Директору Математичког института САНУ
Проф. др Зорану Огњановићу
Научном већу Математичког института САНУ
академику Драгошу Цветковићу

Стручни извештај

о учешћу у научном скупу[1]

3th Conference on DYNAMICAL SYSTEMS Theory and Applications- DSTA 2015, Łódź, December 7-10, 2015, POLAND, Lodz University of Technology, Faculty of Mechanical Engineering Department of Automation, Biomechanics and Mechatronics

http://www.dys-ta.com/

http://www.dys-ta.com/

Моје учешће у раду ове традиционалне међународне конференције под називом: **3th Conference on DYNAMICAL SYSTEMS Theory and Applications- DSTA 2015, Łódź, December 7-10, 2015, POLAND, у организацији Lodz University of Technology, Faculty of Mechanical Engineering Department of Automation, Biomechanics and Mechatronics** је реализовано на основу позива организатора Конференције да будем члан Научног комитета Конференције.

Учешће се огледало у следећим активностима:

* Чланством у Научном комитету Конференције **DSTA 2015, Łódź** и учешћем у седници Научног комитета, као и у оцени квалитета и оригиналности научних доприноса у радовима пристиглих рукописа за програм и штампаним у преконференцјским Зборницима радова Конференције;

*Учешћем питањима и коментарима на седницама Конференције, као и комуникацијама са колегама у току пауза Конференције

* Одржавању три научна саопштења у секцијама Сабилност и управљање и Математички и нумерички приступи, као и коауторству над једним радом саопстеним у оквиру секције Биомеханике.

Саопштења, која сам одржала, су под следећим насловима:

Katica R. Hedrih (Stevanović), (2015), *Vibro-impact dynamics of the rolling disks along rotate circle in vertical plane (* секција Стабилност и управљање);

Katica R. Hedrih (Stevanović), (2015), *Dynamics of impacts and collisions of the rolling balls (*секција Стабилност и управљање);

Katica R. Hedrih (Stevanović), *Angular velocity and intensity change of basic vectors of position vector tangent space of a material system kinetic point - four examples (*секција Математички и нумерички приступи);

Коауторски рад под називом:

Andjelka Hedrih, Katica Hedrih (Stevanovic), (2015), *Deformation work of Zona Pelucida in process of fertilization (секција Наука о живим системма и Биомеханика)*

саопштио први ауор и инспиратор идеје и садржаја тог рада у секцији Биомеханика.

У прилогу су дати библиографски подаци о одговарајућим публикацијама и у којима су штампани апстракти радова, као и сами радови, а назначено је и да су у проширеном садржају позвани за могуће штампање у специјалним бројевима часописа, односно Спрингерових тематских зборника.

Саопштени резучтати су добијени у оквиру истраживања на пројекту ОН174001. Посебно интересовање су изазвали резултати који представљају значајан и оригинални допринос теорији судара котрљајућих се крутих тела и новодобијене формуле за одређивање одлазних угаоних брзина тела поосле судара, као и њихова примена у изучавању кинетичких параметара вибтоудатне динамике класе виброударних система са котрљајућим се крутим телима у сударау.

Такође и садржај рада из биодинамике, који се односи на одређивање компонената тензора напона и тензора деформације, као и специфичног деформационог рада у тачкама зоне пелуцида у процесу фертилизације, је изазвао интересовање слушалаца у тој секцији.

Поред програма Конференције, публикован је Зборник апстраката, и три тома тематских зборника целих адова, и у постпку је додатно рецензирање позваних радова за публиковање у специјалним бројевима интернационалних часописа и Шпрингерових тематских зборника радова.

За учешће у раду Конференције пријављено је **315** радова, од чега је **164** рада оштампано у три тома **конференцијских тематских зборника радова под називом:** Proceedings of the 13th Conference „Dynamical Systems - Theory and Applications" Vol. 13/1 **Mathematical and numerical approach** Vol. 13/2 , **Mechatronics and Life Sciences,** Vol. 13-/ **Control and Stability. 60** радова је планирано за публиковање у тематском Springer Proceedings-у.

Организација Конференције је била добра, предавања и саопстења на високом научном или апликативном и експерименталном нивоу. На овој конференцији је било већи број младих учесника него ранијих година, што посебно радује. Око 50% радова је било представљено у виду кратких предавања, док је други део био представљен у виду постера у посебној Постер секцији!.

НАПОМЕНА: Трошкове пута и учешћа у Конференцији сам покрила сопственим средствима од пензије од које се издржавам.

С поштовањем,

Катица (Стевановић) Хедрих

У Београду, 15 децембра 2015.

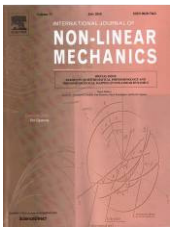
Katica R. (Stevanović) Hedrih
Руководилац пројекта ОМ174001

Апстракт 1:

Katica R. Hedrih (Stevanović), (2015), *Vibro-impact dynamics of the rolling disks along rotate circle in vertical plane* , 13th Conference on DYNAMICAL SYSTEMS Theory and Applications DSTA 2015 ABSTRACTS, EDITORS *J. Awrejcewicz, M. Kaźmierczak, P. Olejnik, J. Mrozowski,* Łódź, December 7-10, 2015, POLAND, Lodz University of Technology, Faculty of Mechanical Engineering Department of Automation, Biomechanics and Mechatronics, 2015, p. 150. http://abm.p.lodz.pl, ISBN 978-83-7283-705-9.

Публиковани рад 1:

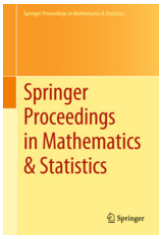
Katica R. Hedrih (Stevanović), (2015), *Vibro-impact dynamics of the rolling disks along rotate circle in vertical plane*, **DYNAMICAL SYSTEMS, Control and Stability, Thematical Proceedings** Editors> JAN AWREJCEWICZ, MAREK KAŹMIERCZAK, JERZY MROZOWSKI, PAWEŁ OLEJNIK, 2015, Vol. 13/3, pp. 251-262. © Department of Automation, Biomechanics and Mechatronics. ISBN 978-83-7283-708-0



Рад 1 је, од рецензената оцењен оценом **"exellant"** и у проширеном облику позван, за могуће пост конференцијско публиковање, у специјалном броју часописа International Journal Non-Linear Mechanics (M21) , познатог издавача научних часописа Elsevuier -а, који ће уредити као гост уредник професор JAN AWREJCEWICZ, чермен конференције.

