



POLISH SOCIETY
OF THEORETICAL AND APPLIED MECHANICS

INSTITUTE OF APPLIED MECHANICS
POZNAN UNIVERSITY OF TECHNOLOGY



VIBSYS 2022

Poznań



XXX Conference
“VIBRATIONS IN PHYSICAL SYSTEMS”

Poznań – Poland
September 26–28, 2022

Redaction

Roman Starosta, Małgorzata Jankowska

Computer processing of the text and cover design

Mikołaj Bilski

Honorary patronage

Marshal of the Wielkopolska Region, Mr. Marek Woźniak

Rector of Poznan University of Technology, prof. dr hab. inż. Teofil Jesionowski

*Dean of Faculty of Mechanical Engineering of
the Poznan University of Technology, dr hab. inż. Olaf Cizsak, prof. PP*

*Section of Dynamics of
The Committee of Mechanics of the Polish Academy of Science*

*Section of Vibroacoustics of
The Committee on Acoustics of the Polish Academy of Science*

Cooperation

National Museum in Poznan, Poland

Supporting institutions

Polish Ministry of Education and Science

Faculty of Mechanical Engineering of the Poznan University of Technology

EC TEST Systems Sp. z o. o.

Mechanical models Sp. z. o. o.



Muzeum Narodowe
w Poznaniu



Poznań 2022, 80 copies

Print & Publisher: Agencja Reklamowa COMPRINT
ul. Nikodema Pajzderskiego 22, 60-469 Poznań, Poland

ISBN 978-83-89333-80-3

Honorary Scientific Committee:

Jan AWREJCEWICZ,
Stefan JONIAK,
Jan KOŁODZIEJ,
Włodzimierz KURNIK,
Tomasz ŁODYGOWSKI,
Stanisław MATYSIAK,
Krzysztof MAGNUCKI,
Wolfgang MUSCHIK,
Andrzej RADOWICZ,
Andrzej TYLIKOWSKI,
Jerzy WARMIŃSKI

Scientific Committee:

Wojciech BATKO,
Romuald BĘDZIŃSKI,
Jacek BUŚKIEWICZ,
Tadeusz BURCZYŃSKI,
Enzo CIANCIO,
Evgen CZAPLA,
Zbigniew DĄBROWSKI,
Marian DOBRY,
Antoni GAJEWSKI,
Joseph GRIMA,
Jan HOLNICKI-SZULC,
Paweł JASION,
Jarosław JĘDRYSIAK,
David JOU,
Jerzy KALETA,
Henryk KAMIŃSKI,
Przemysław LITEWKA,
Krzysztof MARCHELEK,
Stanisław RADKOWSKI,
Liliana RESTUCCIA,
Roman STAROSTA,

Tomasz STREK,
Wojciech SUMELKA,
Grażyna SYPNIEWSKA-KAMIŃSKA,
Tomasz SZOLC,
Grzegorz SZYMAŃSKI,
Maciej TABASZEWKI,
Franciszek TOMASZEWSKI,
Tadeusz UHL,
Józef WOJNAROWSKI.

Organizing Committee:

Małgorzata JANKOWSKA – chairman,
Roman STAROSTA – vice-chairman,
Magdalena MIERZWICZAK – secretary,
Roman BARCZEWSKI,
Mikołaj BILSKI,
Beata CZERKAS,
Paulina FOPP,
Jakub GRABSKI,
Maciej TABASZEWSKI,
Tomasz WALCZAK.

**All published papers received a positive opinion of the members
of the Scientific Committees.**



Prospective insight

The jubilee of the conference, similarly as the jubilee of every important event in our lives, invites us to reflect on the past and the future.

It was April 1960 when prof. Edmund Karaśkiewicz as a chairman of the Poznan Department of the Polish Society of Theoretical and Applied Mechanics (PTMTS) organized and headed the first two-day symposium on linear and nonlinear vibrations. It took place in Poznan. The symposium became an event organized every two years. The chairmen of the conference changed, but all of them set themselves the goal of caring for high scientific level of the symposium. It resulted in obtaining by the conference a high reputation in the Polish scientific world.

