelectric effect. We propose an analysis of the influences of the electrical interface on the dynamics of the harvester, and show how these influences might be used to both optimize the harvested power and tune the resonant frequency of the system. Finally, we present a self-powered integrated circuit that makes use of this effect in order to harvest energy from a piezoelectric energy harvester while adjusting its dynamics in real-time. The total power consumption of our circuit lies around 1µW, its end-to-end efficiency is 94%, and it is able to adjust the resonant frequency of a highly coupled harvester from 49Hz to 60Hz. This makes our circuit a promising solution for extracting energy from piezoelectric energy harvesters while improving their robustness to aging and environmental changes thanks to its frequency tuning ability.

ENERGY HARVESTING & VIBRATION CONTROL IN MECHANICAL SYSTEMS

4. Dynamic Analysis of Beam Coupled with Resonant Piezoelectric Shunt

Braion Barbosa de Moura*, Matheus Canêdo Ribeiro Borges* and Marcela Rodrigues Machado*
**Department of Mechanical Engineering, University of Brasília, Brasília, DF, Brazil*
braionbarbosa@gmail.com

Abstract. The present study deals with analysing a smart beam's dynamic behaviour coupled with piezoelectrics in the unimorph and bimorph configurations connected to the resonant shunt circuit. The resonant circuit shunt's connection is applied to promote the vibration and flexural wave propagation attenuation. The Spectral Element Method (SEM) is used to model smart structure and estimate the vibration and flexural wave attenuation. The wave attenuation is obtained employing the Transfer Matrix Method (TMM). Comparisons between the attenuations of the unimorph and bimorph configurations are demonstrated in this work.

5. Analytical Approach to Design Smart-metamaterial Beam Coupled with Resonant Shunt to Vibration and Flexural Wave Attenuation

Matheus Canedo R. Borges*, Braion Barbosa de Moura* and Marcela R. Machado*
**Department of Mechanical Engineering, University of Brasília, Brasília, Distrito Federal, Brazil*
canedo001@gmail.com

Abstract. This study proposes a comparison between a numerical and an analytical approach for an investigation and analysis of a smart metamaterial beam's dynamic behaviour coupled with piezoelectrics in the unimorph configuration integrated with a resonant shunt circuit. The flexural wave propagation and vibration attenuation are achieved by the resonant shunt circuit dissipating the energy of the structure generated by the piezoelectrics. The results are obtained using the analytical approach based on modal analysis and numerical model via Spectral Transfer Matrix Method.

6. Optimizing piezoelectric energy harvesting absorbers with mechanical and magnetic amplitude stoppers

Tyler Alvis*, Mikhail Mesh**, Abdessattar Abdelkefi*
Department of Mechanical and Aerospace Engineering, New Mexico State University, Las Cruces, NM, USA
*** Sandia National Laboratories, Albuquerque, NM, USA,* ty24@nmsu.edu

Abstract. Tuned mass dampers are a common method to control systems under base excitation. This study adapts a piezoelectric energy harvester as the tuned mass damper to convert the mechanical energy of the system into usable electrical energy. Additionally, amplitude stoppers are included to the energy harvesting absorber to optimize the electrical response from the absorber without adverse effects to the control of the primary system. The stopper type is of interest for this study by comparing mechanical-impact stoppers to magnetic stoppers. Results show that soft mechanical stoppers of $5*103N/m$ show an increase in power generation and adequately controls the primary system, where magnetic stoppers with medium gaps around 5 cm show a slight increase of generated power and excellent control of the primary system.

7. Energy Harvesting in Non Linear energy sinks due to stochastic input forcing

Jishnu Roy Chaudhury, Siddharth Pillai, J. Venkatramani, Pradeep Malaji,
Department of Mechanical Engineering, Shiv Nadar University, Greater Noida, Uttar Pradesh, India
Department of Mechanical Engineering, BLDEA's V P Dr. P G Halakatti College of Engineering and Technology, Bijapur, jr714@snu.edu.in

Abstract: Vibration mitigation is attracting lot of researcher to safeguard machines and structures. Energy harvesting along with vibration mitigation gives added advantage of generating enough electrical energy to powerup sensors. Vibration energy harvesting converts vibration into useful electrical energy using suitable transduction method. Nonlinear energy sinks (NES) is one of the passive method to reduce vibration of the structure. This paper focuses on voltage generated and the performance of NES when the primary system is subjected to random excitations. A white noise is incorporated into the system to obtain random forcing on system. It is observed that pendulum NES is successful in protecting a primary system and broadening the frequency bandwidth of voltage generated, irrespective of the type of excitation on the primary system.

8. How friction influences energy recovery in a magnetic levitation harvester

Krzysztof Kecik*, and Andrzej Mitura*
**Department of Applied Mechanics, Lublin University of Technology, Lublin, Poland,* k.kecik@pollub.pl

Abstract. The paper presents a numerical and experimental analysis of an electromagnetic energy harvester. The concept is based on the oscillation of a permanent cylindrical magnet in a coil wrapped on the tube. A new model of damping which describes the variable friction due to magnetic interactions is proposed. The comparison between classical fixed damping and novel variable damping is presented for selected cases.

Invited Talk

9. Use of magnetomechanical effect for energy harvesting and data transfer

Jerzy Kaleta*, Rafał Mech * and Przemysła Wiewiórski *
** Department of Mechanics, Materials and Biomedical Engineering, Wrocław University of Science and Technology, Wrocław, Poland,* Jerzy.Kaleta@pwr.edu.pl

Abstract. This work is focused on the development of an energy harvester that might be used in various applications including industrial, aerospace, and others. The goal was to prepare a wireless subsystem based on energy harvesting technology which will useful in different areas. The Energy Harvesting devices are shown as small harvesting devices with power output from 10mW up to 5W. Proposed solution could be applied for example in low power microprocessor systems, ultrasonic continuous power supply for low power wireless network systems, and multinodes harvester systems. The main challenge was to obtain enough energy from energy harvesting devices to supplying the chosen 32bit microcontrollers systems.

ENERGY HARVESTING FOR STRUCTURAL HEALTH MONITORING

10. Study of Human Body exposed to undammed free vibrations for Indian subjects intended for Semi-Supine position

P.K. Bharadwaj*, R. Prakash*
** Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, INDIA*
pgljuscic@riteh.hr

Abstract: Past few decades, many mathematical models are developed to explain human beings' biodynamic response by using numerous field measurements. A lumped parameter model is developed under undamped free vibrations based on the 50th percentile, 54-kg Indian male anthropometric data. According to conventional lumped parameter modeling, the current model is developed, which considers the human body as an interconnected network of numerous rigid masses. The interconnection of these masses is made by using various dampers and springs. Modal analysis is numerically simulated to extract the natural frequencies and mode shapes of the designed model. Human body mathematical modeling helps to validate the experimental investigations for the effortlessness of riding when the operator is in a semi-supine position. The results obtained in this study specify the disassociation between fore-and-aft and vertical vibrations. The modal analysis reveals that the body will vibrate only in vertical motion at the lower natural frequencies.

11. Smart Sensoric System for Railway Monitoring

Filip Ksica*, Zdenek Hadas* and Zdenek Machu*
**Institute of Solid Mechanics, Mechatronics and Biomechanics, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic,* filip.ksica@vutbr.cz

Abstract. This contribution presents experimental results of a sensoric system designed for rail monitoring applications. Used sensing elements are made of piezocomposite material, selected as the most suitable due to superior mechanical and electromechanical properties compared to more commonly used PZT plates. Prior to several experiments conducted in laboratory and real world environment, mathematical models of the chosen piezocomposite material were constructed in order to properly convert the measured response to the respective mechanical strain of the host structure. To add the "smart" part to the sensoric system, custom-made hardware designed for automatic triggering, data acquisition and wireless transmission was integrated to fulfill the requirements of modern monitoring systems. Conducted experiments on rail tracks showed promising match between measured strain characteristics caused by a passing train and our expectation based on analytical and numerical modeling of the problem. Achieved results will serve as a base for further development in the field of rail track structure health monitoring (SHM).

12. Analysis of optimal PVDF based active elements layout on the vibrating structure for energy harvesting and SHM applications

Oldřich Ševeček*, Zdeněk Machů* and Zdeněk Hadaš*
**Brno University of Technology, Faculty of Mechanical Engineering, Institute of Solid Mechanics, Mechatronics and Biomechanics, Brno, Czech Republic,* sevecek@fme.vutbr.cz

Abstract. The contribution deals with an analysis of the optimal layout of the PVDF film or its surface electrical contacting on the vibrating structure with respect to excited bending mode shapes during its operation. The aim is to obtain maximal power/signal output from PVDF elements placed on the structure together with the minimal area of used active elements. These pieces of knowledge will be subsequently utilized for an effective energy harvesting or SHM purposes on large vibrating structures. The analysis is performed on the square planar thin plate on which particular bending modes can be precisely defined and excited. Obtained findings can be then easily transferred to any vibrating structure where basic modal characteristics in the operational frequency range are known or determinable.

13. A Numerical Model for Experimental Designs of Vibration-Based Leak Detection and Monitoring of Water Pipes using Piezoelectric Energy Harvesters

Favour Okosun* and Vikram Pakrashi*
** Dynamical Systems and Risk Laboratory, School of Mechanical and Materials Engineering University College Dublin* and *Science Foundation Ireland (SFI) MaREI Centre, University College Dublin, Ireland*
favour.okosun@ucdconnect.ie

Abstract. While the potential use of energy harvesters as structural health monitors show promise, numerical models related to the design, deployment, and performance of such monitors often present significant challenges. One such challenge lies in the problem of leak detection in fluid-carrying pipes. Recent advances in experimental studies on energy harvesters for such monitoring have been promising but there is a paucity in existing literature in linking relevant fluid–structure interaction models around such applications. This submission presents a numerical model developed with Computational Fluid Dynamics (CFD) and Finite Element (FE) tools that addresses the aforementioned issues and shows the analyses comparing the simulation results with existing experiments under controlled laboratory conditions. Conventional Polyvinylidene Fluoride (PVDF) films for leak detection and monitoring of water pipes were considered in this regard.

ENERGY HARVESTING FROM FLOW INDUCED VIBRATIONS

14. Effects of discontinuous nonlinearities on piezoaeroelastic energy harvesting systems

A. Bouma*, E. Le*, R. Vasconcellos**, and A. Abdelkefi*
**Department of Mechanical and Aerospace Engineering, New Mexico State University, Las Cruces, NM, USA*
***São Paulo State* University (UNESP), São João da Boa Vista, Brazil, abouma88@nmsu.edu

Abstract. The effects of discontinuous nonlinearities in the pitch degree of freedom on the response of a two-degree of freedom piezoaeroelastic energy harvesting system is considered. The aerodynamics of the system are modelled using an unsteady formulation based on the Duhamel formulation without considering stall effects. With discontinuous nonlinearities present, a nonlinear analysis is performed on the piezoaerolastic system after the onset of flutter. These nonlinearities, namely multi-segmented nonlinearity in the pitch degree of freedom, can cause sudden jumps and chaotic responses due to the grazing/sliding bifurcation. Results show that discontinuous nonlinearities reduce the flutter speed, allowing for low velocity energy harvesting.

15. Several approaches to improve the efficiency of wind energy harvesting

Wan Sun*
**Department of Mechanical Engineering, Jiangsu University, Zhenjiang, 212013, P.R. China,*
sun_wan123@126.com

Abstract. Over the past decades, techniques in wind energy harvesting have a dramatical development, especially, in the application of wireless sensor network. However, unlike traditional wind turbine, wind energy harvesting based on flow induced vibration (such as galloping, vortex induced vibration and wake induced vibration) appears a relatively low energy conversion efficiency. This nature shortcoming limits its further application in practice and small-scale industrial manufacturing. This presentation tries to introduce several technologies for enhancement of wind energy harvesting efficiency. The content will conclude some solutions for galloping-based, VIV-based, wake induced vibration based piezoelectric energy harvesting system.