Апстракт 2:

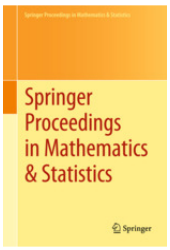
Katica R. Hedrih (Stevanović), (2015), *Dynamics of impacts and collisions of the rolling balls* , 13th Conference on DYNAMICAL SYSTEMS Theory and Applications DSTA 2015 ABSTRACTS, EDITORS *J. Awrejcewicz, M. Kaźmierczak, P. Olejnik, J. Mrozowski,* Łódź, December 7-10, 2015, POLAND, Lodz University of Technology, Faculty of Mechanical Engineering Department of Automation, Biomechanics and Mechatronics, 2015, p. 149, http://abm.p.lodz.pl, ISBN 978-83-7283-705-9.



Рад 2 је, у проширеном облику позван, за могуће пост конференцијско публиковање, у тематском зборнику **Mathematics and Statistics** (for more details you can follow the link http://www.springer.com/series/10533, познатог издавача наулчне литературе Springer, који ће уредити као гост уредник професор JAN AWREJCEWICZ, чермен конференције. Ова серија Springer-ових зборника се приказује и цитира. (Proceedings are abstracted in Conference Proceedings Citation Index – Science (CPCI-S, Thomson Reuters, Web of Science) and are fully citable).

Апстракт 3:

Katica R. Hedrih (Stevanović), *Angular velocity and intensity change of basic vectors of position vector tangent space of a material system kinetic point - four examples,* 13th Conference on DYNAMICAL SYSTEMS Theory and Applications DSTA 2015 ABSTRACTS, EDITORS *J. Awrejcewicz, M. Kaźmierczak, P. Olejnik, J. Mrozowski,* Łódź, December 7-10, 2015, POLAND, Lodz University of Technology, Faculty of Mechanical Engineering Department of Automation, Biomechanics and Mechatronics, 2015, p. 148, http://abm.p.lodz.pl, ISBN 978-83-7283-705-9.



Рад 3 је, у проширеном облику позван, за могуће пост конференцијско публиковање, у тематском зборнику **Mathematics and Statistics** (for more details you can follow the link http://www.springer.com/series/10533, познатог издавача наулчне литературе Springer, који ће уредити као гост уредник професор JAN AWREJCEWICZ, чермен конференције. Ова серија Springer-ових зборника се приказује и цитира. (Proceedings are abstracted in Conference Proceedings Citation Index – Science (CPCI-S, Thomson Reuters, Web of Science) and are fully citable).

Апстракт 4:

Andjelka Hedrih, Katica Hedrih (Stevanovic), (2015), *Deformation work of Zona Pelucida in process of fertilization* , 13th Conference on DYNAMICAL SYSTEMS Theory and Applications DSTA 2015 ABSTRACTS, EDITORS *J. Awrejcewicz, M. Kaźmierczak, P. Olejnik, J. Mrozowski,* Łódź, December 7-10, 2015, POLAND, Lodz University of Technology, Faculty of Mechanical Engineering Department of Automation, Biomechanics and Mechatronics, 2015, Vol. 13, p. 147, http://abm.p.lodz.pl, ISBN 978-83-7283-705-9.

Публиковани рад 4:

Andjelka Hedrih, Katica Hedrih (Stevanovic), (2015), *Deformation work of Zona Pelucida in process of fertilization,* **DYNAMICAL SYSTEMS, Mechatronics and Life Sciences, Thematical Proceedings** Editors: JAN AWREJCEWICZ, MAREK KAŹMIERCZAK, JERZY MROZOWSKI, PAWEŁ OLEJNIK, © Department of Automation, Biomechanics and Mechatronics, 2015, Vol. 13/2, pp. 217-226. ISBN 978-83-7283-707-3

Рад 4 је, од рецензената оцењен оценом **високом оценом** и у проширеном облику позван, за могуће пост конференцијско публиковање, у специјалном броју часописа **Applied Nonlinear Dynamics,** (**ISSN:**2164-6457 (print) , **ISSN:**2164-6473 (online), **Home** L & H Scientific Publishing) који ће уредити као гост уредник професор JAN AWREJCEWICZ, чермен конференције.

https://lhscientificpublishing.com/journals/JAND-Default.aspx

Цитат из предговора Зборницима радова коонференције:

It is a great pleasure that our invitation has been accepted by so many people, including good colleagues and friends as well as a large group of researchers and scientists, who decided to participate in the conference for the first time. With proud and satisfaction we welcome nearly 170 persons from 32 countries all over the world. They decided to share the results of their research and many years experiences in a discipline of dynamical systems by submitting many very interesting papers.

This booklet contains a collection of abstracts, which have gained the acceptance of referees and have been qualified for publication in the conference proceedings. Included abstracts belong to the following topics:

- asymptotic methods in nonlinear dynamics,
- bifurcation and chaos in dynamical systems,
- control in dynamical systems,
- dynamics in life sciences and bioengineering,
- engineering systems and differential equations,
- non-smooth systems
- mathematical approaches to dynamical systems
- original numerical methods of vibration analysis,
- stability of dynamical systems,
- vibrations of lumped and continuous systems,
- other problems.

Proceedings of the 13th Conference „Dynamical Systems - Theory and Applications" summarize **164** and the Springer Proceedings summarize **60** best papers of university teachers and students, researchers and engineers from whole the world. The papers were chosen by the International Scientific Committee from **315** papers submitted to the conference. The reader thus obtains an overview of the recent developments of dynamical systems and can study the most progressive tendencies in this field of science.