More than 60 years have passed. At that time, we observed the rapid development of technology, which fundamentally affected the world, the life of societies and every single person. The development of new technologies was possible thanks to science. On the other hand, we see how much we can support the development of science through the use of modern technical solutions. Faced with the task of organizing the 30th edition of the VIBSYS conference, we asked ourselves a number of questions. First of all, which research topics are currently the most relevant and important from the scientific and application point of view. The second issue was to define an attractive way to exchange knowledge, popularize science and encourage young scientists to conduct research.

We decided to answer the first of these questions together with the conference participants who represent various modern trends in the broadly understood subject of vibrations in physical systems. The current and subsequent editions of VIBSYS will allow us to decide which of the topics are particularly worth considering during the conference. In terms of organization, we plan to maintain new ideas that turned out to be right during the conference in 2020. These include a hybrid form of participation both stationary face-to-face on the spot and remote via an online platform, a competition for young scientists on the best presentation of the research results, popularization of history and art through trips to interesting places in the Greater Poland region and the emission of short films encouraging to see, e.g., the exhibition of the National Museum in Poznan during breaks in the sessions.

The special moment during the 30 edition of VIBSYS will be a session dedicated to the memory of prof. Czesław Cempel. Prof. Cempel worked in the Institute of Applied Mechanics and organized the VIBSYS conference many times. He was a chairman and honorary member of the scientific committee. Employees of our Institute, co-authors and friends will present the profile of the professor and his scientific achievements.

At the end of this introduction, we wish the participants fruitful discussions and many pleasant moments during the VIBSYS conference at the Poznan University of Technology.

Chairs of the Conference



Table of Contents

Mohamed ABOHAMER, Jan AWREJCEWICZ, Tarek AMER	10
<i>ENERGY HARVESTING USING A PIEZOELECTRIC TRANSDUCER ON EXTERNALLY FORCED BUT DAMPED OSCILLATOR</i>	
Krzysztof AUGUSTYNEK, Andrzej URBAŚ, Jacek STADNICKI	12
<i>STUDY OF THE CLEARANCE EFFECT IN REVOLUTE AND PRISMATIC JOINTS ON THE DYNAMICS OF A SPATIAL MECHANISM WITH FLEXIBLE LINK</i>	
Samuel AYANKOSO, Pawel OLEJNIK, Jan AWREJCEWICZ	14
<i>IDENTIFICATION OF SELECTED ELECTROMECHANICAL SYSTEMS USING ACQUIRED TIME-SERIES DATA</i>	
Marek BARSKI, Adam STAWIARSKI, Małgorzata CHWAŁ, Marcin AUGUSTYN	16
<i>NUMERICAL SIMULATION OF FUNDAMENTAL ELASTIC WAVE MODES COUPLING IN COMPOSITE PLATES</i>	
Wojciech BATKO	18
<i>IDENTIFICATION OF ACOUSTIC PHENOMENA IN A NON-EUCLIDES METRIC SPACE</i>	
Hugo BÉCU, Claude-Henri LAMARQUE, Alireza TURE SAVADKOOHI	20
<i>TRANSLATION OF A CABLE WITH A SUSPENDED MASS: EFFECTS ON THE VIBRATION MODES</i>	
Piotr CZUBAK, Weronika ŻMUDA	22
<i>STUDY OF TRANSPORT POSSIBILITIES IN THE RESONANCE ZONE OF THE NEW VIBRATORY CONVEYOR EQUIPPED WITH THE SINGLE ELECTROVIBRATOR</i>	
Slawomir DUDA, Grzegorz GEMBALCZYK, Zygmunt KOWALIK, Pawel LIPSKI, Oskar KOZERA	24
<i>SUSPENSION SYSTEM WITH VARIABLE STIFFNESS FOR MOBILE ROBOTS</i>	
Jan FREUNDLICH, Radosław NOWAK	25
<i>VIBRATIONS OF A 3D-PRINTED FRACTIONAL CANTILEVER BEAM WITH A DOUBLE-QUICK-MOUNTS PIEZOELECTRIC TRANSDUCER</i>	
Pawel FRITZKOWSKI	27
<i>ANALYSIS OF VIBRO-IMPACT DYNAMICS BASED ON THE METHOD OF MULTIPLE SCALES</i>	
Michał HAĆ	29
<i>INFLUENCE OF MACHINING AND DESIGN PARAMETERS OF SHAFTS ON COOPERATION OF TOOTHED GEAR</i>	
Grzegorz ILEWICZ	30
<i>DYNAMICS OF RCM MECHANISM OF SURGICAL ROBOT FOR PERIODIC MOVEMENTS WITH CONSIDERATION OF BLDC ACTUATORS, FUZZY PID CONTROL AND GMS FRICTION MODEL</i>	
Grzegorz ILEWICZ	31
<i>DETERMINATION OF OPTIMAL SOLUTIONS FOR BALANCED RCM MECHANISM OF SURGICAL ROBOT DURING NATURAL VIBRATION, LINEAR BUCKLING AND SPHERICAL MOVEMENT TAKING INTO ACCOUNT INPUTS FROM IN VITRO EXPERIMENTS ON CARDIOVASCULAR TISSUE</i>	



