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

# Стручни извештај

## о учешћу у научном скупу

**The 24th International Congress of Theoretical and Applied Mechanics (ICTAM 2016, held in Montreal, Canada, from 21 to 26 August, 2016. У организацији Интернационалне уније Теоријске и примењене механике (IUTAM)**

Please visit the ICTAM 2016 Web Site. http://www.ictam2016.org/

У раду овог Конгреса учествовала сам са кратком оралном комуникацијом у великој конгресној сали којим сам приказала основне науцне резултате рада и касније пратећом презентацином на постеру ради објашњацања детртаља заинтересованим учесницима, којих је било већии број.

*Својим учешћем сам ставила на увид широј научној јавности мој оригинални допринос проширењу класичне теорије судара доприносом кинематиком и динамиком централних и косих судара крутих тела у котрљању. Увела сам хипотезу о конзервацији суме момената количине кретања (момената импулса) крутих тела у котрљању после судара у односу на кинетичко стање пре судара, на помоћу исте увела нову дефиницију коефицијента судара (рестиуитуције) помоћу угаоних брзина котрљања два крута тела у котрљању пре и подле судара. Такође сам приказала и новоизведене изразе за одлазне угаоне брзине котрљања тела после судара. До ових резултата сам дошла инспирисана теопријом Михаила Петровича ''Елементи математичке феноменологијеЋ и ''Феноменолошко пресликавање'', а затим резултате извела, проверила и потврдила елементарним приступом. Мористећи ово проширење класичне теорије судара, ковим доприносима кинематиком и динамиком судара, поставила сам методологију изучавања динамике виброударних система који садрже тела у котрљању и сукцесивним сударима истих, и показала феномене виброударне динамике у фазној равни на фазним потретима и портретима кривих константне унупне механичке енергије система, на четири примера виброударних система.*

*Очекујем да ови моји нови и оригинални резултати добију у наредном периоду ширу примену у изучавању динамике, нелинеарних и дискунтинуалних феномена, који се јављају у инжењерским системима са котрљајућим деловима и елементима који се сударају у процесу рада и функционисања..*

Кратки двостранични чланак, као и чланси свих 2000 учесника су публиковани електронски, на порталу ИЦТАМ Монтреал 2016, је са седећом библиографским подацима и насловом:

Hedrih (Stevanović ) Katica, (2016), *Vibro-impact dynamics in systems with trigger of coupled three singular points: Collision of two rolling bodies*, The 24th International Congress of Theoretical and Applied Mechanics (ICTAM 2016), Montreal, Canada, 21 - 26 August, 2016, Book of Papers, pp. 212 -213. IUTAM permanent site. ISBN: NR16-127/2016E-EPUB; Catalogue Number: 978-0-660-05459-9

После одржаног кратког излагања, уз постер, од већег броја заинтересованих учесника, постављана су ми питања, на која сам, са задовољством одговарала и

давала исцрпна објашњења. И после, током пауза Конгреса био је већи број младх заинтересованих за научне комункације са мном, као и за разговоре.

Имајући у виду да сам учествовала у дискосијама по већем броју саопштења, као и давала коментаре и научне информације и инструкције, у разним секцијама, један број учесника и млађе, као и старије генерације, изразио је интересовање за сарадњу, због ширини мојих зања која сем уложилча у научни рад појединх секција Конгреса. Коментар је био, и нивоа оцена, да су на Конгресима ретко сретали научнике тако широких знања и видика. Наравно, то је најлепше, што један учесник Светсјиг конгреса Теоријске и примењене механике са великим бројем истраживачких и специјализованих области механике, може да доживи од својих савреемника. Лепота научних емоција, и сећање на изузетну клегијалну пажњу коју сам овде доживела и од сасвим младих истраживача, као и оних који су у поодмаклим годинама представља за мене изузетну енергију коју сам са и са овог светског конфреса донела у Србију, где је тешко добити и најмању похвалу од својих колега и признање за достигнуте стваралачке и научне резултате!

По позиву председника ICTAM Montreal 2016, професора Н. Флориана, била сам гост на коктелу канадских учесника Конгреса и тамо сам упознала **директорку Natural Science and Engineering Research Council of Canada, Памелу Мос,, која је изразила жељу да се оствари сарадња са Министарством науке у Србији.**

Не могу а да не напоменем у овом извештају, да сам учествовала у следећим претходним светским конгресима ICTAM Haifa 1992, ICTAM Warsaw 2004, ICTAM Adelaide 2008 (**15 минутно секцијско предавање**), ICTAM Beijing 2012, I ICTAM Montreal 2016, u organiyaciji Интернационалне уније Теоријске и примењене механике (**(IUTAM). Напомиwем да је селекција радова веома строга и да се по статиостичким подацима у периоду од претходних 30 година одбија око 30% поднетих и пријављених радова. То значи да су моји научни резултати оцењени добро и представљају у дужем периоду допринос Теоријској и примењеној механицим који је уграђен у научне програме ових пет светских конгреса Теоријске и примењене механике , који се одржавају сваке четврте године.**

**Из Србије у последњих осам година, у овим** ICTAM **– конгресима, после строге селекције радова, у програме су били уврштени, поред мојих радона, само радови истраживача са пројеката координираних у Математичком институт САНУ, а којима сам руководила у претходном и текућем пројектном циклусима: А то су радови истраживача: др Јулијане Симоновић (ктазко излагање и постер на ICTAM Adelaide 2008), др Анђрлка Хедрих (15 минутно секцијско предавање у секцији динамика биосистема на ICTAM Beijing 2012, ктазко излагање и постер на I ICTAM Montreal 2016).**

Организација Конференције је била добра, предавања и саопстења 200 учесника на високом научном нивоу. На овој конференцији је било већи број младих учесника него ранијих година, што посебно радује.