2. Tuesday, December 8, 2015

8:00 - 19:00 Trip to Polish Jura

3. Wednesday, December 9, 2015

Session 5C, 12:20 - 13:35

1.	Kęcik K., Mitura A.	*Non-linear dynamics of a vibration harvest-absorber system*
2.	Hedrih (Stevanović) K.	*Vibro-impact dynamics of two rolling heavy disks along rotate circle with constant angular velocity*
3.	Hedrih (Stevanović) K.	*Dynamics of impacts and collisions of the rolling balls*
4.	Soukup J., Skočilas J., Skočilasova B.	*Experimental determination of eigen frequency and stiffness of suspension of elastically embedded body – vehicle application*
5.	Morais E., Vigh L., Krähling J.	*Fragility estimation and comparison using IDA and simplified macro-modeling of in-plane shear in old masonry walls*

Lunch 13:35 - 15:00

Session 6B, 15:50 - 17:05

1.	Hedrih A., Hedrih (Stevanović) K.	*Deformation work of Zona Pelucida in process of fertilization*
2.	Harlecki A., Urbaś A.	*Dynamics simulations of spatial linkages using the LuGre friction model*
3.	Klimina L., Dosaev M., Selyutskiy Y., Hwang S.-S., Lin K.-H.	*Asymptotic analysis of the model of a wind-powered vehicle moving against the flow*
4.	Klaerner M., Wuehrl M., Marburg S., Kroll L.	*Efficient FEA simulation of structure borne sound radiation*
5.	Hedrih (Stevanović) K.	*Angular velocity and intensity change of basic vectors of position vector tangent space of a material system kinetic point - four examples*

13th INTERNATIONAL CONFERENCE
on
DYNAMICAL SYSTEMS
THEORY AND APPLICATIONS
ŁÓDŹ, DECEMBER 7-10, 2015

ABSTRACTS

EDITORS:
J. AWREJCEWICZ
M. KAŹMIERCZAK
P. OLEJNIK
J. MROZOWSKI

DSTA 2015

DYNAMICAL SYSTEMS
Mathematical and Numerical Approaches

Editors
J. AWREJCEWICZ
M. KAŹMIERCZAK
J. MROZOWSKI
P. OLEJNIK

DSTA 2015

DYNAMICAL SYSTEMS
Mechatronics and Life Sciences

Editors
J. AWREJCEWICZ
M. KAŹMIERCZAK
J. MROZOWSKI
P. OLEJNIK

DSTA 2015

DYNAMICAL SYSTEMS
Control and Stability

Editors
J. AWREJCEWICZ
M. KAŹMIERCZAK
J. MROZOWSKI
P. OLEJNIK

DSTA 2015

SCIENTIFIC COMMITTEE

H. Altenbach – Germany
M. Alves – Brazil
I.V. Andrianov – Germany
J. Awrejcewicz – Chairman, Poland
J.M. Balthazar – Brazil
T. Burczyński – Poland
Cz. Cempel – Poland
F. Chernousko – Russia
F. Dohnal – Switzerland
V.-F. Duma – Romania
I. Elishakoff – USA
M. Fečkan – Slovakia
N. Ferreira – Portugal
B. Gallacher – UK
O. Gendelman – Israel
O. Gottlieb – Israel
P. Hagedorn – Germany
K. (Stevanovic) Hedrih – Serbia
L. Kolar-Anić – Serbia
I. Kovacić – Serbia
J. Kowal – Poland
J. Kozanek – Czech Republic
P. Krasilnikov – Russia
V.A. Krysko – Russia
W. Lacarbonara – Italy
L.V. Kurpa – Ukraine
C.-H. Lamarque – France
S. Lenci – Italy
G.A. Leonov – Russia
A. Luo – USA
E. Macau – Brazil
J.A. Machado – Portugal
N.M.M. Maia – Portugal
L.I. Manevitch – Russia
A.A. Martynyuk – Ukraine
S. Maruyama – Japan
G.I. Mikhasev – Belarus
Y. Mikhlin – Ukraine
G. Olivar – Colombia
M. Pascal – France
Ch. Pierre – USA
V.N. Pilipchuk – USA
C.M.A. Pinto – Portugal
J. Przybylski – Poland
S. Radkowski – Poland
B. Radziszewski – Poland
P. Ribeiro – Portugal
R. Sampaio – Brazil
A. Seyranian – Russia
Ch.H. Skiadas – Greece
S. Theodossiades – UK
J.J. Thomsen – Denmark
J.J. Trujillo – Spain
A. Tylikowski – Poland
F. Udwadia – USA
T. Uhl – Poland
A.F. Vakakis – USA
F. Verhulst – The Netherlands
J. Warmiński – Poland
M. Wiercigroch – UK
E. Wittbrodt – Poland
H. Yabuno – Japan
H.M. Yehia – Egypt
K. Zimmermann – Germany

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications
December 7-10, 2015. Lodz, POLAND.

paper id: BIF125

Vibro-impact dynamics of the rolling disks along rotate circle in vertical plane

Katica R. Hedrih (Stevanović)

Abstract: Use Petrović's elements of mathematical phenomenology, especially mathematical analogy between kinetic parameters of collision of two bodies in translator motion and collision of two different rolling disks, new original expressions of two outgoing angular velocities for each of rolling disks after collision are defined in author previous papers. Using this new and original result vibro-impact dynamics of two different rolling heavy disks on the rotating circle trace in vertical plane in period of series of collisions is investigated. Use series of the elliptic integrals, new nonlinear equations for obtaining angles of disks positions at positions of collisions are defined. Phase trajectories of the disks in vibro-impact dynamics are theoretically presented. Two cases vibro-impact dynamics when phase portraits contain trigger of coupled singularities and homoclinic orbit in the form of number "eight" as well as and case without that trigger of coupled singularities are discusses. Keywords: Theory, rolling disks, collision, pre-impact, post-impact, impulse, moment of impulse, impact forces, impact couple, rolling trace, arrival angular velocity, impact angular velocity, outgoing angular velocity, collision of rolling disks on rotate circle line, phase trajectory, angular velocity discontinuity.

[1)] Katica R. Hedrih (Stevanović), Professor: Mathematical Institute of Serbian Academy of Science and Arts (SANU), ul. Vojvode Tankosica no. 3, Stan 22, 18000-Nis, SERBIA (khedrih@sbb.rs), the author presented this work at the conference.