Mateusz JAKUBOWSKI, Maciej MAJCHRZAK, Roman STAROSTA, Paweł FRITZKOWSKI	32
<i>FSI SIMULATION OF FLOATING WIND TURBINE BASED ON SPH METHOD</i>	
Anna JASKOT, Bogdan POSIADAŁA	34
<i>MODEL OF THE DYNAMICS OF MOTION OF A FOUR-WHEELED MOBILE PLATFORM WITH THE DYNAMIC INTERACTIONS OF DRIVE WHEEL SYSTEMS</i>	
Jarosław JEDRYSIAK	35
<i>VIBRATIONS OF AXIALLY FUNCTIONALLY GRADED BEAMS WITH AXIAL FORCE</i>	
Iryna KACHURA-ZHECHYTSKA, Błażej GABRYSZEWSKI, Martyna SOPA, Tomasz WALCZAK	37
<i>BIOMECHANICAL ANALYSIS OF THE JUMP SHOT IN BASKETBALL</i>	
Magda KAŻMIERCZAK-SOBIŃSKA	38
<i>THE LOWER FREE VIBRATIONS FREQUENCIES OF THIN PLATES WITH FUNCTIONALLY GRADED STRUCTURE</i>	
Lukasz KLODA, Stefano LENCI, Jerzy WARMINSKI, Zofia SZMIT	40
<i>NONLINEAR MODE COUPLING AND INTERNAL RESONANCES IN A PLANAR BEAM-SPRING SYSTEM</i>	
Krzysztof KOSAŁA	42
<i>COMPARATIVE ANALYSIS OF THE ACOUSTIC PROPERTIES OF GRANULAR MATERIALS</i>	
Tomasz KRAKOWSKI, Bartosz ZIEGLER, Witold STANKIEWICZ	43
<i>ANALYSIS OF DYNAMIC CHARACTERISTICS OF THE TURBINE SHAFT VIBRATION IN OXIDIZER TURBO-PUMP DEMONSTRATOR</i>	
Pavlo KROT, Hamid SHIRI, Radosław ZIMROZ	45
<i>USING THE NATURAL MODES OF TRANSIENT VIBRATIONS IN PREDICTIVE MAINTENANCE OF INDUSTRIAL MACHINES</i>	
Ewelina KUBACKA, Kamil WAWRZYŃIAK	47
<i>OPTIMIZATION ANALYSIS OF BAR STRUCTURE INCLUDING NATURAL FREQUENCY</i>	
Wojciech ŁAPKA	48
<i>ACOUSTICALLY IMPROVED POLISH PHARMACY ROBOT FABLOX</i>	
Magdalena ŁASECKA-PLURA, Jan BIAŁASIK, Mieczysław KUCZMA, Alireza TABRIZIKAHOU	49
<i>APPLICATION OF ISOGEOMETRIC APPROACH TO DYNAMICS OF CURVED BEAMS</i>	
Waldemar ŁATAS, Zygmunt DZIECHCIOWSKI	50
<i>LABORATORY STAND OF CHAIN CONVEYOR</i>	
Waldemar ŁATAS, Jerzy STOJEK	51
<i>OPTIMAL VIBROISOLATION OF MECHANICAL PRESS SUBJECTED TO POLYHARMONIC EXCITATION</i>	
Krzysztof MAGNUCKI, Joanna KUSTOSZ, Damian GOLIWAŚ	52
<i>FREE FLEXURAL VIBRATIONS OF AN EXPANDED-TAPERED SANDWICH BEAM</i>	