16. Metamaterial Beam based Piezoelectric System for Galloping Energy Harvesting

Guobiao HU*, Junlei WANG**, Lihua TANG***, Yaowen YANG*
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***Engineering Research Center of Energy Saving Technology and Equipment of Thermal Energy System, Ministry of Education, Zhengzhou University, 100 Science Avenue, Zhengzhou 450000, China*
****Department of Mechanical Engineering, University of Auckland, 20 Symonds Street, Auckland 1010, New Zealand;*
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Abstract. In this study, we present the design and modelling of a galloping piezoelectric energy harvester (GPEH) based on a metamaterial beam. The results show that the cut-in wind speed of the metamaterial-based GPEH can be reduced and the power output can be increased.

17. Impact of Dual Splitters on the Flow-Induced Vibration of Piezoelectric Energy Harvesters

Chandan Bose1, Junlei Wang2 and Abdessattar Abdelkefi3
1Department of Aerospace and Mechanical Engineering, University of Liege, Liege 4000, Belgium.
2School of Mechanical and Power Engineering, Zhengzhou University, Zhengzhou 450000, China.
3Department of Mechanical and Aerospace Engineering, New Mexico State University, Las Cruces, NM 88003, USA, cb.ju.1991@gmail.com

Abstract. This study is focused on investigating hybrid piezoelectric energy harvesting from the flow-induced vibration of a circular cylinder by using two symmetric splitters in different relative angular positions with respect to the oncoming uniform flow. Wind tunnel experiments and numerical simulations are carried out to study the effect of different angular positions of the dual splitters on the energy harvesting efficiency with the increasing flow velocity. It is observed that, in the absence of any splitter, the energy harvesting performance is constricted to only the lock-in regime for the vortex-induced vibration of the circular cylinder. Whereas, a significant improvement in the harvested energy is observed by introducing the dual splitters at an optimal position of 600 with respect to the inflow direction because of an ensuing transition from vortex-induced vibration to galloping phenomena. The underlying vortex interactions behind the transitional dynamics are investigated by analyzing the flow-field through the results obtained from the computational fluid dynamic simulations

18. Amplitude reduction through energy harvesting in vortex-induced vibrations

Sérvio Túlio Suenai Haramura Bastos* and Rui Marcos Grombone de Vasconcellos*
**São Paulo State University (Unesp), Campus of São João da Boa Vista, São João da Boa Vista, SP,Brazil*
tulio.haramura@unesp.br

Abstract. In this work, an identified electrical-mechanical model is implemented to describe complex behavior, such as upper and lower branches, and the piezoelectric coupling to harvest electric power in a 1DOF cylinder exposed to a transverse flow, presenting vortex induced vibration (VIV). A classical Van der Pol model was modified to represent the variations of Strouhal number and aerodynamic damping coefficient in order to represent the experimentally observed upper and lower branches. By comparing the numerical simulation with experiments presented in the literature the proposed model was validated. Then, the effects due to the electrical coupling were analyzed in terms of electrical power generation and the suppression of high amplitude oscillations. Results demonstrate that the electrical coupling contributed to reduce the amplitude of oscillation. The results of this research can be helpful in order to design efficient energy harvesters based on VIV and can assist the development of strategies to suppress vibrations.

19. Dynamics of a Wave Energy Converter considering Flexible Multibody Systems

Marten Hollm, Leo Dostal, Christian Kühne, Tobias Rückwald, Alexander Held and Robert Seifried
Institute of Mechanics and Ocean Engineering, Hamburg University of Technology, Hamburg, Germany
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Abstract. We investigate the dynamics of a novel wave energy converter, which is based on an inclined point absorber connected to a generator. Thereby, we consider different inclination angles of the wave energy converter as well as regular waves of different frequencies. Furthermore, the effect of elastic deformations due to gravity and wave excitation forces are studied by modelling the wave energy converter as a flexible multibody system.

20. Measuring the Kinetic Energy Potential for Wave Energy Converter On Non-Moored Surface Buoys in Random Sea

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Abstract. This paper focuses on the challenge of measuring the dynamics of a wave energy converter (WEC) on a non-moored drifting sensor platform in random waves. The WEC is based on a simple linear generator gaining energy from a relative movement between stator and translator. To get first information about the dynamics, a measuring prototype was developed which allows to measure the energy potential of that system in random sea waves. Dynamic parameters of the prototype are adaptable including the nonlinear damping by the generator. Prototype was tested in a wave channel with excitation in different sea states. The results allowed an estimation of the energy potential of the system

MATERIALS AND DEVICES FOR ENERGY HARVESTING

21. Piezoelectric Energy Harvesting Device For Electronic Gadgets

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Abstract. Piezoelectric energy harvesting technologies are still competing for a solid establishment in the market as most applications still face many drawbacks which imposes considerable limitation for their practical use [1,2]. For this reason, this study presents the novel design and concept of a harvester that operates based on free mechanical vibration due to initial displacement induced by a moving mass. It is then used to convert mechanical energy to electrical energy through the bending mode of piezoelectric beams. Presented experimental results validate the proposed Finite Element and analytical dynamic models, thereby validating the entire concept. In the context of energy harvesting (EH) technology development, a method of *leisure* EH from the routine use of electronic gadgets is introduced.

22. Design of multifunctional ultra-wide bandwidth energy harvesting gyroscopes

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Abstract. Developing a reliable reduced-order model for the design and optimization of a piezoelectric microelectromechanical (MEMS) inertial sensing gyroscope with broadband energy harvesting capabilities is proposed. Harvesting energy from wasted mechanical vibrations can reduce and quite possibly eliminate the need to replace the power source of small devices that are in remote or otherwise hard to reach locations. The presence of broadband frequency between the driving and sensing direction of the MEMS multifunctional gyroscope has been observed. This broadband frequency is deeply investigated in such a way to manipulate the design of the system for enhanced energy harvesting capabilities. .

23. Modeling of Multilayer Piezoelectric Ceramic Vibration Energy Harvester

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Abstract. The cantilever beam type piezoelectric energy harvesting device has a narrow working bandwidth. To further increase the harvested power and broaden the working frequency, a pre-compressed piezo stack structure is developed to form a new energy harvesting device. The electric equation and equivalent circuit model are established and the experimental platform is set up. The experiment results are in good agreement with the theoretical model. An effective energy density value of 8mW/cm3 is observed when the external excitation force is 250N at 50 Hz with an optimal load.

Invited Talk

24. Flexible magneto electric energy harvester based on PVDF-HFP composites

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Abstract. In this work, a flexible magnetoelectric (ME) laminate structure is developed based on PVDF-HFP composites. Nanocomposite films were prepared by solution mixing method, where the piezoelectric composite is formed with PVDFHFP containing barium titanate BaTiO3 and silver nanoparticles to boost the piezoelectric coefficient, while the ME layer involves PVDF-HFP/cobalt iron oxide (CO2Fe4). Several parameters, including the laminate structure, the magnet magnetization direction and magnet geometry, are investigated based on numerical and experimental analyses. Furthermore, the performance of the designed harvester was studied for different magnet' geometries. The results show that the ME with tri-layers configuration has better performance in terms of output voltage and power. The achieved performance is a sign of good magnetoelectric coupling between the layers owing to the enhanced piezoelectric coefficient generated from high crystal phase transformation within the PVDF-HFP.

25. Metamaterial with Piezoelectric Elements for Harvesting and Sensing Purposes

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Abstract. This contribution deals a metamaterial for energy harvesting and sensing purposes under cyber-physical applications. The presented of metamaterial is based on an auxetic structure which is made by Direct Metal Laser Sintering technology. The stain steel auxetic structure could integrate smart material elements or systems for electromechanical conversions. The proposed concept of metamaterial uses the auxetic structure with piezoelectric elements or stacks to transduce external load of structure into electric signal. The auxetic structure could provide uniform mechanical load on several smart piezoelectric elements in middle layers due to negative Poisson ration. Deformation of auxetic structure with piezoceramic PZT plates and PVDF stack are presented and the voltage response is analysed, and future development will be discussed. There is a promising potential for future Industry 4.0 applications

26. Passive energy management solution for an electromagnetic vibration converter

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Abstract. Powering wireless sensor systems from vibration converters is still challenging due to the lack of efficient energy management circuit that enables to store the generated energy through the converter passively. In fact, electromagnetic converters are one of the robust and reliable converters, nevertheless realization of an energy management solution to store the generated energy through them is challenging due to their low output voltage. This paper presents a passive energy management solution for electromagnetic converter characterized with a low output voltage limited to 2V as pk-pk. In particular, an energy management circuit based on voltage multiplier is proposed to rectify and improve the energy output level of the converter. Investigation of the required voltage multiplier stages and the losses through the circuit is carried out. Simulation and experimental investigations are conducted considering as input an electromagnetic converter with limited output voltage, an energy management circuit based double stage voltage multiplier and a DC-DC converter.

27. Response analysis and experimental assessment of an electromagnetic vibration converter

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Abstract. In this paper, we report an electromagnetic vibration converter based on a moving coil attached to a mechanical spring surrounding fixed ring magnets. The focus is given to the study of the dynamics of the harvester in which the interaction between the fixed magnets and the moving coil is investigated. As well, the modelling of the magnetic damping relative to the moving coil is carried out. The converter is modelled as a single-degree-of-freedom (SDOF) with the effective mass, m, attached to the mechanical spring and damper. The dynamic response of the harvester is then obtained by solving the specified equation of motion of the harvester. The analytical results for the coil position relative to the magnets are evaluated and compared to the developed numerical model. For the validation of the theoretical models, a prototype for the converter is realized and tested experimentally for different applied accelerations and frequencies.

28. Design study of a nonlinear electromagnetic converter using magnetic spring

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Abstract. In this paper, an experimental and theoretical study for designing nonlinear electromagnetic converter based magnetic spring is performed. The governing equation of the converter is investigated. A special focus is given to the magnetic force acting on the moving magnet in function of its volume and the geometry of the two fixed magnets, i.e., cylindric or ring. For the developed analytical and numerical model, the same converter volume has been used for all conducted investigations. Several parameters have been studied that can be used to tune the nonlinearity behaviour. Further, the damping effect on the nonlinear behaviour of the converter is investigated, in particular the coil properties in terms of length and position. An energy harvesting prototype consisting of an oscillating cylindrical magnet levitated between two stationary cylindrical magnets is fabricated and evaluated through experiments. The open circuit voltage obtained through the analytical model have been compared to the experiment.

29. Plasma nanoengineering for the development of hybrid piezo and tribonanogenerators

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Abstract. We present the development and plasma-assisted optimization of hybrid piezo and triboelectric nanogenerators. We take advantage of the application of low-pressure plasma procedures for the nanoscale design of ZnO polycrystalline shells and formation of conducting metallic cores in core@shell nanowires and for the solventless surface modification of polymeric coatings and matrix. In this way, Ag@ZnO convoluted piezoelectric nanogenerators are produced on flexible substrates and embedded in PDMS compatible with a top-bottom triboelectric architecture. Factors like crystalline texture, ZnO thickness, and surface chemical modification of the PDMS are explored to optimize the power output of the nanogenerators aimed for harvesting from low-frequency vibrations.

30. Dynamics of two coupled rotary pendula based wave energy harvester

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Abstract. The aims of this research are the dynamics and stability study of two pairs of pendulums coupled with a common elastic base, when harmonically excited by an electromagnetic shaker, see Figure 1(a). The main focus is to identify the optimum parameters for energy harvesting and the pendulums influence on the electromagnetic shaker when varying the pendulum motions. The new pendulums system configuration will require less energy input to sustain the rotatory motion and therefore, the energy harvested is increased. This study has been motivated by the possibility of application of this concept to a new generation of Wave Energy Converters (WEC) which could harvest energy from the quasi-harmonic vibrations generated by ocean waves on a pendula device floating structure.

Multi-functional materials for energy harvesting and sensing

31. A brief review of various A15B16C17-type compounds and their nanocomposites for energy harvesting application

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Abstract. Currently, there is a growing demand for leaving fossil fuels and using renewable energy sources instead. The conversion of solar, heat, and wind energy into electricity is commonly used since the middle of the 20th century. Nowadays, the development of renewable energy sources of any kind e.g. piezoelectric nanogenerators is essential due to the desire of going climate-neutral by 2050 by developed countries. Such nanogenerators may harvest body-motion, vibration, pressing, shock pressure, acoustic wave, and many other mechanical energy forms and can supply low energy-consuming, mobile electronics.