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications
December 7-10, 2015. Lodz, POLAND.

paper id: ENG96

Dynamics of impacts and collisions of the rolling balls

Katica R. Hedrih (Stevanović)

Abstract: In the paper the theory of dynamics of impacts and collisions of the rolling balls is presented for different types of impacts and collisions depending of balls configuration in kinetic state of impacts and collisions. By use analogy between central impacts or collision of balls in translator motion and balls rolling motions before impacts or collisions corresponding relations between outgoing velocities and outgoing angular velocities of rolling and impact velocities are expressed. Also, change of impact impulse (linear momentum) and moment of impulse (angular momentum) of ball rolling motion after and before impacts and collision are expressed. By use phenomenological mappings between a set of elements dynamics of balls impact and collisions for central and skew impacts as well as collisions corresponding analogies are identified. Different ball rolling traces before and after of skew impacts and skew collisions as a set of different elements of kinematic for each type of impacts and collision are discussed and kinematical plans of impacts and corresponding outgoing translator and angular velocities are graphically presented by series of Figures. In conclusion, dynamics of elliptic billiards is presented. Keywords: Theory, rolling balls, impact, collision, impulse, moment of impulse, impact forces, impact couple, rolling trace, impact angular velocity, outgoing angular velocity, theorems.

[1)] Katica R. Hedrih (Stevanović), Professor: Mathematica Institute of Serbian Academy of Science and Arts (SANU),Belgrade, Serbia, ul. Vojvode Tankosica no. 3, Stan 22, 18000-Nis, SERBIA (khedrih@sbb.rs), the author presented this work at the conference.

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications
December 7-10, 2015. Lodz, POLAND.

DSTA 2015

paper id: STA109

Angular velocity and intensity change of basic vectors of position vector tangent space of a material system kinetic point - four examples

Katica R. Hedrih (Stevanović)

Abstract: Paper starts from author's previous published results about nonlinear transformations of coordinate systems, from affine space to functional-nonlinear curvilinear coordinate system and corresponding geometrical and kinematical invariants along nonlinear transformations their coordinates from one to other coordinate system. In a curvilinear coordinate system, coordinates of a geometrical or kinematical point are not equal as coordinates of its corresponding position vector. Expressions of basic vectors of tangent space of kinetic point vector position in generalized curvilinear coordinate systems for the cases of orthogonal curvilinear coordinate systems are derived and four examples are presented. Next, expressions of change of basic vectors of tangent space of kinetic point vector position with time, also, are done. In this paper, new and original expressions of angular velocity and velocity of dilatations of each of the basic vectors of tangent space of kinetic point vector position, in for orthogonal curvilinear coordinate systems are presented. List of these curvilinear coordinate systems are: three dimensional elliptical cylindrical curvilinear coordinate system; generalized cylindrical bipolar curvilinear coordinate system; generalized elliptical curvilinear coordinate system and Generalized oblate spheroidal curvilinear coordinate system. Keywords: Nonlinear, transformation, mapping, curvilinear coordinate systems, basic vectors, vector position, tangent space, angular velocity of basic vector rotation, velocity of basic vector dilatation

[1)] Katica R. Hedrih (Stevanović), Professor: Mathematical Institute of Serbian Academy of Science and Arts (SANU) , ul. Vojvode Tankosica no. 3, Stan 22, 18000-Nis, SERBIA (khedrih@sbb.rs), the author presented this work at the conference.

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications
December 7-10, 2015. Lodz, POLAND.

DSTA 2015

paper id: LIF223

Deformation work of Zona Pelucida in process of fertilization

Andjelka Hedrih, Katica Hedrih (Stevanovic)

Abstract: Zona pelucida (ZP) is an extracellular mantel that surrounds mammalian oocytes. This structure is important for fertilization, especially for gamete recognition and integrity of the embryo. ZP is highly sulfated and glycosylated polymer gel that exhibit visco-elastic properties and changing in diameter in different maturation stages. In the process of fertilization numerous spermatozoa impact its external surface giving some energy to the structure. The aim of this paper is to present a possible approximate mechanical model of the ZP in the form of elastic body bound by two concentric spherical surfaces loaded by discrete continuum distribution of spermatozoa impacts in radial directions. Using theory of elasticity for this approximate model, expressions for component stresses and strains are presented, as well as expressions for specific and total deformation work of the model deformation under external constant pressure. On the basis of obtained expressions an analysis of possible stress and strain state and a model of ZP deformation work some conclusions are derived. A specific deformation work as criteria for determination area of possible open put for passing spermatozoa through ZP is proposed.

[1)] Andjelka Hedrih, M.Sc. (Ph.D. student): State University of Novi Pazar, 36 300 Novi Pazar, SERBIA (handjelka@gmail.com), the author presented this work at the conference.

[2)] Katica Hedrih (Stevanovic), Ph.D.: Mathematical Institute SANU Belgrade, Faculty of Mechanical engineering University of NIs, 11 000 Belgrade, SERBIA (khedrih@sbb.rs).

Vibro-impact dynamics of two rolling heavy disks along rotate circle with constant angular velocity

Katica R. (Stevanović) Hedrih

Abstract: Under the authors' use Petrović's elements of mathematical phenomenology, especially mathematical analogy between kinetic parameters of central collision of two bodies in translator motions and central collision of two rolling different disks, new original expressions of two outgoing angular velocities for each of rolling disks after collision are defined in author previous papers. Using this new and original result of vibro-impact dynamics of two rolling heavy different disks on the rotating circle trace in vertical plane in period of series of collisions is investigated. Use series of the elliptic integrals, new nonlinear equations for obtaining angles of disks positions at positions of collisions are defined. Phase trajectories of the disks in vibro-impact dynamics are theoretically presented. Two cases of vibro-impact dynamics when phase portraits contain trigger of coupled singularities and homoclinic orbit in the form of number "eight" as well as in the case without that trigger of coupled singularities are discussed. Phase trajectory branches of both rolling disks in period from initial positions to first collision between rolling disks are presented..