Krzysztof MAGNUCKI, Iwona WSTAWSKA, Piotr KĘDZIA	54
<i>FREE FLEXURAL VIBRATIONS OF A SANDWICH BEAM ON AN ELASTIC FOUNDATION WITH VARIABLE PROPERTIES</i>	
Leszek MAJKUT, Krzysztof KOSALA	56
<i>DETERMINATION OF SOUND INSULATION PROPERTIES OF HOMOGENEOUS BAFFLES USING FINITE ELEMENT METHOD</i>	
Mykhailo MARCHUK, Vira PAKOSH	57
<i>NATURAL FREQUENCIES HINGED ALONG THE LOWER RIBS OF THE TRANSVERSAL-ORTHOTROPIC PLATE-STRIP</i>	
Jakub MARCZAK	58
<i>TOLERANCE MODELLING OF VIBRATIONS OF A SANDWICH PLATE WITH A HONEYCOMB CORE</i>	
Jakub MICHALSKI, Tomasz STREK	60
<i>RESPONSE OF LATTICE STRUCTURES BASED ON THE TRIPLY PERIODIC MINIMAL SURFACES TO PROJECTILE IMPACT</i>	
Paweł OLEJNIK, Krzysztof PEPA, Godiya YAKUBU, Jan AWREJCEWICZ	61
<i>THE EXPERIMENTAL STAND FOR OBSERVATION AND CONTROL OF DYNAMICS OF AN EXTENDED ATWOOD'S MACHINE</i>	
Agnieszka OZGA, Marek SULEWSKI	62
<i>APPLICATION OF SUPERVISED LEARNING ALGORITHMS FOR ANALYSIS THE VIBRATIONS OF AN OSCILLATOR FORCED BY A RANDOM SERIES OF IMPULSES</i>	
Agnieszka OZGA, Marek SULEWSKI	63
<i>APPLICATION OF UNSUPERVISED LEARNING ALGORITHMS FOR ANALYSIS THE VIBRATIONS OF AN OSCILLATOR FORCED BY A RANDOM SERIES OF IMPULSES</i>	
Paulina PIETRUSIĆ, Piotr GIERLAK, Andrzej BURGHARDT	64
<i>MODEL OF THE MANIPULATOR WITH FLEXIBLE JOINTS</i>	
Pavel POLACH, Luboš SMOLÍK, Jan RENDL, Štěpán DYK, Miroslav BYRTUS, Michal HAJŽMAN	65
<i>AN OVERVIEW OF NONLINEAR VIBRATION PHENOMENA IN HYDRODYNAMIC JOURNAL BEARINGS</i>	
Volodymyr PUZYROV, Nataliya LOSEVA, Nina SAVCHENKO	67
<i>ON MITIGATION OF OSCILLATIONS OF A MECHANICAL SYSTEM WITH TWO DEGREES OF FREEDOM IN THE VICINITY OF EXTERNAL RESONANCES</i>	
Godwin SANI, Jan AWREJCEWICZ	68
<i>SYNCHRONIZATION AND ENERGY TRANSFER IN 4DOF FRICTION-INDUCED SELF- AND PARAMETRICALLY EXCITED OSCILLATORS</i>	
Filip SARBINOWSKI, Roman STAROSTA	70
<i>COMPREHENSIVE STUDY OF GALLOPING ENERGY HARVESTERS</i>	
Martyna SOPA, Grażyna SYPNIEWSKA-KAMIŃSKA, Tomasz WALCZAK	71
<i>TWO DIMENSIONAL MECHANICAL MODEL OF HUMAN STABILITY IN EXTERNAL FORCE-CAUSED FALL</i>	
Witold STANKIEWICZ	72
<i>REGISTRATION, MODAL DECOMPOSITION AND ANALYSIS OF HUMAN LEFT VENTRICLES</i>	