Invited
32. Molecular ferroelectric materials as piezoelectric energy harvesters

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Abstract. Nanogenerators derived from oxides, polymers and other molecular substances have gained prominence in recent years. We present our findings on the use of composites based on non-piezoelectric polymers and crystalline solids made-up of ferroelectric organic and hybrid molecules as efficient devices for mechanical energy harvesting applications.

33. A piezoelectrically powered optical sensor and an opto-thermal dual-source sensor based on a single narrow band gap photoferroelectric material

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Abstract. Recently, band gap engineering of conventionally wide gap ferroelectric materials has been increasingly explored. The reduction of band gap into the visible light range, compared to the previous UV range, provides an additional degree of freedom to manipulate the ferroelectric (and subsequently piezoelectric) response by visible light. This benefit stimulates the development of multi-functional energy harvesting and/or sensing devices relying on only one active material. In this talk, such a multi-functionality is demonstrated by a device made from a narrow band gap photoferroelectric material, KNBNNO (K,Na,Ba)(Nb,Ni)O3-δ. The device is capable of simultaneously harvesting kinetic energy such as vibration to supply power via the piezoelectric effect and sensitively responding to visible light with different spectra and intensities via the photovoltaic effect. Consequently, the harvested kinetic energy can be used to power necessary circuits and supplementary components, and the incident light acts as a stimulus for passive sensing. Alternatively, the same device is able to simultaneously and sensitively respond to temperature fluctuation via the pyroelectric effect and visible light (as mentioned above). This enables the device to work as a passive dual-source sensor. The materials, structures and potential issues of the device will be discussed in this talk.

Multi-functional materials for energy harvesting and sensing

Invited

34. one-reactor fabrication of multifunctional 3D nanoarchitectures: energy harvesting, wetting and nanosensors

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Abstract. In this communication, we will share our last advances in the development of multifunctional 1D and 3D supported nanostructures in the fields of solar cells, micro-energy harvesting (piezoelectric and triboelectric nanogenerators), wetting, and anti-icing. Advantages of the soft-template procedure based on the use of single-crystal organic nanowires as 1D templates and multishell scaffolds will be framed together with the presentation of the vacuum and plasma one-reactor system. The steps required for the exploitation of these nanomaterials as supported or in-device applications will be presented.

35. Semitransparent ITO nanostructured electrodes synthesized by plasma and vacuum one-reactor configuration.

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Abstract. The fabrication of one-dimensional (nanotubes) and three-dimensional (nanotrees) transparent conducting oxides (TCOs) by a scalable vacuum and plasma process implemented in one chamber is demonstrated. The new method comprises the formation of organic nanowires serving as 1D and 3D soft templates, followed by deposition of polycrystalline Indium Tin Oxide (ITO) layers by magnetron sputtering, and removal of the template under mild vacuum conditions. The process variables are tuned to control the stoichiometry, morphology, and alignment of the ITO nanotubes and nanotrees. As a result, high quality crystalline, semitransparent and conductive nanostructured layers particularly interesting for optoelectronic, energy harvesting and sensing applications.

NEW TRENDS AND TOOLS FOR ENERGY HARVESTING USING SMART MATERIALS AND SYSTEMS

36. Robust Design of Energy Harvesting Resonant Devices using Multiobjective Optimization and Polynomial Chaos Expansions

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Abstract. Research on piezoelectric energy harvesting devices has been growing steadily over the last decades. However, since the harvestable energy is generally small, optimization and design techniques are necessary. These procedures may lead to high computational cost depending on the device modeling, analyzed parameters and presence of uncertainties. This work presents interesting strategies to perform robust design of energy harvesting devices considering parametric uncertainties, focusing on the estimation of harvested energy mean and variance and multiobjective optimization to provide adequate compromise solutions. Results show that devices with larger masses provide better average output energy, as expected, but also to higher variance.

37. Exploring the behavior of a bistable energy harvester via global sensitivity analysis

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Abstract. A bistable energy harvester presents a rich and complex dynamic behavior due to high sensitivity to the input parameters. The uncertainties arising from the environmental and manufacturing process can significantly affect the energy generation process and, ultimately, the harvester's performance. Understanding how uncertain parameters and excitation variability affect the harvester response is a nontrivial task and can be a preliminary step for uncertainty quantification and optimization problems. In this sense, this study evaluates, via a variance-based global sensitivity analysis technique known as Sobol' indices. These system parameters influence the power recovered from a bistable vibratory energy harvester, such as which parameter most affects the system response.

38. Optimization design of multi-frequency response piecewise linear piezoelectric vibration energy collector

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Abstract. In the design of piecewise linear piezoelectric vibration energy collector under multiple frequency responses, parameter optimization is a practical means to widen the working frequency and improve the energy harvesting efficiency. Under the constant vibration acceleration, the multiple frequency response of the piecewise linear piezoelectric vibration energy collector is design. Combined with the equivalent lumped parameter model, cantilever beam gap dimension and chip array configuration are optimized. According to the theoretical optimization, the prototype is machined and analysed.

39. Asymmetric Potential Well Based Piezoelectric Harvesters: A Comprehensive Review

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Abstract. Energy harvesting from ambient vibration sources using piezoelectric materials has presented promising outcomes over past three decades. The advancements in the piezoelectric harvesters span right from early linear models to the recent nonlinear multi-stable asymmetric potential well harvesters. In this work, we have reviewed the influence of asymmetries on the performance of the mono-stable, bi-stable, and tri-stable configurations of the PEH. The discussion on effects of asymmetries is based on multi-stable potential wells, strength and frequency of excitation, relative height of potential barriers as well as size of potential well. Dynamic asymmetries which emanate during the operation under stochastic excitation conditions are also discussed. At last, comments are presented regarding the usefulness of asymmetries for a particular nonlinear configuration of PEH.

40. Preliminary work on the development of resonant power supply, with use of energy harvesting phenomena

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Abstract. The paper presents the results of research on a device for energy transmission with the use of the energy harvesting phenomenon. The material used for the construction of the stand was a magnetostrictive material, which allowed the use of the Villari's effect in order to generate electricity from vibrations of the structure. The results obtained during the preliminary research showed that it is possible to use the proposed solution to transmit energy over a certain distance.

41. Triboelectric charge sensors

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Abstract. Triboelectric phenomenon seems to be promising source of useful signal for sensing applied force and change of displacement. The PVDF material which is made by electrospinning is very suitable as a base active material. Electrospinning is manufacturing way how to provide to this material required β-phase which bring promising piezo electric potential. However, it is hard to predict polarization vector due to chaotic structure of final product and piezo electric effect is hard to measure and quantify itself. Compare to that triboelectric effect is possible to measure much easier and repeatable. There were tested three type of movement-contact of electrodes: contact-separation mode, slide mode and permanent contact mode. Finally, 3 types of sensors were built and tested.

42. Perovskite based energy harvester as a multi source harvesting system

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Abstract. The concept is to implement a single multifunctional material as the multi-source harvesting system. The design is built using perovskite as the sole energy conversion component. The active material is able simultaneously to harvest kinetic energy or visible light by incorporating its peizoelectric, photovoltaic effect respectively. The system is expected fundamentally to progress the dynamic principles underlying the current hybrid and multi-source energy harvesting structures. Here, we tend to optimize the PEH (Perovskite energy harvester) through modelling based on different parametric sweep in order to maximize the energy conversion efficiency. Key attributes realized through analysis determine the importance of parametric tuning in enhancing the device performance for various applications.

43. A Parametric Analysis of the Nonlinear Dynamics of Bistable Vibration-based Piezoelectric Energy Harvesters

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Abstract. Piezoelectric materials exhibit electromechanical coupling properties and have been gained importance over the last few decades due to their broad range of applications. Vibration-based energy harvesting systems (VBEHS) have been proposed using the direct piezoelectric effect by converting mechanical into electrical energy. Performance enhancement strategies are essential to improve the applicability of these system and have been studied substantially. This work addresses a numerical investigation of the influence of cubic polynomial nonlinearities in energy harvesting systems considering a bistable structure subjected to harmonic excitation. A deep parametric analysis is carried out employing comparisons over a great number of cases. Results show the best parameters associated with the trigger of inter-well motion. Electrical power output and efficiency are monitored to evaluate the configurations associated with best system performances.

44. Multidirectional Vibration-Based Piezoelectric Energy Harvester

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Abstract. Ambient vibration excitations may feature in a multidirectional and broadband frequency spectrum. Usually,piezoelectric energy harvesting systems based on a cantilever beam cannot explore all energy potential available in the environment. In this work, a multidirectional multimodal broadband piezoelectric energy harvester is investigated. The device is modeled using ANSYS finite element software. Results for in-plane and out-of-plane excitations show that the proposed device has potential to operate in a wideband frequency spectrum, extracting energy from excitations in multiple directions.

45. Some Strategies for the Enhancement of Vibration-Based

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Abstracts: The energy harvesting concept has an increasing importance nowadays due to the huge necessity to find renewable energy sources. In this regard, vibration-based energy harvesting is an interesting alternative applicable in different situations as portable device charges. Bioinspiration is a paradigm that extracts design principles from biological and natural systems, being useful to guide some challenging solutions needed. Smart materials have an essential importance on this idea being used as sensors and actuators that define the remarkable system characteristics. Nonlinear dynamics, chaos and control are establishing other design paradigms. This presentation shows a general overview of nonlinear mechanics of energy harvesting systems, highlighting some strategies to enhance system capacity. The presentation discusses system modeling, pointing potential applications. Different system configurations, nonlinear dynamics analysis, synergistic use of smart materials are some strategies discussed during the presentation. The rich, complex dynamical response of thesesystems is of special interest.

NONLINEAR EFFECTS IN ENERGY HARVESTING

46. Improving energy harvesting in an excited van der Pol device using time delay

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Abstract. We investigate quasi-periodic (QP) vibration-based energy harvesting (EH) in a nonlinear device consisting in an excited van der Pol oscillator coupled to a delayed piezoelectric coupling mechanism. We consider the case of primary resonance for which the frequency of the harmonic excitation is near the natural frequency of the oscillator. Analytical approximation of the QP response and the corresponding power output are obtained using the double-step multiple scales method. The effect of time delay on the EH performance is studied; It is shown that for appropriate combination of time delay parameters, QP vibration can be used to scavenge energy over a broadband of the excitation frequency away from the resonance with a significant performance. An optimum range of the system parameters where the QP vibration-based EH is maximum is determined. Numerical simulations are conducted to support the analytical predictions.

47. Nonlinear dynamics of a magneto-mechanical system with two degrees of freedom

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Abstract. This paper presents the modelling process and the results of the numerical study of the magneto-mechanical system. The tested system consists of a tube with two fixed magnets at its ends. Two movable magnets can move inside the tube. During experimental research the relationship of magnetic forces versus the distance between magnets was determined. Based on these dependencies a nonlinear model of a system with two degrees of freedom was developed. In the next step the numerical simulations were performed. Finally, the obtained results allowed for the determination of nonlinear effects in the investigated system.

48. Coupled nonlinear harvesters for broadband energy harvesting

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Abstract. The present work investigates the energy harvesting potential of a system comprising an array of mechanically coupled vertical piezoelectric cantilevers. The governing electromechanical equations for the harvester array are derived using Galerkin's approach and Euler Lagrange equation. Numerical simulations have been carried out in the current study for an elementary case of array consisting of five beams under monostable and bistable potential configurations. The role of important parameters such as the tip mass and coupling springs on tailoring the coupled system response are investigated to determine strategies for improved energy harvesting performance over already existing nonlinear techniques. Key findings observed through numerical investigations demonstrate the benefits of exploiting the complex dynamics of coupled nonlinear systems via parametric tuning for broadband energy harvesting.

49. Analysis of the response of a nonlinear system for energy harvesting from short-term vibrations of variable frequency

Wolszczak Piotr*, Litak Grzegorz*
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Abstract. The non-linearity of the system was achieved by the use of elastic beam limiters, which cause impacts and additional beam stimulation. On the deformed beam a piezoelectric energy recovery system is located. A numerical model of the system was developed and a physical experiment was performed. The reaction of the system to stimulations of variable frequency was examined. The excitation variability consisted in a short-term linear increase or decrease in the excitation frequency. The beam response was recorded using an optical system. The aim of the analysis was to detect deformation of the beam with higher modes caused by the collision. Recurrence plots analysis of system vibrations caused by inertia during swing and collisions was performed.