1. Introduction

Non-linear differential equations of non-linear dynamics of a rolling heavy disk along rotate circle, with constant angular velocity, about axis in three different positions are derived and presented in author's Reference [1]. From comparison between these three nonlinear differential equations, some conclusions of nonlinear dynamics of rolling heavy disk along rotate circle with constant angular velocity about different axis in three different positions are pointed out. For two cases, first that axis of the circle rotation is vertical and central and second that axis is vertical and eccentrically, corresponding equations of phase trajectory portraits depending of kinetic parameters of the system, are obtained. Existence of trigger of coupled singularities [2-7] and homoclinic orbit in the form of number "eight" depending on system kinetic parameters and appearance of the bifurcation of relative equilibrium positions are investigated. For the case that axis of the circle rotation is vertical and central, functional dependence between angle of disk relative arbitrary position on rotate circle and duration of time are derived [1]. For obtaining this solution, an elliptic integral [8] is derived. For solving elliptic integral, a transformation is introduced and functions under the elliptic integral are developed in three series along angle of disk relative arbitrary position on rotate circle [1]. By use obtained functional dependence between time of disk rolling and angle of disk relative position,

positions of two rolling disks at rotate circle trace around vertical central axis with constant angular velocity, taking into account expression (8) for each disk, that is $t_{1,impct,1} = t_{2,impct,1}$ is in the following form:

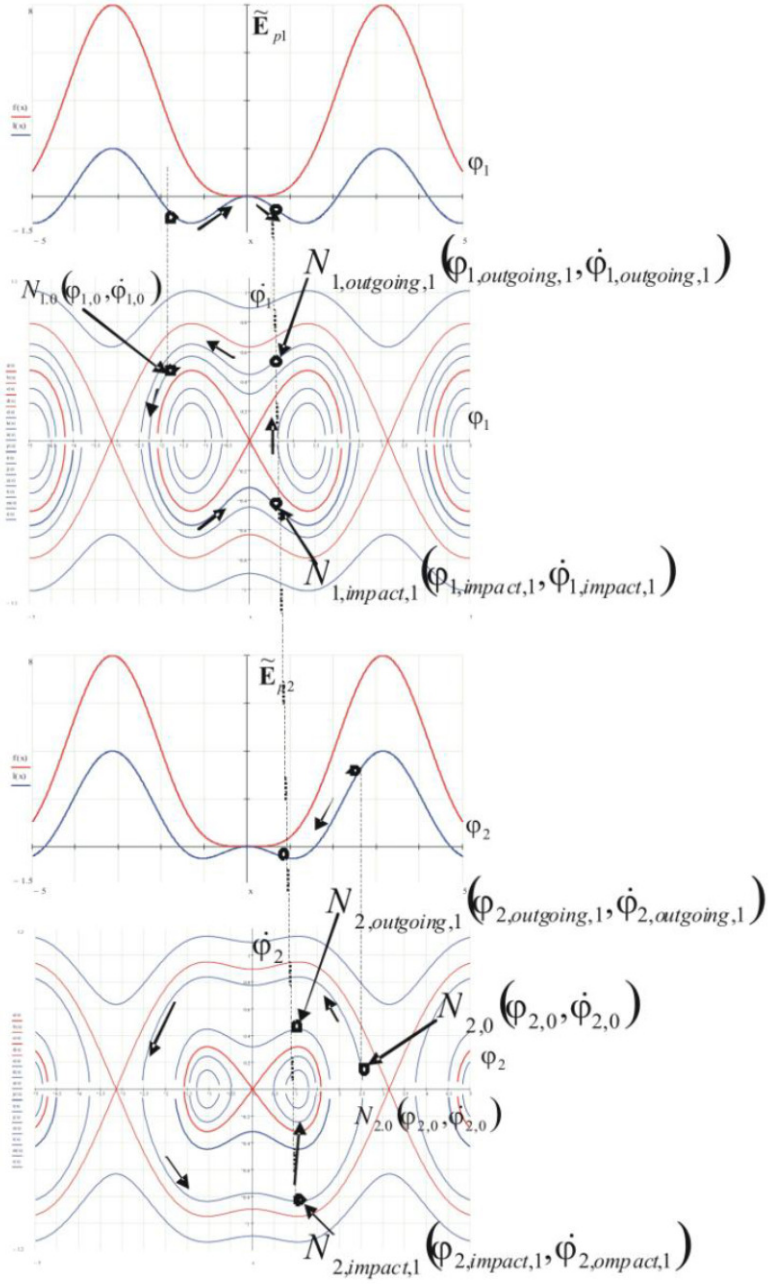


Figure 5. Phase trajectory branches in phase portraits of two rolling disks for relative motion in interval between initial configuration and configurations of pre-first-collision and post-first-collision between two rolling disks

[20] Petrović M., Elementi matematičke fenomenologije (Elements of mathematical phenomenology), Srpska kraljevska akademija, Beograd, 1911. str. 89.

[21] Petrović M., Fenomenološko preslikavanje (Phenomenological mapp), Srpska kraljevska akademija, Beograd, 1933. str. 33. http://elibrary.matf.bg.ac.rs/handle/123456789/475

[22] Petrović M., Mecanismes communs aux phenomenes disparates, Paris 1921.

[23] Elements of mathematical phenomenology and phenomenological mapping in non-linear dynamics, Edited by Katica R. (Stevanovic) Hedrih, Ivan Kosenko, Pavel Krasilnikov and Pol D. Spanos, Special Issue of International Journal of Non-Linear, Mechanics, Volume 73, Pages 1-128 (July 2015)

[24] Hedrih (Stevanović) R. K., Central collision of two rolling balls: Theory and examples, (manuscript in review process, May 30, 2015).

[25] Hedrih (Stevanović) R. K., *DYNAMICS OF THE ELLIPTIC BILLIARDS AND ROLLING BALL IMPACTS*,.Proceedings, The 5th International Congress of Serbian Society of Mechanics. Arandjelovac, June 15-17, 2015, pp. 98-98. Published by Serbian Society of Mechanics and Faculty of Technical Sciences Novi Sad, ISBN 978-86-7892-715-7, COBISS.SR-ID 296997639. Plus at USB M2c, pp. 1-4.

[26] Hedrih (Stevanović) K R., Raičević V. and Jović S., Phase Trajectory Portrait of the Vibro-impact Forced Dynamics of Two Heavy Mass Particles Motions along Rough Circle, Communications in Nonlinear Science and Numerical Simulations, 2011 16 (12):4745-4755, DOI 10.1016/j.cnsns.2011.05.027..

Katica R. (Stevanović) Hedrih, University Professor, Doctor of technical Sciences, Department of Mechanics at Mathematical Institute of Serbian Academy of Science and Arts (SANU), Belgrade and Faculty of Mechanical Engineering University of Niš, Serbia, e-mail: khedrih@sbb.rs; Priv. address: 18000- Niš, Serbiam ul. Vojvode Tankosića 3/22.e-mail: khedrih@eunet.rs.