Stanislaw STRZELECKI	74
<i>DYNAMIC CHARACTERISTICS OF MULTILobe JOURNAL BEARINGS WITH THE LOBES OF DIFFERENT GEOMETRY</i>	
Anna SYGULSKA	75
<i>CINEMA HALL ADAPTED FOR OPERA SINGING – ACOUSTIC ASSESSMENT</i>	
Ryszard SYGULSKI	76
<i>STABILITY AND VIBRATIONS OF PLATES IN AXIAL FLUID FLOW</i>	
Janusz SZMIDLA, Anna JURCZYŃSKA	77
<i>CHANGE IN THE DYNAMIC PROPERTIES OF A COLUMN AS A RESULT OF A VARIABLE DISTRIBUTION OF BENDING STIFFNESS - NUMERICAL AND EXPERIMENTAL RESEARCH</i>	
Janusz SZMIDLA, Anna JURCZYŃSKA	78
<i>FREE VIBRATIONS OF A FLAT FRAME PARTIALLY RESTING ON A WINKLER ELASTIC FOUNDATION IN TERMS OF UNEVEN DISTRIBUTION OF FLEXURAL STIFFNESS</i>	
Zofia SZMIT, Lukasz KLODA, Marcin KOWALCZUK, Jerzy WARMINSKI	79
<i>EXPERIMENTAL DYNAMICS ANALYSIS OF THE THREE-BLADED ROTOR</i>	
Tomasz SZOLC	81
<i>STRUCTURAL HYBRID MODELLING APPLIED TO INVESTIGATE CURRENT PROBLEMS OF ROTOR DYNAMICS</i>	
Maria Teresa TEJEDOR SASTRE, Christian VANHILLE	83
<i>AMPLITUDE-DEPENDENT EFFECTS OF ULTRASOUND IN BUBBLY LIQUIDS</i>	
Andrzej URBAŚ, Krzysztof AUGUSTYNEK, Jacek STADNICKI	84
<i>KINETIC ENERGY BASED INDICATORS TO COMPARE DIFFERENT LOAD MODELS OF A MOBILE CRANE</i>	
Tomasz WALCZAK, Martyna SOPA, Martyna BIAŁECKA, Agata MROZEK, Jakub K. GRABSKI, Aleksander BŁAŻKIEWICZ	86
<i>LOAD ANALYSIS OF HYDROFOIL WINDSURFING ATHLETE</i>	
Tomasz WALCZAK, Martyna SOPA, Adam M. POGORZAŁA, Artur ROHDE	87
<i>GAIT SYMMETRY ASSESSMENT AFTER TWO-SIDE LOWER LIMB AMPUTATION</i>	
Ryszard WALENTYŃSKI, Agnieszka PADEWSKA-JURCZAK, Maciej WIŚNIEWSKI, Dawid CORNIK	88
<i>DYNAMIC ANALYSIS OF HIGH COOLING TOWERS</i>	
Hanna WEBER, Anna JABŁONKA, Radosław IWANKIEWICZ	90
<i>NON-LINEAR DYNAMIC RESPONSE OF A GUY LINE OF A GUYED TOWER TO THE STOCHASTIC WIND EXCITATION BY EQUIVALENT LINEARIZATION TECHNIQUE</i>	
Godiya YAKUBU, Paweł OLEJNIK, Jan AWREJCIEWICZ	91
<i>A DOUBLE PENDULUM WITH FRICTION UNDER THE ELECTROMAGNETIC FORCING AND KINEMATIC EXCITATION: SIMULATION AND EXPERIMENTATION</i>	