Invited
50. Energy harvesting using subharmonic solutions in the asymmetric double well potential

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Abstract. A frequency transmission band of the vibration energy harvester is studied numerically. For the analysis, the nonlinear piezoelectric energy harvesting system based on cantilever elastic beam is applied to harvest kinetic energy of the moving frame. We used an asymmetric double well potential induced by permanent magnets for a ferromagnetic beam resonator. A piezoelectric patch attached along the beam was used as a transducer of the mechanical into electrical energy. It occurs that the system can work in a wide interval of frequency beyond the linear resonance. Besides the response with a single period of excitation, we found solutions with dominating sub-harmonic 2 of the harmonic inertial force excitation and chaotic solutions with hopping between the potential wells. Particular solutions were illustrated, classified, and discussed using standard methods.

Invited
51. Identification of chaotic motion zones in the QZEH system

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Abstract. The subject of model research is the QZEH energy harvesting system (Quazi Zero Energy Harvester), in which the potential barrier was mapped with the quasi zero stiffness characteristic. With regard to design solutions based on a flexible beam and permanent magnets, the system proposed by us is characterized by an almost flat energy potential well. The paper presents multi-colour maps of the distribution of the Lyapunov exponent, determined depending on the parameters characterizing the external excitation, defined as a superposition of two harmonic functions with different amplitudes and frequencies.

52. Nonlinear dynamics of the TEEH energy harvesting system

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Abstract. The subject of the model research is the system of harvesting energy with the tunnelling mechanical characteristics TEEH (Tunnel Effect Energy Harvester), in which the potential barrier was mapped with the use of three elastic elements. The paper presents multi-colour maps of the distribution of the largest Lyapunov exponent and diagrams of the effective values of the voltage induced on the piezoelectric electrodes, showing the influence of the dimensionless excitation amplitude on the effectivity of energy harvesting. The non-linear dynamics of the TEEH system was investigated in the range of low and high values of the control parameter characterizing the source of excitation.

53. Quasiperiodic energy harvesting in a forced Rayleigh-Duffing harvester near secondary resonance

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Abstract.This paper studies quasiperiodic vibration-based energy harvesting in a nonlinear delayed Rayleigh-Duffing oscillator coupled to piezoelectric harvester device. Analytical investigation is performed using the multiple scales method to obtain approximation of periodic and quasiperiodic amplitude responses as well as the corresponding power output. The influence of different parameters of the harvester on the amplitude of solutions and powers is examined. Results show that for appropriate values of the delay parameters, quasiperiodic vibration-based energy harvesting is significantly improved far from the resonance while the periodic vibration-based one is almost absent near the resonance.

54. Impact of circuitry on vibration energy harvesting using bi-stable oscillators under stochastic resonance

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Abstract. The development of vibration energy harvesters is highly susceptible to the properties of the driving vibrations. Ambient interactions usually lead to random vibrations of mechanical and structural systems that host these devices. Despite the adverse effect on tuning, randomness has been exploited to improve harvesting performance by utilizing the concept of stochastic resonance. The latter refers to the combined action of random fluctuations with a harmonic component upon oscillators with multiple potential wells, triggering cross-well oscillations and significant improvements in the electrical power output. In this paper, the effect of rectifiers and capacitors on the conditions enabling stochastic resonance is investigated using the mean crossing rate between potential wells. It is shown that rectification introduces highly nonlinear damping in the harvester dynamics that modify the optimal load conditions. Furthermore, a critical capacitance is found with respect to optimisation of the harvested power.

ON EMERGENT NONLINEAR ENERGY TRANSFER VIBRATING PROBLEMS AND PHENOMENA

55. Axial vibration attenuation and energy harvesting with nonlinear absorbers without addition of mass

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Abstract. In this work, we explore the use of nonlinear stiffness in vibration absorbers for attenuation of steady-state axial vibration under harmonic excitation in a metastructure without increasing the total mass. Specifically, one of the absorbers is substituted by one with hardening type stiffness, and an optimization procedure is proposed using sequential quadratic programming (SQP) to find the optimal position of this absorber and also the linear and nonlinear stiffness coefficients which minimizes the H2 norm in four frequency ranges of the leftmost block. A simplified approach is used to compare linear and nonlinear stiffness based on deformation energy.

56. Pitch-voltage interaction in nonlinear piezoaeroelastic energy harvesting with cubic stiffness and quadratic piezoelectrical coupling at flutter condition

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Abstract. In this paper, we show the contributions of nonlinear stiffness and piezoelectrical coupling on the dynamic behaviour of an aeroelastic energy harvesting system. The influence of plunge cubic nonlinear stiffness and nonlinear piezoelectrical coupling is investigated with respect to flutter speed, mechanical and electrical power. Four cases are considered, showing the behaviour of a linear system, the effect of each nonlinear term separately, and the combined effect of both nonlinear terms.

57. About oscillations in drives of vibration machines with unbalanced vibration exciters during passage through the resonance zone

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Abstract. It is found that when a speed of vibration exciter stucks in the resonance zone, its slow damping oscillations with relatively large amplitudes are excited. It is shown that oscillations of vibration machine's drive during this period of motion also will be large enough.

58. Nonlinear energy transfer on a Magneto piezo elastic oscillator with Bouc-Wen damping

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Abstract. In this work, we analyzed the dynamic behavior of parameter D that defines the amplitude of the Bouc-Wen damping and the variation of the frequency of the external force applied in a structure defined by a cantilever containing piezoceramic patches connected in a circuit for Energy Harvesting and the other end of the bar is subjected to the field generated by two magnetic poles. Thus, we present the mathematical model and analysis of nonlinear dynamics and output power.

59. Generalized energy dissipation function of fractional type in the dynamics of discrete and discrete-continuous systems of fractional type

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Abstract. Expressions for the generalized function of energy dissipation of fractional type for standard elements, mechanical and electrical, fractional type are derived, their application in discrete and continuously discrete oscillatory systems of fractional type is given. Several theorems on the change of energy of systems and modes of fractional type are defined. Communication is Review of Author's research results.

60. LQR Optimal Control Applied in an Energy Harvesting System with Non-Ideal Excitation Operating with Uncertain Parameters

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Abstract. Most applications of active control in vibrational dynamic systems are used to reduce vibrations. However, the aim of this research is specifically the use of vibrations to generate electrical energy, in such a way that the vibration becomes a desired phenomenon. Aiming at improving the modeling of complex energy harvesting systems with non-ideal excitation, bringing greater robustness, and bringing them closer to reality, the variation of the physical parameters of the system was performed in this work. The optimal control technique via Linear Quadratic Regulator (LQR) is applied to stabilize the orbits and compare the power generated between the systems with and without control.

61. Reduction of the Sommerfeld effect on a non-ideal system with electromagnetic interaction

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Abstract. A non-ideal system consisting of a cantilever beam with an unbalanced shaft motor, coupled with a permanent magnet and a coil is constructed and its analytical, numerical, and experimental solutions are obtained for the analysis of the considered vibrating system. The experiment obtained show relevant results from the effect of the electromagnetic interaction near the resonance region (Somerfield Effect).

Invited

62. Time-Frequency Analysis Methods and their Engineering Applications: An Overview in Nonlinear Dynamics

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Abstract. Time-frequency analysis (TFA) of mechanical vibration signals in nonlinear dynamics applications is the main subject of this lecture. The theory will be carefully exposed and complemented with examples of applications in vibration systems and nonlinear dynamics.

ROTATIONAL AND MULTI-DIRECTIONAL VIBRATION ENERGY HARVESTING FOR SMART SENSING

63. A rotating string-disk nonlinear electromagnetic energy harvester for vibration energy harvesting

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Abstract. This paper presents a rotating string-disk nonlinear electromagnetic energy harvester to harvest the planar vibration energy. The design consists of a buckled elastic string with a rigid rotor at the mid-span and a stator. Three permanent magnets are symmetrically embedded into the disk, and correspondingly, three coils are distributed on the stator. Therefore, the vibration from arbitrary direction can cause the rotation of the buckled elastic string with disk, which leads to the relative movement between the stator and rotor. The energy generated by the coils can be harvested under a wide bandwidth. The theoretical analysis is carried out based on a simplified nonlinear model. The simulation results show that the system could maintain a good performance over a broad bandwidth (from 5 to 23 Hz). Corresponding experiment results are in good agreement with the simulation results, and the maximum peak power can reach to 1.12 mW at 23 Hz under the up-sweep excitation of 5 ms-2.

64. Complex rotational energy harvesting from a novel curved-cylinder type dielectric elastomer generator

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Abstract. A novel curved-cylinder type dielectric elastomer generator (CC-DEG) is proposed in this paper to scavenge energy from rotational environment. The proposed CC-DEG consists of a hollow curved cylinder, a rigid ball, four identical cylindrical frames and two pre-stretched membranes, which can convert rotational energy into electrical energy through the impacts between the ball and the membranes. A harmonic rotational excitation is first considered to act on the proposed CCDEG, laying the foundation for the CC-DEG's applications in complex rotational environments such as torsional vibration and pendulum, etc. The dynamical behaviors and energy harvesting (EH) process of the proposed CC-DEG under rotational excitations are analyzed theoretically. The EH process at each impact have been verified by measuring the output voltages of a single-sided impact (SSI) model under different impact velocities. Furthermore, the system dynamical and electrical responses under different rotational excitations are fully presented through numerical simulations, and the influences of some key parameters, including the frequency/ amplitude of the rotational excitation and the system dimensional parameters, are discussed in detail. Research results show that the system energy harvesting (EH) performance can be enhanced by appropriately setting the frequency and amplitude of the rotational excitation and the system dimensional parameters. This work also provides guidelines to investigate the system EH performance with given dimensional parameters or optimize of the system's dimensional parameters under a given rotational excitation.

65. Self-Powered Rotor Vibration Measurement Unit Using Macro Fiber Composite-Magnet Energy Harvester

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Abstract: The paper presents the design, fabrication, and characterization of a self-powered rotor vibration sensor using macro fiber composite (MFC) energy harvester. The measurement system is supplied with the MFC-based energy harvested. The non-contact sensor is applied for an active magnetic bearing (AMB) rotor vibration sensing. The MFC radial beams configuration, together with neodymium magnets, is used for the contact-free rotor vibration energy harvesting. The MFC transducer output voltage that supplies the sensor's electronics is investigated for different air-gaps and rotor speeds. This work investigates the optimum conditions of self-powered sensor operation and assesses the rotor vibration sensitivity and accuracy. In order to verify, the MFC-based vibration sensor output is compared with measurements obtained using the fiber optic laser sensor. The mismatched vibration amplitude for both sensors does not exceed 1 μm

66. A rotational impact energy harvester utilizing the centrifugal softening effect

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Abstract: Harvesting ambient rotational energy is a potential way to provide the sustainable and clean power for wireless sensor nodes or small-scale portable devices. Rotational energy can be harvested in varying natural and artificial surroundings such as wind turbines, automobile tires and turnstile gates. However, the achievement of high energy output at low rotational frequencies is still a significant challenge. In order to overcome this issue, Guan and Liao [1] presented a piezoelectric beam that was subjected to the centrifugal softening force. Sufficient power for a wireless sensor over a wide rotational frequency range was experimentally realized. Zou et al. [2] magnetically coupled two inverted piezoelectric beams and utilized the centrifugal softening force to produce large-amplitude vibrations. High output power at low frequencies and multiple frequency bands were demonstrated experimentally. However, they found that at higher rotational frequencies, the beam would continuously deflect until it was broken. This phenomenon indeed was found by Kim et al. [3] who utilized the inverted flag for fluid energy harvesting, which was defined as the deflected mode. Despite this, Païdoussis et al. [4] found that such deflected mode was caused by the negative equivalent stiffness of the system, which indicated that the stiffness could be changed to be positive to prevent the deflected mode. This inspires us to use the impact force to drag the inverted beam from the deflected mode with its large impact stiffness. Furthermore, the impact energy output can be improved as the harvester is being knocked out of the static divergence state.