Deformation work of Zona Pelucida in process of fertilization

Andjelka N. Hedrih, Katica R. (Stevanovic) Hedrih

Abstract: Zona pelucida (ZP) is an extracellular mantel that surrounds mammalian oocytes. This structure is important for fertilization, especially for gamete recognition and integrity of the embryo. ZP is highly sulfated and glycosylated polymer gel that exhibit visco-elastic properties and changing in diameter in different maturation stages. In the process of fertilization numerous spermatozoa impact its external surface giving some energy to the structure. The aim of this paper is to present a possible approximate mechanical model of the ZP in the form of elastic body bound by two concentric spherical surfaces loaded by discrete continuum distribution of spermatozoa impacts in radial directions. Using theory of elasticity for this approximate model, expressions for component stresses and strains are presented, as well as expressions for specific and total deformation work of the model deformation under external constant pressure. On the basis of obtained expressions an analysis of possible stress and strain state and a model of ZP deformation work some conclusions are derived. A specific deformation work as criteria for determination area of possible open put for passing spermatozoa through ZP is proposed.

1. Introduction

Zona pelucida (ZP) is an extracellular, 3D mash –like structure that surrounds mammalian oocytes. It is highly sulfatated glikoprotein gel 2-6% (w/v) where the glikoproteins are interconnected with non-covalent bounds [1]. The structure is important for fertilization, gamete recognition and integrity of the embryo. It is formed during the process of oocyte maturation [2] and change mechanical and structural properties during oocyte maturation and fertilization process [3]. During these processes it change its diameter. In fully-grown oocyte ZP is the thickest. This structure exists till the early blastocyst stage of an embryo. ZP is mechanically responsive structure [3, 4]. Using atomic force microscope and Arruda–Boyce eight-chain model visco-elastic properties of ZP could be modeled [4]. A computational model of impact of one sperm to the ZP was done in [5]. The ZP can be considered as an oscillatory structure that exhibits transition in oscillatory behavior before and after fertilization [6, 7]. Dissipation of its oscillatory energy occurs when it exhibits visco-elastic properties [7].

1.1. Effect of sperm velocity and its arrangement on mouse ZP oscillatory behavior

During the process of fertilization many spermatozoa will influence the surface of ZP. Spermatozoa are motile cells and in ejaculate there are many spermatozoa (in range of 10^6) with different velocities

Acknowledgments

This work was supported by the Ministry of Education, Sciences and Technology of the Republic of Serbia through Mathematical Institute SANU, Belgrade and Faculty of Mechanical Engineering, University of Niš, State University of Novi Pazar Grant ON174001.

References

[1] Green, P.D. Three-dimensional structure of the zona pellucida, *Reviews of Reproduction*, 2, (1997), 147-156.

[2] Jovine, L., Qi, H., Williams, Z., Litscher, E.S., Wassarman PM. Features that affect secretion and assembly of zona pellucida glycoproteins during mammalian oogenesis. *Society of Reproduction and Fertility Supplement.* 2007, 63: 187-201.

[3] Murayama, Y., Mizuno, J., Kamakura, H., Fueta, Y,, Nakamura, H., Akaishi, K., Anzai, K., Watanabe, A., Inui, H., and Omata, S. Mouse zona pellucida dynamically changes its elasticity during oocyte maturation, fertilization and early embryo development. *Human Cell* 19 (2006), 119–125.

[4] Boccaccio, A., Lamberti, L., Papi, M., De Spirito, M., Douet, C., Goudet, G., Pappalettere, C. A hybrid characterization framework to determine the visco-hyperelastic properties of a porcine zona pellucida. *Interface Focus* 4, (2014) 20130066.

[5] Kozlovsky, P., and Gefen, A. Sperm penetration to the zona pellucida of an oocyte: a computational model incorporating acrosome reaction. *Computer Methods in Biomechanics and Biomedical Engineering* 16, 10 (2013) pp.7.

[6] Hedrih, A. Transition in oscillatory behavior in mouse oocyte and mouse embryo trough oscillatory spherical net model of mouse Zona Pellucida" ch in *Applied Non-Linear Dynamical Systems*, Springer Proceedings in Mathematics & Statistics 93, J. Awrejcewicz (ed.), 93, 295-303. Springer International Publishing Switzerland, 2014.

[7] Hedrih, N.A., and (Stevanović) Hedrih, R.K. Analysis of energy state of discrete fractional order spherical net of mouse zona pellucida before and after fertilization. *International Journal of Mechanics* SI, 8, (2014), 365-370.

[8] Hsiao, WW., Liao, HS., Lin, HH., Ding, RF., Huang, KY., and Chang, CS. Motility Measurement of a Mouse Sperm by Atomic Force Microscopy. *Analytical Sciences* 29 (2013), 3-8.

[9] Hedrih,A., Mitrovic-Jovanovic, A., and Lazarevic, M. Effect of sperm velocity and its arrangement on mouse Zona Pellucida oscillatory behaviour. *to appear*

[10] Khalilian, M., Navidbakhsh, M., Valojerdi, MR., Chizari, M., Yazdi, PE. Estimating Young's modulus of zona pellucida by micropipette aspiration in combination with theoretical models of ovum. *Journal of the Royal Society Interface.* 7, 45 (2010) 687-94.

[11] Hedrih (Stevanović), R.K. *Izabrana poglavlja Teorije elastičnosti (Selected Chapter in Theory of Ekasticity)*. Masinski fakultet Univerziteta u Nisu, Nis, 1988, pp. 424.

[12] Rašković D. P., *Teorija elasti;nosti (Theory of elasticity)*, Maučma knjiga, Beograd , 1985.

Andjelka Hedrih, M.D. (Ph.D. student): State University of Novi Pazar, 36 300 Novi Pazar, Serbia (handjelka@gmail.com), The author gave a presentation of this paper during one of the conference sessions.

Katica (Stevanovic) Hedrih, Professor: Mathematical institute SANU, 11 000 Belgrade, Serbia, Faculty of Mechanical engineering, University of Nis, 18 000 Nis, Serbia (khedrih@sbb.rs).