ENERGY HARVESTING USING A PIEZOELECTRIC TRANSDUCER ON EXTERNALLY FORCED BUT DAMPED OSCILLATOR

Mohamed ABOHAMER^{1,2}, Jan AWREJCEWICZ³, Tarek AMER⁴

¹Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, Lodz, Poland.

²Tanta University, Faculty of Engineering, Department of Physics and Engineering Mathematics, Tanta, Egypt.

e-mail: mohamed.abohamer@dokt.p.lodz.pl

³Lodz University of Technology, Department of Automation, Biomechanics and Mechatronics, Lodz, Poland.

e-mail: jan.awrejcewicz@p.lodz.pl

⁴Tanta University, Faculty of Science, Mathematics Department, Tanta, Egypt.

e-mail: tarek.saleh@science.tanta.edu.eg

ABSTRACT

We are focused on the investigation of the motion of a novel 3-DOF system composed of two parts. The first part contains a linear damped oscillator moving horizontally without any friction. The oscillator is connected to a piezoelectric device for the purpose of energy harvesting. The second part consists of a nonlinear damped pendulum system which is hung up at the center of the system. The dynamical model is excited by harmonic external forces. The Lagrange equations are employed to construct the governing equations, and the multiple scales technique is utilized to evaluate the analytical solutions. The analysis of the resonance scenarios and the solvability constraints yields the modulation equations. The time series of generalized coordinates of the system are analyzed. The dynamical model serves as the source of vibrations for operating the piezoelectric device in order to convert these vibrations to electrical energy. Graphical representations are used to show the effects of excitation amplitude, coupling coefficient, capacitance, load resistance, natural frequency, and damping coefficient versus the output voltage and power. The resonance shapes constructed to explore the steady-state solutions and stability analyses is carried out.

1. INTRODUCTION

Non-renewable fossil fuels are the main energy-producing resources, but they are quickly depleting and will run out within the next several decades. Energy harvesting, which captures unused ambient energy and converts it into a more useful form of energy, is the most promising renewable energy source and a perfect alternative source for energy instead of traditional sources. A piezoelectric device [1, 2] is one of the energy-harvesting devices used to transform mechanical vibrations into electrical power. In this paper, we have developed a novel physical model for energy harvesting.

2. RESULTS AND DISCUSSION

The vibrational analysis covers the system composed of the piezoelectric transducer and vibrational 3DOF mechanical system. The equations of motion are solved analytically [3], and compared with the numerical ones for more consistency and reliability (see Fig. 1). The influence of the coupling between the mechanical model and the piezoelectric device on the electrical production is represented graphically in (Fig. 2). The following non-dimensional governing equations of the model are obtained using Lagrange equations