67. A multi-directional multi-stable energy harvester: Modeling and experiment verification

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Abstract. Multi-stable vibration energy harvester based on spring-mass system has received widespread attention from many researchers, because the spring-mass multi-stable system has the advantages of low natural frequency, simple structure and high output power. This work considers such an energy harvesting system, but with the additional novelty of using the link mechanism to improve the bistable smooth and discontinuous oscillator, and a multi-directional multi-stable structure is proposed. Equilibrium analysis demonstrates the multi-stable mechanism and the bifurcation conditions for the unperturbed system. While for the perturbed system, the Extended Averaging Method is carried out to demonstrate the multi-stable behaviors, transitions between different potential wells, and their large amplitude inter-well motions. The experimental results are compared to theoretical results. Both theoretical and experimental data suggest that the MMD produces a large amplitude response at ultra-low frequencies, enabling motion throughout all equilibrium positions. The designed prototype can be easily adopted for efficient energy harvesting from ultra-low frequency vibration sources.

68. The effect of centrifugal force on the dynamic performance of beam-type rotational energy harvesters

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Abstract. To realize the high-efficiency energy harvesting in rotational motion, the beam-type piezoelectric energy harvesters attract considerable attention. However, few theoretical model in these studies could successfully reveal the underlying mechanism of the centrifugal force. To full in this gap, a mathematical model has been established in a rotational coordinate system to describe the effect of centrifugal force on the dynamic performance of beam-type rotational energy harvesters. The theoretical analyses demonstrate that for the forward configuration, the centrifugal force contributes to the centrifugal stiffening effect (**C_stiffen_E**) which can be used to design a self-tuning energy harvester with wide frequency range, and for the inverse configuration, the corresponding centrifugal softening effect (**CSE**) is an effective way for energy harvesting in ultralow-frequency rotational motion. This study provides the theoretical guidance for the design of energy harvester in rotational motion.

Invited
69.Nonlinear response regimes and analysis methods of multi-stable energy harvesters

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Abstract. In this talk, the nonlinear response regimes and theoretical analysis methods of multi-stable energy harvesters will be introduced. Firstly, the amplitude-frequency response equations and the stability analysis of multi-stable energy harvesters with high-order stiffness terms will be presented. Complex multi-valued characteristics are observed in the amplitude of the response displacement. Then, resonance mechanism of nonlinear vibrational multistableenergy harvesters under narrow-band stochasticparametric excitations will be discussed. The largest Lyapunov exponent which determines the stability of the trivial steady-state solutions is derived. The nontrivial steady-state moments of multistable energy harvesters are considered. To explore the stochastic bifurcation phenomenon between the nontrivial and trivial steady-state solutions, the Fokker–Planck–Kolmogorov equation corresponding tothe two-dimensional stochastic differential equations is solved by using the finite difference method. Finally, response analysis of the nonlinearvibration energy harvester withan uncertain parameter, the Chebyshev polynomial approximation is firstly utilized to analyze the dynamical characteristics of thenonlinear vibration energy harvester with an uncertain parameter. The ensemblemean response of the stochastic energy harvester is introduced to discuss the stochastic response. The bifurcation property of thedisplacement and voltage is analyzed.

Invited

70. Self-power Wireless Sensor Node for Smart Railway Axle Box bearing via a Variable Reluctance Energy Harvester System

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Abstract: The condition monitoring of the railway axle box bearing is important to the safety of the high speed train. This presentation introduces our recent progress on a self-powered smart bearing for sensing the operation status in real time. A variable reluctance energy harvest was designed to scavenge the rotation motion energy to electrical energy. The influences of key geometrical parameters on the energy harvesting performance were investigated by the theoretical modeling the finite element analysis. A power management circuit was designed to achieve the purposes of impedance matching, voltage boosting, rectification and regulation. The energy harvester was prototyped and used for powering a wireless sensor node embedded in the bearing. The powering capability of the energy harvester was experimentally verified under the rotation speed range of 400 r/min to 1200 r/min. It is proved that the designed energy harvesting system is capable of powering the wireless sensor node for detecting the rotation speed, vibration, strain and temperature information of the bearing. The proposed smart bearing system has a great potential for improving the reliability of the high speed train.

THERMOELECTRIC ENERGY HARVESTING

Invited

71. Electrical resistivity and thermal expansion (4.2 – 820 K) of skutterudites after severe plastic deformation via high-pressure torsion

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Abstract. Severe plastic deformation via high-pressure torsion has a structural influence on the structural and as a consequence on the transport and mechanical properties of thermoelectric materials. Skutterudites, high promising thermoelectric materials, show after high-pressure torsion an enhanced figure of merit, ZT. The temperature dependent changes of the electrical resistivity and in parallel of the thermal expansion were investigated in detail to shed light on the intrinsic mechanisms in SPS processed samples.

Invited
72. Development of high-efficient thermoelectric skutterudites and modules for waste heat harvesting

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Abstract. Thermoelectrics have gained increasing recognition as a sustainable source of electric energy that can be able to meet a wide range of applications. The energy conversion efficiency of the thermoelectric (TE) materials is determined by the dimensionless figure of merit (ZT), which depends on the thermal and electrical conductivity, the Seebeck coefficient, and the temperature gradient. But the major barriers to mainstream the use of TE devices in the practical application are their low ZT and high cost. Cobalt antimonide (CoSb3) based skutterudites have advantages over other TE materials due to the ease in the fabrication process and cost-effectiveness. Chemical substitution and filling in the binary CoSb3 skutterudites draw enormous attention for automotive TE modules due to their stable TE properties in the temperature range 573 K to 773 K. This leads to the development of novel filled/doped skutterudites having enhanced ZT values at intermediate temperatures.

73. Enhancement of thermoelectric properties of Co4Sb12 via the combined strategy of filling the voids and nanocomposites

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Abstract. The Co4Sb12 based skutterudite materials are the most widely explored thermoelectric materials after PbTe and Bi2Te3 for mid-temperature (300-800 K) applications due to their high thermoelectric efficiency. Despite a reasonably high Seebeck coefficient (S) and a low electrical resistivity (ρ), the high lattice thermal conductivity (κL) of Co4Sb12-based materials due to strong Co-Sb covalent bonding leads to a low thermoelectric figure of merit (zT) [1]. Filling the voids of cage forming compounds by electropositive elements and homogeneous distribution of nano-sized secondary phases in the bulk matrix are promising approaches to enhance zT of these materials. These two approaches were combined in this work by filling electropositive elements (In, Ba) into the void of Co4Sb12 and dispersing InSb and GaSb nanoparticles in the bulk matrix of Ba0.3Co4Sb12 and In0.2Co4Sb12, respectively

74. Investigation of the Thermoelectric Properties of Single and Double Substituted $Cu_{12}Sb_4S_{13}$ Tetrahedrite

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Abstract. Tetrahedrite ($Cu_{12}Sb_4S_{13}$) is a potential p-type candidate for thermoelectric applications in the mid-temperature range (500–800 K). In the first part of the work, the thermoelectric properties of *d*-block transition metals (TM = Mn, Fe, Co, Ni, Zn) and *p*-block (Al) single substitution at the Cu(1) tetrahedral site in $Cu_{12}Sb_4S_{13}$ were investigated. The $TM^{+2/+3}$ or Al^{+3} substituting at $Cu(1)^{+1/+2}$ site compensated holes resulting in a decrease in electronic thermal conductivity. The highest band degeneracy and density of states (DOS) near Fermi level (E_F) among the substituted samples was exhibited by $Cu_{11.5}Co_{0.5}Sb_4S_{13}$, resulting in a high zT of 0.98 at 673 K. In the second part of the work, it was shown that Sn can exhibit double substitution at Cu(2) and Sb sites in tetrahedrite, resulting in a maximum zT of 0.96 at 673 K. Next, the effect of Zn and Se double substitution at the Cu(1) and S sites was studied. Zn substitution tuned the charge carrier concentration whereas Se substitution resulted in enhanced charge carrier mobility and DOS near E_F, which led to a maximum zT of 0.86 at 673 K. The results obtained in this work present a deeper understanding of substitution effects in tetrahedrite and enable a future direction for thermoelectric device applications.

75. Reduction of thermal conductivity through complex microstructure by dispersion of Carbon nanofiber in p-type $Bi_{0.5}Sb_{1.5}Te_3$ alloys

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Abstract. The influence of nano dispersion on the thermoelectric properties of Bi_2Te_3 was actively investigating to wide-spread thermoelectric applications. Among different low-dimensional materials, Carbon based nanostructures were highly investigated due to their peculiar structural, thermal, mechanical, optical, and electrical properties. Herein this report, we have systematically controlled the microstructure of $Bi_{0.5}Sb_{1.5}Te_3$ (BST) alloys through the incorporation of carbon nanofiber (CNF), and studied their effect on thermoelectric properties, and mechanical properties. identification of CNF in bulk composites was analyzed in Raman spectroscopy and corresponding CNF peaks were recognized. The BST matrix grain size was greatly reduced with CNF dispersion and consistently decreased along CNF percentage. The electrical conductivity was reduced and Seebeck coefficient varied in small-scale by embedding CNF. The thermal conductivity was progressively diminished, obtained lattice thermal conductivity was lowest compared to bare sample due to induced phonon scattering at interfaces of secondary phases as well as highly dense fine grain boundaries. The peak ZT of 0.95 achieved for 0.1 wt.% dispersed BST/CNF composites. The Vickers hardness value of 101.8 Hv was obtained for the BST/CNF composites.

76. Effect of Biaxial Strain on Power Factor of Silicene: A First-Principles Study

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Abstract. In this paper, we present a first principles based study on the effect of biaxial tensile strain on thermoelectric (TE) power factor in extrinsic low buckled silicene using HSE06 hybrid functional. The tensile strain opens-up a small bandgap of 3.9meV in the material and improves the power factor.

77. Vacancy assisted thermoelectric properties in CuSbSe2 system

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Abstract: Chalcostibite,CuSbSe2 is a low cost and eco-friendly thermoelectric(TE) material with a *p*-type conducting nature.Here,we have successfully synthesized CuSb1-xSe2(X=0.01,0.02,0.05) samples.Powder XRD diffraction pattern confirms the formation of CuSbSe2 with a space group of P-*nma* . Further, structural, vibrational, morphological and TE properties have been studied and will be presented.

78. GeTe Thermoelectrics: Materials to Devices

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Abstract: Thermoelectric (TE) materials, directly convert the untapped waste-heat into usable electricity, have gained a great attention in the renewable energy resource sectors as they are anticipated to boost up the primary conversion technologies and to power the small-scale electronic devices. Interestingly, the heat-to-electricity conversion efficiency (□TE) predomina ntly depends on materials' parameter called as figure-of-merit, *zT = S2σT*/κ*total*, where *S,* σ, κ*total* and *T* stand for Seebeck coefficient, electrical conductivity, total thermal conductivity, and absolute temperature, respectively. Though the □TE is product of Carnot efficiency and zT, the interdependency of the TE parameters makes the enhancement efforts of zT to be of more challenging.

79. Influence of rGO on Thermoelectric Properties of nano-structured p-type MnSe2

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Abstract: Nanostructure rGO/MnSe2 composites have been prepared by simple hydrothermal process. is semiconducting material with that can exhibit thermoelectric nature. Structural, microstructural, optical properties of rGO/MnSe2 composites studied using XRD, SEM, UV spectroscopy. In addition, influence of rGO TE properties of MnSe2 nano-composite is studied and results will be presented.

80. Experimental and Numerical Analysis of Thermoelectric generator

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Abstract: Energy is the most basic infrastructure input for the economic growth and development of a country. Thermal Energy is used to meet various industrial and domestic requirements. Thermal energy is low-grade energy. About 40% of thermal energy is lost in the form of waste heat. A thermoelectric generator directly converts this waste heat into electricity without any moving parts. Thermoelectric energy harvesting will assess multibillion dollar opportunities by 2030[1]. Several TEMs are commercially available in market few analysis of TEMs have reported [2],[3]. The present work reports analysis of commercially available thermoelectric generator. Experiments are carried out in a vacuum to maintain thermal stability. High Temperature is maintained on one side of the Thermoelectric Generator and on the other side low temperature is maintained. The power produced by TEG is measured by the varying temperature of the hot junction and load resistance. The power produced by TEG-241-1.4-1.2 is a maximum when the load resistance is matched with internal resistance. As temperature difference increases power produced increases. Numerical results are validated by experimental results.