DSTA 2015

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications

December 7-10, 2015
Łódź, POLAND

Lodz, December 10th, 2015

CERTIFICATE OF ATTENDANCE

This is to certify that ***Katica Hedrih (Stevanović)*** has attended

13th International Conference

"Dynamical Systems – Theory and Applications"

held in Lodz, Poland, December 7-10, 2015.

Chairman of the DSTA 2015 Conference

Prof. Jan Awrejcewicz

Department of Automation, Biomechanics and Mechatronics, Faculty of Mechanical Engineering
Lodz University of Technology, 1/15 Stefanowski Str., 90-924 Łódź, Poland, Phone: +48 42 6312225, Fax: +48 42 6312489
E-mail: secretariat2015@dys-ta.com, www.dys-ta.com

DSTA 2015

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications

December 7-10, 2015
Łódź, POLAND

Lodz, December 10th, 2015

Dear Participant,

I am glad to inform you that basing on received paper, your work

Vibro-impact dynamics of two rolling heavy disks along rotate circle with constant angular velocity

by

Hedrih (Stevanović) K.

has been proposed by Scientific Committee for publication of the extended version in the journal

International Journal of Non-Linear Mechanics

All necessary information about preparation of extended version and procedure of paper submission will be soon available in your Participant Profile.

Please note that final decision on publication will be made after Peer Review Process.

Best regards,

Prof. Jan Awrejcewicz
Chairman of the International Conference
"Dynamical Systems - Theory and Applications" (DSTA 2015)

Paper ID BIF 125

Department of Automation, Biomechanics and Mechatronics, Faculty of Mechanical Engineering
Lodz University of Technology, 1/15 Stefanowski Str., 90-924 Łódź, Poland, Phone: +48 42 6312225, Fax: +48 42 6312489
E-mail: secretariat2015@dys-ta.com, www.dys-ta.com

DSTA 2015

13th INTERNATIONAL CONFERENCE
Dynamical Systems - Theory and Applications

December 7-10, 2015
Łódź, POLAND

Lodz, December 7th, 2015

Dear Professor **Hedrih**

I have pleasure to invite you to the DSTA 2015 Scientific Committee's meeting, which will take place on Monday, December 7th, at 3: 00 PM

Looking forward to see you, with my warmest regards

Chairman of the DSTA 2015 Conference

Prof. Jan Awrejcewicz

Department of Automation, Biomechanics and Mechatronics, Faculty of Mechanical Engineering
Lodz University of Technology, 1/15 Stefanowski Str., 90-924 Łódź, Poland, Phone: +48 42 6312225, Fax: +48 42 6312489
E-mail: secretariat2015@dys-ta.com, www.dys-ta.com

Учесници научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**

На седници Научног одбора научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**

Чланови Научног одбора научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**

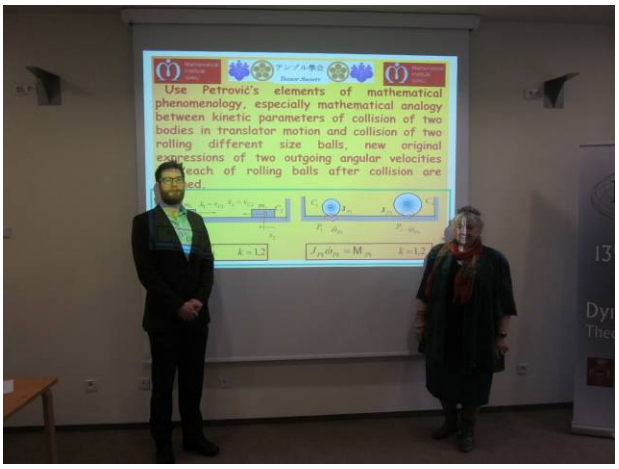
Са професором Јаном Аврејцевићем, черменом научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND,** поред постера који приказују корице **публикација које је написао или уредио.**


ographs and Text Books by
Jan Awrejcewicz
MONOGRAPHS IN ENGLISH
MONOGRAPHS IN POLISH
BIFURCATION AND CHAOS IN SIMPLE DYNAMICAL SYSTEMS
BIFURCATION AND CHAOS IN COUPLED OSCILLATORS
BIFURCATION AND CHAOS IN NONSMOOTH MECHANICAL SYSTEMS
Asymptotical Mechanics of Thin-Walled Structures
Nonlinear Dynamics of Continuous Elastic Systems
NONLINEAR DYNAMICS OF A WHEELED VEHICLE
Introduction to Asymptotic Methods
SMOOTH AND NONSMOOTH HIGH DIMENSIONAL CHAOS AND THE MELNIKOV-TYPE METHODS
Chaos in Structural Mechanics
Nonsmooth Dynamics of Contacting Thermoelastic Bodies
Classical Mechanics
Classical Mechanics
Classical Mechanics
Asymptotic Methods in the Theory of Plates with Mixed Boundary Conditions
Ordinary Differential Equations and Mechanical Systems
drgania deterministyczne układów dyskretnych
drgania układów ciągłych
Płyty i powłoki w przyrodzie, mechanice i biomechanice
Od piramid do gwiazd
Trójwymiarowe zagadnienia teorii płyt w polu temperaturowym
Matematyczne modelowanie systemów
MECHANIKA
MECHANIKA
MONOGRAPH IN RUSSIAN
TEXT BOOKS
PODSTAWY BIOMECHANIKI

Edited Volumes and Conference Proceedings by **Jan Awrejcewicz**

Lodz University of Technology
Faculty of Mechanical Engineering

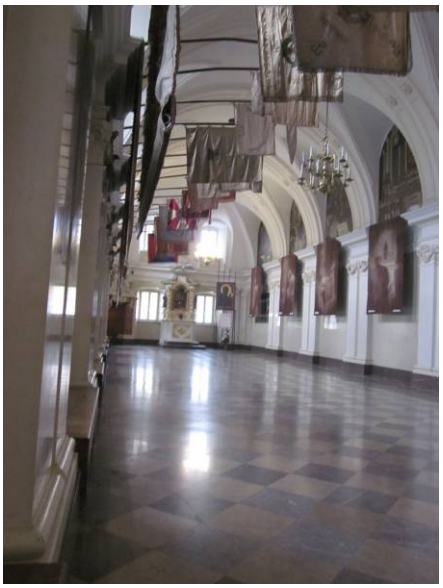
Department of Automation, Biomechanics and Mechatronics
1/15 Stefanowski Str., 90-924 Łódź



Са секције Стбилност и управљање научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**: са професором Harry Grigg-ом, професором из У.К. , председавајућом секције, који се после одржаних саопстења интересовао за нове прилоге теорији судара котрљајућих се кугли и крутих тела, главним доприносом који сам представила.