$$\begin{aligned}
 \ddot{x} + \beta \ddot{z} \sin \theta + \beta (1+z) \ddot{\theta} \cos \theta + 2\beta \dot{z} \dot{\theta} \cos \theta - \beta (1+z) \dot{\theta}^2 \sin \theta + c_1 \dot{x} + x + \mu v + \omega^2 \\
 = f_1 \cos p_1 \tau, \\
 \ddot{z} + \ddot{x} \sin \theta - (1+z) \dot{\theta}^2 + c_2 \dot{z} + \varpi^2 z + 3\eta^2 \alpha z + 3\eta \alpha z^2 + \alpha z^3 + \omega^2 (1 + \cos \theta) \\
 = f_2 \cos p_2 \tau, \\
 (1+z)^2 \ddot{\theta} + (1+z) \ddot{x} \cos \theta + 2(1+z) \dot{z} \dot{\theta} + c_3 \dot{\theta} + \omega^2 (1+z) \sin \theta = f_3 \cos p_3 \tau, \\
 \dot{v} + \frac{v}{c_p R_L \omega_1} = \frac{l \gamma}{c_p} \dot{x}.
 \end{aligned} \tag{1}$$

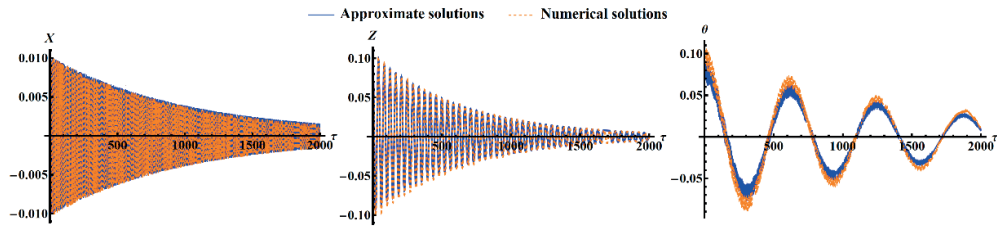


Fig. 1. Time histories of the solutions of Eqs (1).

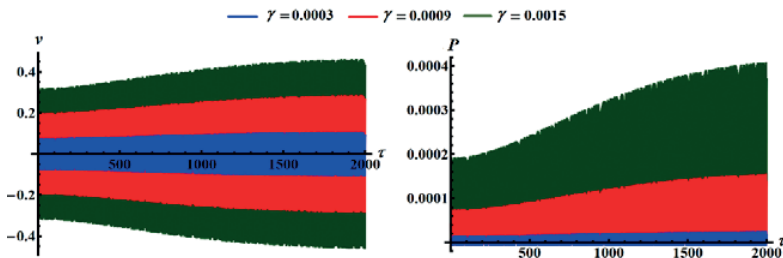


Fig. 2. The effect of different values of the coupling coefficient γ on the output voltage and power of the piezoelectric transducer.

3. CONCLUSION

A novel physical dynamical system connected with a piezoelectric harvesting transducer is investigated. Energy-harvesting technologies have a wide range of uses in daily life such as environmental monitoring, and remote medical diagnosis. The equations of motion are derived and the multiple scale technique is used to obtain the analytical solution. A comparison between the numerical and approximate solutions is represented graphically. The external resonance case is illustrated and then we get the modulation equations. The influence of the effective different parameters of the model on the output voltage and power is examined. Furthermore, resonance response curves are constructed, and then their stability has been investigated.

Acknowledgments

This work has been supported by the Polish National Science Centre, Poland under the grant OPUS 18 No. 2019/35/B/ST8/00980.

REFERENCES

- [1] S. Sharma, R. Kiran, P. Azad, R. Vaish, A review of piezoelectric energy harvesting tiles: Available designs and future perspective, *Energy Convers. Manag.* 254, 115272 (2022)
- [2] H. Elahi, M. Eugeni, P. Gaudenzi, A review on mechanisms for piezoelectric-based energy harvesters, *Energies*, 11, 1850 (2018)
- [3] M.K. Abohmer, J. Awrejcewicz, R. Starosta, T.S. Amer, M.A. Bek, Influence of the motion of a spring pendulum on energy-harvesting devices, *Appl. Sci.* 11 (18), 8658 (2021)