Invited
81. Strain Engineering in Tuning the Electronic and Vibrational Properties of silicene and other 2D materials

Rekha Verma, *Department of Electronics and Communication Engineering, Indian Institute of Information Technology, Allahabad. Utter Pradesh, India.* r.verma@iiita.ac.in

Abstract. Whenever a material is grown on a substrate, an external strain induces which may be compressive or tensile in nature and affects the material properties differently. This is due to the lattice mismatch between the material and the substrate and hence, cannot be ignored while investigating the properties of a material. Also, in accordance with the phonon-glass electron-crystal paradigm to obtain the better thermoelectric (TE) figure-of-merit (ZT), research is being carried out to tune the material properties by several means. Strain engineering is one by which the electronic and vibrational properties in 2D materials can be modified and is a current trend to estimate the effective ZT of a material. In this work,

VIBRATION ENERGY HARVESTING APPLICATIONS FOR WIRELESS SENSING AND CONDITION MONITORING

82. Pendulum-Type Wave Energy Converter System for Low-Power Marine Monitoring Applications

Matias Carandell, Daniel Mihai Toma, Manel Gasulla and Joaquín del Río
Electronic Engineering Department, Universitat Politècnica de Catalunya, Spain,
matias.carandell@upc.edu

Abstract. A pendulum-type wave energy converter (WEC) system has been designed to harvest energy from oceanic drifters.It consists of an articulated double pendulum capable of transforming the drifter oscillation into energy. The system includes a Power Management Unit (PMU) with a “maximum power point tracking” (MPPT) technique to maximize energy production. The system has been previously tested on several controlled environments like a lineal shaker or a wave flume. Later, short-term sea deployments have been conducted to evaluate its performance in real sea conditions

83. Vibration Energy Harvester Powered Wireless Vibration Sensor Node

Ondrej Rubes*, Jan Chalupa*, Filip Ksica*, and Zdenek Hadas*
** Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2896/2, 616 69 Brno, Czech Republic,* ondrej.rubes@vut.cz

Abstract. This contribution deals with a development of a self-powered solution for wireless vibration sensing. An autonomous operation of the proposed vibration sensor node is based on an electromagnetic energy harvesting device which converts kinetic energy of ambient mechanical vibration. Moreover, mechanical vibrations are monitored via electric signal from a piezoelectric patch and the measured signal is transmitted to the monitoring unit. Operation of this system was experimentally validated in laboratory environment and examples of vibration monitoring are presented. Main aim of this paper is to present a complex system which could be used in many engineering applications, e.g., aircrafts, transportation, or civil structure monitoring.

84. Evaluation of the triboelectric effect on the PVDF and Nylon fibres and possibility to use them for the condition monitoring

Pavel Tofel*, Klara Castkova**, David Riha* and Zdenek Hadas***
** Department of Physics, Faculty of Electrical Engineering and Communication, Brno University of Technology, Technicka 10, 616 00 Brno, Czech Republic ,** Department of Ceramics and Polymers, Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2, 616 69 Brno, Czech Republic ,*** Department of Mechatronics, Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2896/2, 616 69 Brno, Czech Republic,* tofel@feec.vutbr.cz

Abstract. Using the triboelectric effect, a very cheap and simple sensor or energy harvester can be fabricated, which is flexible and can exhibit better output performance than similar device based on piezoelectric effect. Our group is focused on fabrication of fibre-based mats via electrospinning with a goal of using them for fabrication of triboelectric devices. This contribution deals with comparison of different PVDF and nylon PA6 fibres from triboelectric point of view. Different fibre materials were spun such as PVDF fibres, PA6 fibres, PVDF + PA6 fibres, PVDF+PVDF/PA6 + PA6 fibres. These materials were electrically examined by a simple device working in vertical contact-separation mode. Best output performance was achieved for triboelectric device, which was assembled from Cu electrode with PVDF fibre mats against Cu electrode with PA6 fibre mats. This device generated Vout = 10V, Iout = 1.5µA and Qout = 3.5 nC in each touch of the fibre mats.

85. Energy Harvesting and Autonomous Sensing Based on Train Induced Vibration

Zdenek Hadas*, Ondrej Rubes* and Jan Chalupa* **Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2896/2, 616 69 Brno, Czech Republic,* hadas@fme.vutbr.cz

Abstract. This contribution deals with a development and a lab test of train relevant environment with electromagnetic energy harvester as a source of energy for sensing and wireless communication. The electromagnetic resonator was developed for energy harvesting from sleeper vibration during train passing. This course of vibrations was replicated on a labs shaker and harvested energy was rectified, accumulated, and used for signal processing and wireless communication. This autonomous system using a strain piezoelectric energy harvester to obtain active electrical signal, which is proportional with vibration and deformation of a rail under passing train. This signal could be used for track wear detection and LoRa communication module could transmit information about state of track under passing trains.

86. A battery free wireless sensor node for vibration monitoring

Namanu Panayanthatta1, Roberto LaRosa2, Skandar Basrour3, Edwige Bano1, Laurent Montes1
* 1Institut IMEP-LaHC, univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, Grenoble INP*, IMEP-LaHC, GRENOBLE, FRANCE,2ST Microelectronics, Stradale, Primosole 50, 95121 Catania,Italy 3TIMA, Univ. Grenoble Alpes, CNRS, Grenoble INP*, 38000 Grenoble, France ,* Institute of Engineering & Management, Univ. Grenoble Alpes Public Experimental Establishment,
namanu.panayanthatta@grenoble-inp.fr

Abstract. We propose a battery free wireless sensor scheme, based on piezoelectric transducer that can be used for monitoring engine vibrations by measuring the time that a storage capacitor takes to charge between two fixed voltage levels. The proposed vibration sensor not only can continuously transmit the vibration characteristics via Bluetooth but also can power the signal transmission. Wireless sensor nodes are the fundamental part of an IoT system that detects and transmits data to a master
node for their processing

Author Index

ICAEHT 2021

Indo-Polish International Conference on Advances in Energy Harvesting Technology
March 18-20, 2021

Day 1 March 18, 2021

Virtual program Schedule

March 18, 2021
14.30 – 15.45 (CET)/19.00-20.15 (IST) **Zoom:**https://zoom.us/j/94167238658?pwd=Z0poWkFwZjJGQ3pJdGJnREVYdUdMQT09 **YouTube:**https://www.youtube.com/channel/UCdfXvbvttyY5sSlqGk_Hi6g
Opening Ceremony Dr. M B Patil, President, BLDE Association, Vijayapur, India Prof. Zbigniew Pater, Rector, Lublin University of Technology, Poland Prof. Grzegorz Litak, Lublin University of Technology, Poland
Inaugural KeynoteChair: Grzegorz Litak, Lublin University of Technology, Poland Dr.AbdessattarAbdelkefi Department of Mechanical and Aerospace Engineering New Mexico State University, Las Cruces, NM, USA Topic: Aeroelastic energy harvesting: concepts, modelling, and effectiveness

Date- 18/03/2021 Time- 16.00 to 17.25 (CET)/ (20.30-21.55 IST)

Joining link- https://zoom.us/j/98662022672?pwd=OXVGc1RBeWRXRy8yMGtEZFdTQ3FEZz09

Workshop Session - New trends and tools for energy harvesting using smart materials and systems (I)

Organizers:

Americo Cunha, Rio de Janeiro State University

Marcelo Savi, Federal University of Rio de Janeiro, Brazil

Paulo Sérgio Varoto, University of São Paulo, Brazil

Samuel da Silva, São Paulo State University, Brazil

S No	Time (min)	Title of the Paper	Name of the corresponding Author	Affiliation
1(IS)	16.00-16.25	Can origami be used as an energy harvesting solution?	Larissa Novelino	Georgia Tech
2	16.25-16.40	Robust Design of Energy Harvesting Resonant Devices using Multiobjective Optimization and Polynomial Chaos Expansions	Paulo Henrique Martins	University of São Paulo
3	16.40-16.55	Exploring the behavior of a bistable energy harvester via global sensitivity analysis	João Pedro Norenberg	São Paulo State University
4	16.55-17.10	Optimization design of multi-frequency response piecewise linear piezoelectric vibration energy collector	Jinhui LIANG	Shandong University
5	17.10-17.25	Asymmetric Potential Well based Piezoelectric Harvesters: A review	Abhijeet Giri	Indian Institute of Technology Madras

Date- 18/03/2021 Time- 16.00 to 17.25 (CET)/(20.30-21.55 IST)				
Joining link- https://zoom.us/j/98561940389?pwd=ZFVsMjlnK3pJcGQrN0wzTU1UTDliZz09				
Workshop Session - On emergent nonlinear energy transfer vibrating problems and phenomena (I) **Organizer:** J M Balthazar, UNESP-UniversidadeEstadualPaulista, Bauru-SP, Brasil and UniversidadeTecnológica Federal do Paraná, Ponta Grossa, PR, Brasil				
S No	**Time (min)**	**Title of the Paper**	**Name of the corresponding Author**	**Affiliation**
1 (IS)	16.00-16.25	Time-Frequency Analysis Methods and their Engineering Applications: An Overview in Nonlinear Dynamics	Marcus Varanis	Federal University of Grande Dourados (UFGD)
2	16.25-16.40	Axial vibration attenuation and energy harvesting with nonlinear absorbers without addition of mass	Marcos Silveira	State University of São Paulo (UNESP), School of Engineering, Bauru, SP, Brazil
3	16.40-16.55	Pitch-voltage interaction in nonlinear piezoaeroelastic energy harvesting with cubic stiffness and quadratic piezoelectrical coupling at flutter condition	Marcos Silveira	State University of São Paulo (UNESP), School of Engineering, Bauru, SP, Brazil
4	16.55-17.10	About oscillations in drives of vibration machines with unbalanced vibration exciters during passage through the resonance zone	Nikolai P. Yaroshevich	Lutsk National Technical University
5	17.10-17.25	Nonlinear energy transfer on a Magneto piezo elastic oscillator with Bouc-Wen damping	Mauricio A. Ribeiro	UniversidadeTecnológica Federal do Paraná

Day 2 March 19, 2021
Virtual program Schedule

March 19, 2021

Date: 19/03/2021 Time- 8.30 to 9.25 (CET)/(13.00-13.55 IST)

Joining link-
https://zoom.us/j/98279832914?pwd=c1c0TFRUMWFta3NUQ2hYdnpSRG9JZz09

Workshop Session - Electrical interfaces for efficient energy harvesting
Organizer:
Prof. Mickaël Lallart, Univ. Lyon, INSA-Lyon, LGEF EA 682, F-69621, France

S No	Time	Title of the Paper	Name of the Presenting Author	Affiliation
1(IS)	8.30-8.55	Resonant frequency tuning of piezoelectric energy harvesters thanks to electrical interfaces	Morel Adrien	Univ. Grenoble-Alpes / CEA-LETI
2	8.55-9.10	A unified nonlinear circuit combining piezoelectric and electromagnetic transducers	Giulia LOMBARDI	Univ. Lyon, INSA Lyon, LGEF, EA682, F 6 9621, VILLEURBANNE, FRANCE
3	9.10-9.25	Analysis and Improvement of Self-powered P-SSHI Circuit for Piezoelectric Energy Harvesting：Eliminating the Effect of the Second Inversion	Hongsheng LIU	School of Mechanical, Electrical & Information Engineering, Shandong University

Date- 19/03/2021 Time- 8.30 to 9.30 (CET)/ (13.00-14.00 IST)
Joining link- https://zoom.us/j/94960842642?pwd=MHJFNGFXdllMVXhvNy9hbkpraHVVQT09
Workshop Session - Energy Harvesting for Structural Health Monitoring **Organizers:** Vikram Pakrashi, Dynamical Systems and Risk Laboratory, School of Mechanical and Materials Engineering, University College Dublin, Ireland Favour Okosun, Dynamical Systems and Risk Laboratory, School of Mechanical and Materials Engineering, University College Dublin, Ireland