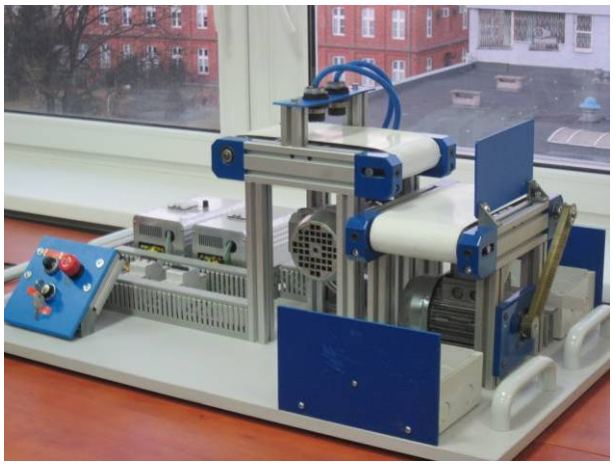
У паузама научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND са члановима Научног комитета конференције Професором ЛаМарком и прогесором Мачадом.**

Детаљи архитрктуре и простора у коме су се кретали учесници и одржавале научне и друштвене активности научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**

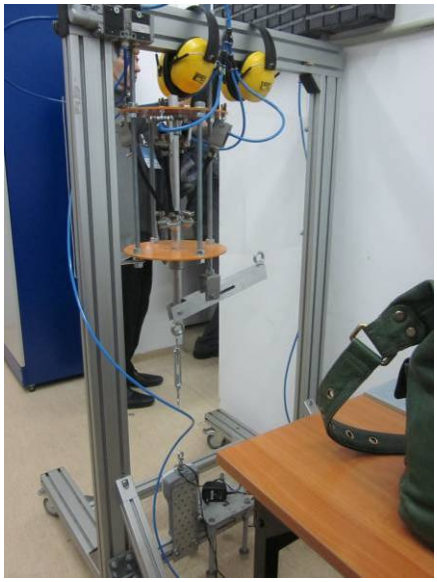


Детаљи са једнодневне екскурзије “Poland Jura” учесника научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**

Детаљи из Замка са једнодневне екскурзије “Poland Jura” учесника научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**

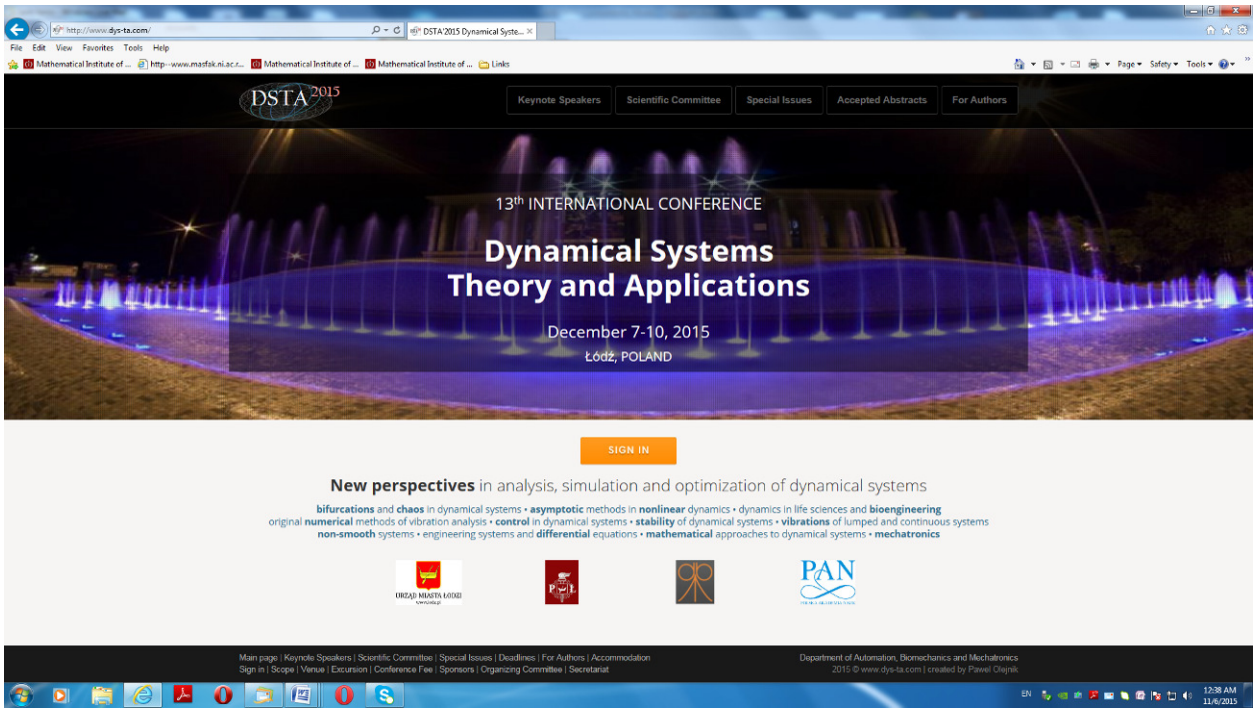


Детаљи из посете учесника научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND,** лабораторијама мехатронике и биодинамике Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics.



Детаљи из посете учесника научне конференције **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND,** лабораторијама мехатронике и биодинамике Lodz University of Technology, Faculty of Mechanical Engineering, Department of Automation, Biomechanics and Mechatronics.

Новогодишњи изглед улица **Łódź-a** у коме се одржавала научна конференција **13th INTERNATIONAL CONFERENCE Dynamical Systems - Theory and Applications – DSTA Łódź 2015, December 7-10, 2015 Łódź, POLAND**



http://www.dys-ta.com/