S No	Time	Title of the Paper	Name of the Primary Author	Affiliation
1	8.30-8.45	Coupled electromechanical behaviour of kinetic energy harvesters for SHM	Petar Gljušćić	University of Rijeka Faculty of Engineering
2	8.45-9.00	Smart Sensoric System for Railway Monitoring	Filip Ksica	Faculty of Mechanical Engineering, Brno University of Technology
3	9.00-9.15	Analysis of optimal PVDF based active elements layout on the vibrating structure for energy harvesting and SHM applications	Oldřich Ševeček	Brno University of Technology, Faculty of Mechanical Engineering
4	9.15-9.30	A Numerical Model for Experimental Designs of Vibration-Based Leak Detection and Monitoring of Water Pipes using Piezoelectric Energy Harvesters	Favour Okosun	University College Dublin

Date-19/03/2021				**Time- 8.30 to 9.55 (CET)/ (13.00-14.25 IST)**
Joining link- https://zoom.us/j/94284072769?pwd=ejNTVmpuZ3k0eTFseVlwcTlMcVR0Zz09				
Workshop Session - Materials and Devices for Energy Harvesting (I) **Organizers:** Prof. Dr.-Ing. Olfa Kanoun, Chemnitz University of Technology Dr.-Ing. Sonia Bradai, Chemnitz University of Technology Dr.-Ing. Slim Naifar, Chemnitz University of Technology				
S No	**Time**	**Title of the Paper**	**Name of the corresponding Author**	**Affiliation**
1(IS).	8.30-8.55	Flexible magnetoelectric energy harvester based on PVDF-HFP composites	Ayda Bouhamed	Chemnitz University of Technology
2.	8.55-9.10	Piezoelectric Energy Harvesting Device For Electronic Gadgets	Lucas Machado	Heriot-Watt University
3.	9.10-9.25	Design of multifunctional ultra-wide bandwidth energy harvesting gyroscopes	Manuel Serrano	New Mexico State University
4.	9.25-9.40	Modelling of Multilayer Piezoelectric Ceramic Vibration Energy Harvester	Hanxiao ZHOU	School of Mechanical, Electrical & Information Engineering, Shandong University
5.	9.40-9.55	Metamaterial with Piezoelectric Elements for Harvesting and Sensing Purposes	Zdenek Hadas	Brno University of Technology

March 19, 2021
19/03/2021 10.00– 10.45 (CET)/ (14.30-15.15 IST) Zoom: https://zoom.us/j/98783507683?pwd=cHZVWHhhbUJnMEdQTlhUSzBYYXAydz09 YouTube:https://www.youtube.com/channel/UCdfXvbvttyY5sSlqGk_Hi6g
Keynote II Chair: Vikram Pakrashi, University College Dublin, Ireland Prof. Steve Beeby Head of Smart Electronic Materials and Systems Group School of Electronics and Computer Science University of Southamption Topic: Vibration Energy Harvesting for Structural Health Monitoring

Date- 19/03/2021 Time- 11.15 to 13.05 (CET)/ (15.45-17.35 IST)

Joining link- https://zoom.us/j/99250487429?pwd=RkxVSmFpeWhkMFZaemoxUzRxdHYzUT09

Workshop Session - Thermoelectric energy harvesting (I)

Organizer:
Ramesh Chandra Mallik, IISc, Bangalore

Rekha Verma, IIIT Allahabad

S No	Time (min)	Title of the Paper	Name of the Primary Author	Affiliation
1(IS)	11.15-11.40	Electrical resistivity and thermal expansion (4.2 – 820 K) of skutterudites after severe plastic deformation via high-pressure torsion	Gerda Rogl	Institute of Materials Chemistry, University of Vienna, Austria
2 (IS)	11.40-12.05	Development of high-efficient thermoelectric skutterudites and modules for waste heat harvesting	Manjusha Battabyal	International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), India
3	12.05-12.20	Enhancement of thermoelectric properties of Co4Sb12 via the combined strategy of filling the voids and nanocomposites	Sanyukta Ghosh	Indian Institute of Science
4	12.20-12.35	Investigation of the Thermoelectric Properties of Single and Double Substituted Cu12Sb4S13 Tetrahedrite	Sahil Tippireddy	Indian Institute of Science, Bangalore, India
5	12.35-12.50	Reduction of thermal conductivity through complex microstructure by dispersion of Carbon nanofiber in p-type Bi0.5Sb1.5Te3 alloys	Pathan Sharief	Kongju National University
6	12.50-13.05	Effect of Biaxial Strain on Power Factor of Silicene: A First-Principles Study	Neelesh Gupta	Indian Institute Of Information Technology Allahabad

Date- 19/03/2021 Time- 11.15 to 12.55(CET)/ (15.45-17.25 IST)

Joining link-https://zoom.us/j/99312118532?pwd=MnkvTEVaQVJ4TFdWZUhVejFtcDluQT09

Workshop Session - Energy harvesting & vibration control in mechanical systems

Organizers:

Krzysztof Kecik, Lublin University of Technology, Poland

Marek Borowiec, Lublin University of Technology, Poland

S No	Time (min)	Title of the Paper	Name of the Primary Author	Affiliation
1(IS)	11.15-11.40	Use of magnetomechanical effect for energy harvesting and data transfer	prof. Jerzy Kaleta	Wroclaw University of Science and technology
2	11.40-11.55	Dynamic Analysis of Beam Coupled with Resonant Piezoelectric Shunt	Braion Babrosa de Moura	University of Brasilia
3	11.55-12.10	Analytical Approach to Design Smart-metamaterial Beam Coupled with Resonant Shunt to Vibration and Wave Attenuation	Matheus Canedo Ribeiro Borges	University of Brasília
4	12.10-12.25	Optimizing piezoelectric energy harvesting absorbers with mechanical and magnetic amplitude stoppers	Tyler Alvis	New Mexico State University
5	12.25-12.40	Energy Harvesting in Non Linear energy sinks due to stochastic input forcing	Jishnu Roy Chaudhury	Shiv Nadar University, Greater Noida
6	12.40-12.55	Influence of nonlinear electromechanical coupling on energy harvesting in a magnetic levitation harvester.	Krzysztof Kecik	Lublin University of Technology

19/03/2021 14.00 – 14.45 (CET)/(18.30-19.15 IST)
Zoom: https://zoom.us/j/97988525915?pwd=RzN0cUxlMU02YU8rTGhld1M4VHF5dz09 YouTube:https://www.youtube.com/channel/UCdfXvbvttyY5sSlqGk_Hi6g
Keynote IIIChair: Ramesh Chandra Mallik, IISC, Bangalore, India Dr. Kanishka Biswas New Chemistry Unit (NCU) & School of Advanced Materials (SAMat), International Centre of Materials Science (ICMS) Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Jakkur, Bangalore, India Topic: Nanostructured Thermoelectric Energy Conversion

Date- 19/03/2021Time- 15.00 to 16.35 (CET)/(19.30-21.05 IST)

Joining link- https://zoom.us/j/94483218111?pwd=QjRERndIVHJGQ0ZpZWJHSEV2OXpQQT09

Workshop Session - Thermoelectric energy harvesting (II)

Organizer:

Ramesh Chandra Mallik, IISc, Bangalore

Rekha Verma, IIIT Allahabad

S No	Time (min)	Title of the Paper	Name of the Primary Author	Affiliation
7(IS)	15.00-15.25	GeTeThermoelectrics: Materials to Devices	Dr. Suresh Perumal	SRM Institute of Science and Technology, Chennai
8(IS)	15.25-15.50	Strain Engineering in Tuning the Electronic and Vibrational Properties in Silicene and other 2D Materials	Rekha Verma	IIIT Allahabad.
9	15.50-16.05	Vacancy assisted thermoelectric properties in CuSbSe2 system	Manojkumar Moorthy	SRM institute of science and technology,Chennai,Kattankulathur,India
10	16.05-16.20	Influence of rGO on Thermoelectric Properties of nano-structured p-type MnSe2	P. Jothilal	SRM Institute of Science and Technology, Kattankullathur-603 203
11	16.20-16.35	Experimental and Numerical Analysis of Thermoelectric Generator	R S KONDAGULI	BLDEA's V.P.Dr.P.G.HALAKATTI COLLEGE OF ENGINEERING AND TECHNOLOGY Affiliated to VTU Belagavi

Date- 19/03/2021 Time-15.00 to 16.15 (CET)/(19.30-20.45 IST)
Joining link- https://zoom.us/j/94084498892?pwd=Z1JkN2NBaWM5RWRSMjhsSjl6ZEprdz09

Workshop Session - Materials and Devices for Energy Harvesting (II)

Organizers:

Prof. Dr.-Ing. OlfaKanoun, Chemnitz University of Technology

Dr.-Ing. Sonia Bradai, Chemnitz University of Technology

Dr.-Ing. Slim Naifar, Chemnitz University of Technology

S No	Time	Title of the Paper	Name of the corresponding Author	Affiliation
6.	15.00-15.15	Passive energy management solution for an electromagnetic vibration converter	Ghada Bouattour	Chemnitz University of Technology
7.	15.15-15.30	Response analysis and experimental assessment of an electromagnetic vibration converter	Sonia Bradai	Chemnitz University of Technology
8.	15.30-15.45	Design study of a nonlinear electromagnetic converter using magnetic spring	Slim Naifar	Chemnitz University of Technology
9.	15.45-16.00	Plasma nanoengineering for the development of hybrid piezo and tribonanogenerators	Xabier Garcia-casas	CSIC (Materials Science Institute of Seville)
10.	16.00-16.15	Dynamics of two coupled rotary pendula based wave energy harvester	Alicia Terrero Gonzalez	University of Aberdeen

Date- 19/03/2021		**Time- 15.00 to 16.20 (CET)/(19.30-20.50 IST)**		
Joining link- https://zoom.us/j/92414792401?pwd=YVVRU01jbkZ3V05JbjBXU0FXUjhjUT09				
Workshop Session - Multi-functional materials for energy harvesting and sensing I **Organizers:** Yang Bai, University of Oulu, Finland Chris Bowen, University of Bath, UK				
S No	**Time**	**Title of the Paper**	**Name of the corresponding Author**	**Affiliation**
1(IS)	15.00-15.25	One-reactor fabrication of multifunctional 3D nanoarchitectures: energy harvesting, wetting and nanosensors	Ana Borras	CSIC (Materials Science Institute of Seville)
2(IS)	15.25-15.50	Molecular ferroelectric materials as piezoelectric energy harvesters	Ramamoorthy Boomishankar	Indian Institute of Science Education and Research (IISER), Pune
3	15.50-16.05	A piezoelectrically powered optical sensor and an opto-thermal dual-source sensor based on a single narrow band gap photoferroelectric material	Yang Bai	University of Oulu
4	16.05-16.20	A brief review of various A15B16C17-type compounds and their nanocomposites for energy harvesting application	BartłomiejToroń	Silesian University of Technology, Institute of Physics – Center for Science and Education

Date- 19/03/2021 Time- 16.45 to 18.25 (CET)/(21.15-22.55 IST)				
Joining link- https://zoom.us/j/95286617566?pwd=cSt5dkk5ZGc4eXc4Q3dyb2FZODVEUT09				
Workshop Session - New trends and tools for energy harvesting using smart materials and systems (II) **Organizers:** Americo Cunha, Rio de Janeiro State University, Marcelo Savi, Federal University of Rio de Janeiro, Brazil Paulo SérgioVaroto, University of São Paulo, Brazil Samuel da Silva, São Paulo State University, Brazil				
S No	**Time (min)**	**Title of the Paper**	**Name of the corresponding Author**	**Affiliation**
6(IS)	16.45-17.10	Some Strategies for the Enhancement of Vibration-Based Energy Harvesting Capacity	Marcelo A. Savi	Universidade Federal do Rio de Janeiro COPPE - Department of Mechanical Engineering Center for Nonlinear Mechanics, Brazil
7	17.10-17.25	On the development of resonant power supply, with use of energy harvesting phenomena	Rafal Mech	Wroclaw University of Science and Technology
8	17.25-17.40	Triboelectric charge sensors	David Riha	Brno University of Technology
9	17.40-17.55	Perovskite based energy harvester as a multi source harvesting system	Reshma Liyakath	Indian Institute of Technology Madras
10	17.55-18.10	Nonlinear Dynamics Investigation of Bistable Vibration-based Piezoelectric Energy Harvesters	Luã Costa	Federal University of Rio de Janeiro
11	18.10-18.25	Multidirectional Vibration-Based Piezoelectric Energy Harvester	Virgilio Júnior Caetano	Federal University of Rio de Janeiro

Date- 19/03/2021 Time- 16.45 to 17.45 (CET)/(21.15-10.15 IST)				
Joining link- https://zoom.us/j/92749893705?pwd=L1BnVHFWdkRWL0NlblJqRnh0UmhWdz09				
Workshop Session - On emergent nonlinear energy transfer vibrating problems and phenomena (II) **Organizer:** J M Balthazar, UNESP-UniversidadeEstadualPaulista, Bauru-SP, Brasil and UniversidadeTecnológica Federal do Paraná, Ponta Grossa, PR, Brasil				
S No	**Time (min)**	**Title of the Paper**	**Name of the corresponding Author**	**Affiliation**
6	16.45-17.00	Generalized energy dissipation function of fractional type in the dynamics of discrete and discrete-continuous systems of fractional type	Katica R. (Stevanović) Hedrih	Mathematical Institute of Serbian Academy of Science and Arts, Belgrade, Serbia
7	17.00-17.15	LQR Optimal Control Applied in an Energy Harvesting System with Non-Ideal Excitation Operating with Uncertain Parameters	EstevãoFuzaro de Almeida	São Paulo State University (FEIS/UNESP)
8	17.15-17.30	On the Bifurcation Analysis of a Bistable Piezo-Magneto-Elastic Energy Harvester	Vinicius Lopes	Rio de Janeiro State University
9	17.30-17.45	Reduction of the Sommerfeld effect on a non-ideal system with electromagnetic interaction	Eduardo A. Petrocino	São Paulo State University (UNESP), School of Engineering, Bauru, Brazil

Day 3 March 20, 2021

March 20, 2021

Date- 20/03/2021 Time- 8.30 to 10.00 (CET)/ (13.00-14.30 IST)

Joining link- https://zoom.us/j/92395610857?pwd=RmlpU3Qwc2RNMkluM0xkNVMzaUlhQT09

Workshop Session - Multi-functional materials for energy harvesting and sensing II
Organizers:
Yang Bai, University of Oulu, Finland
Chris Bowen, University of Bath, UK

S No	Time (min)	Title of the Paper	Name of the corresponding Author	Affiliation
5 (IS)	8.30-8.55	MOF Mediated Effective Mechanical Energy Harvesting Approach for Self-Powered Devices	Dipankar Mandal	Institute of nano science and technology, Knowledge City, India
6 (IS)	8.55-9.20	Influence of domain walls in photophysics and photochemistry of ferroelectric materials	Steve dunn	London South Bank University, UK
7(IS)	9.20-9.45	Modelling and characterisation of porous piezoelectric particulate composites	Hamideh Khanbareh	University of Bath, UK
8	9.45-10.00	Semitransparent ITO nanostructured electrodes synthesized by plasma and vacuum one-reactor configuration	Javier Castillo-Seoane	1) Institute of Materials Science of Seville (Spanish National Research Council (CSIC) - University of Seville), Seville (Spain), 2) Department of Atomic, Molecular and Nuclear Physics (University of Seville), Seville (Spain)

Date- 20/03/2021 Time- 8.30 to 9.55 (CET)/ (13.00-14.25 IST)
Joining link- https://zoom.us/j/99953515808?pwd=SHZOaDEwSG5SUWFLWHVTRzBTVHZJQT09
Workshop Session - Nonlinear effects in energy harvesting (I) **Organizers:** Krzysztof Kucab, University of Rzeszów, Poland Mohamed Belhaq, University Hassan II – Casablanca, Morocco

S No	Time (min)	Title of the Paper	Name of the corresponding Author	Affiliation
1. (Is)	8.30-8.55	Energy harvesting using subharmonic solutions in the asymmetric double well potential	Grzegorz Litak	Lublin University of Technology
2.	8.55-9.10	Improving energy harvesting in an excited van der Pol device using time delay	Zakaria Ghouli	Polydisciplinary Faculty of Taroudant, University Ibn Zohr, Morocco
3.	9.10-9.25	Nonlinear dynamics of a magneto-mechanical system with two degrees of freedom	Andrzej Mitura	Lublin University of Technology
4.	9.25-9.40	Coupled nonlinear harvesters for broadband energy harvesting	Aravindan Muralidharan	Indian Institute of Technology Madras
5.	9.40-9.55	Analysis of the response of a nonlinear system for energy harvesting from short-term vibrations of variable frequency	Piotr Wolszczak	Lublin University of Technology

Date- 20/03/2021	Time- 8.30 to 9.55 (CET)/ (13.00-14.25 IST)

Joining link- https://zoom.us/j/98773995240?pwd=V0xESzFHeDdzSEtxS1RmQ0hQN1E0dz09

Workshop Session - Rotational and Multi-directional vibration energy harvesting for smart sensing (I)

Organizers:

Shengxi Zhou, Northwestern Polytechnical University, China

Wenbin Huang, Chongqing University, China

S No	Time (min)	Title of the Paper	Name of the Primary Author	Affiliation
1(IS)	8.30-8.55	Nonlinear response regimes and analysis methods of multi-stable energy harvesters	Dongmei Huang	Xidian University
2	8.55-9.10	A rotating string-disk nonlinear electromagnetic energy harvester for vibration energy harvesting	Sijia Wang	Chongqing University
3	9.10-9.25	Complex rotational energy harvesting from a novel curved-cylinder type dielectric elastomer generator	Zhihui Lai	Shenzhen University
4	9.25-9.40	Self-Powered Rotor Vibration Measurement Unit Using Macro Fiber Composite-Magnet Energy Harvester	Arkadiusz Mystkowski	Bialystok University of Technology
5	9.40-9.55	A rotational impact energy harvester utilizing the centrifugal softening effect	FANG Shitong	The Chinese University of Hong Kong

Date- 20/03/2021	Time- 10.15 to 11.40 (CET)/ (14.45-16.10 IST)

Joining link- https://zoom.us/j/93271086087?pwd=YkVTZ21Yc012ZU5nSmxxOUxWVUV4Zz09

Workshop Session - Vibration energy harvesting applications for wireless sensing and condition monitoring

Organizers:

ZdenekHadas, BRNO UNIVERSITY OF TECHNOLOGY, Czech Republic

S No	Time (min)	Title of the Paper	Name of the corresponding Author	Affiliation
1 (IS)	10.15-10.40	Pendulum-Type Wave Energy Converter System for Low-Power Marine Monitoring Applications	Matias Carandell	UniversitatPolitècnica de Catalunya
2	10.40-10.55	Vibration Energy Harvester Powered Wireless Vibration Sensor Node	Ondrej Rubes	Brno University of Technology, Czech Republic
3	10.55-11.10	Evaluation of the triboelectric effect on the PVDF and Nylon fibres and possibility to use them for the condition monitoring	Pavel Tofel	Brno University of Technology
4	11.10-11.25	Energy Harvesting and Autonomous Sensing Based on Train Induced Vibration	ZdenekHadas	Brno University of Technology
5	11.25-11.40	A battery free wireless sensor node for vibration monitoring	Namanu Panayanthatta	univ. Grenoble Alpes

Date- 20/03/2021	Time- 10.15 to 12.00 (CET)/ (14.45-16.30 IST)

Joining link- https://zoom.us/j/92767075435?pwd=azVuZVlzYnpkV2dWQi9CZmxNTkVLQT09

Workshop Session - Energy Harvesting from Flow Induced Vibrations
Organizers:
Daniil Yurchenko, Heriot-Watt university
Junlei Wang, Zhengzhou University, china

S No	Time (min)	Title of the Paper	Name of the corresponding Author	Affiliation
1	10.15-10.30	Effects of discontinuous nonlinearities on piezoaeroelastic energy harvesting systems	Adam Bouma	New Mexico State University
2	10.30-10.45	Several approaches to improve the efficiency of wind energy harvesting	Wan Sun	Micro/Nano Science and Technology Center, Jiangsu University, Zhenjiang, 212013, P.R. China
3	10.45-11.00	Metamaterial Beam based Piezoelectric System for Galloping Energy Harvesting	Guobiao Hu	Nanyang Technological University
4	11.00-11.15	Impact of Dual Splitters on the Flow-Induced Vibration of Piezoelectric Energy Harvesters	Chandan Bose	Department of Aerospace and Mechanical Engineering, University of Liège, Belgium
5	11.15-11.30	Amplitude reduction through energy harvesting in vortex-induced vibrations	Sérvio Túlio Suenai Haramura Bastos	São Paulo State University (Unesp)
6	11.30-11.45	Dynamics of a Wave Energy Converter considering Flexible Multibody Systems	Marten Hollm	Hamburg University of Technology
7	11.45-12.00	Measuring the Kinetic Energy Potential for Wave Energy Converter on Non-Moored Surface Buoys in Random Sea	Julius Harms	Hamburg University of Technology

Date- 20/03/2021	Time- 12.00 to 13.10 (CET)/ (16.30-17.40 IST)			
Joining link- https://zoom.us/j/99932972043?pwd=T0xBUC8zZHhkWldEdEtreVRITHZQUT09				
Workshop Session - Nonlinear effects in energy harvesting (II) **Organizers:** Krzysztof Kucab, University of Rzeszów, Poland Mohamed Belhaq, University Hassan II – Casablanca, Morocco				
S No	**Time (min)**	**Title of the Paper**	**Name of the corresponding Author**	**Affiliation**
1. (IS)	12.00-12.25	Identification of chaotic motion zones in the QZEH system	Jerzy Margielewicz	Silesian University of Technology
2.	12.25-12.40	Nonlinear dynamics of the TEEH energy harvesting system	Jerzy Margielewicz	Silesian University of Technology
3.	12.40-12.55	Quasiperiodic energy harvesting in a forced Rayleigh-Duffing harvester device in the presence of nonlinear time-delayed feedback	Ilham Kirrou	Ibn Zohr University Morocco
4.	12.55-13.10	Impact of circuitry on vibration energy harvesting using bi-stable oscillators under stochastic resonance	Panagiotis Alevras	University of Birmingham

Date- 20/03/2021	Time- 12.00 to 12.55 (CET)/(16.30-17.25 IST)

Joining link- https://zoom.us/j/98428946195?pwd=RThudDZ1NWZwMStpcHRjSEI0VVIrQT09

Workshop Session - Rotational and Multi-directional vibration energy harvesting for smart sensing (II)

Organizers:

Shengxi Zhou, Northwestern Polytechnical University, China

Wenbin Huang, Chongqing University, China

S No	Time (min)	Title of the Paper	Name of the Primary Author	Affiliation
6 (IS)	12.00-12.25	Self-power Wireless Sensor Node for Smart Railway Axle Box bearing via a Variable Reluctance Energy Harvester System	Wenbin Huang	Chongqing University
7	12.25-12.40	A multi-directional multi-stable energy harvester: Modeling and experiment verification	Tao Yang	Northwestern Polytechnical University
8	12.40-12.55	The effect of centrifugal force on the dynamic performance of beam-type rotational energy harvesters	XUTAO MEI	The University of Tokyo

March 20, 2021
14.30 – 15.45 (CET)/ (19.00-20.15 IST) **Zoom:** https://zoom.us/j/97266839275?pwd=NXJPZGJkUjllRXR2TkJ5MXF4VEJUdz09 YouTube:https://www.youtube.com/channel/UCdfXvbvttyY5sSlqGk_Hi6g
Industry-Academia panel discussion **Chair: Dr. Shaikh Faruque Ali, IIT Madras, India** Tomasz Szewczyk, Sitaniec Technology, Poland PrzemysławŁagód, Cubetech, Poland ŁukaszKurzępa LBR lab, Poland Tomasz Korbiel, AGH University of Science and Technology, Poland Grzegorz Litak, LUT, Poland J. AroutChelvane,DMRL-DRDO,India D. D. Ebenezer, Adjunct Faculty, CUSAT, Kochi, Retired Director (Systems), NPOL-DRDO, India Aravindan Ramalingam, FTD solutions,Singapore
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