С поштовањем,

Катица (Стевановић) Хедрих

У Београду, 12 октобра 2016.

Katica R. (Stevanović) Hedrih
Руководилац пројекта ОМ174001


## MS04 - Nonlinear Dynamics of Engineering Systems

**Room:** 517d

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**PO.MS04-1.07.9** | Hedrih, Katica (Stevanovic): Vibro-impact dynamics in systems with trigger of couped three singular points

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## Welcome

**J.M. Floryan,**
President, 24th International Congress of Theoretical and Applied Mechanics

It is indeed a pleasure and an honour for me to finally welcome you, my colleagues, to Canada and to the fantastic city of Montreal. ICTAM 2016 has taken years of planning and countless hours of work by an entire community. Collectively, we have built a program that I trust you will find both scientifically stimulating and personally rewarding as we explore our field's latest developments with old friends and new contacts. When this Congress is over, I hope that we will all return to our labs with even greater momentum fueling our efforts into the future.

While there are too many individuals to name, I would like to highlight the contributions of several groups: the IUTAM Congress Committee, the International Papers Committee, the Session Chairs and the National Committee reviewers whose dedication has resulted in the program I am proud to present to you today; the National Research Council of Canada, which has acted as our partner in the local management of this congress; all our sponsors and exhibitors and in particular our Gold Sponsor, Virginia Tech's Department of Biomedical Engineering and Mechanics; and finally the volunteers whose participation contributes so much behind the scenes. I thank each and every one of you, and wish you a productive and pleasurable Congress.

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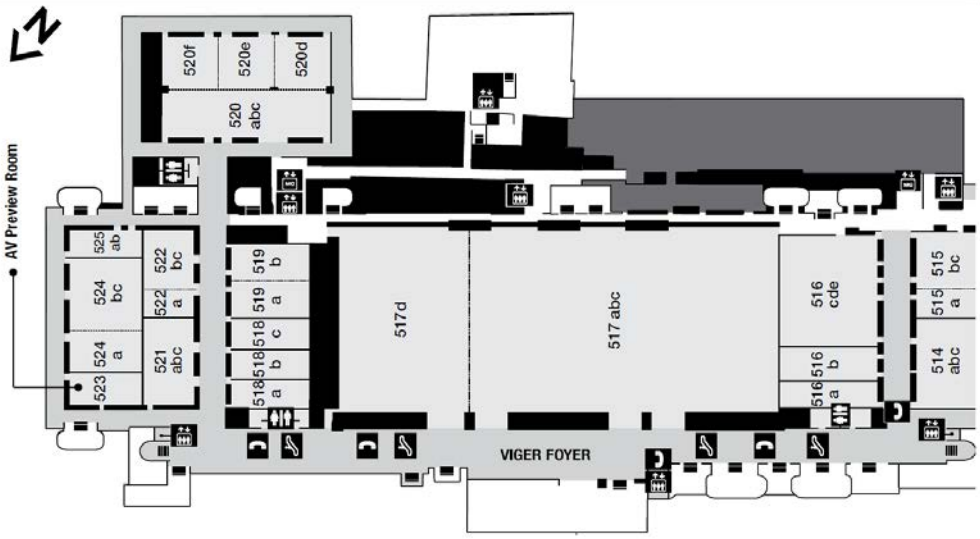
**Level 5**



## Mini-Symposia

**MS01** **Bypass Transition**
Co-chairs: Bruno Eckhardt, Michael Graham

**MS02** **Fluid Active Matter**
Co-chairs: William Durham, Federico Toschi

**MS03** **Multiphase Flow in the Processing Industry**
Co-chairs: Patrick Anderson, Staffan Lundström

**MS04** **Nonlinear Dynamics of Engineering Systems**
Co-chairs: Giuseppe Rega, Dick van Campen

**MS05** **Soft Solid Active Matter**
Co-chairs: Vikram Deshpande, Zhigang Suo

**MS06** **Topology Optimization**
Co-chairs: Ole Sigmund, Fred van Keulen


The oldest participant Professor Tomomaasa Tatsu,I (Kyoto University, Japan) and profesor Hiroshi Yabuno (Tsukuba University, Japan)

ICTAM Montreal 2016, Chirman of Minisysmposia Nonlinear Dynamics Professors Guoseppe Rega (Italy, University La Sapienza) I Dick Van Camoen ( University of Eudhoven, Holand).

IUTAM International Union of Theoretical and Applied Mechanics

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**FM03** **Combustion and Flames**
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**FM04** **Compressible Flow**
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**FM05** **Convection**
Co-chairs: Joerg Schumacher, Ke-Qing Xia

**FM06** **Drops, Bubbles and Multiphase Flows**
Co-chairs: Jens Eggers, Howard Stone

**FM07** **Flow Instability and Transition**
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**FM08** **Flow in Thin Films**
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## THEMATIC SESSIONS



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**FM10** **Low Reynolds Number Flow**
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**FM12** **Non-Newtonian and Complex Fluids**
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**FM16** **Waves in Fluids**
Co-chairs: John Grue, Yaron Toledo

**FM17** **Other Topics in Fluid Mechanics**

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Co-chairs: Nadia Lapusta, Jean-Pierre Vilotte

**SM07** **Impact Mechanics and Wave Propagation**
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**SM09** **Phase and Chemical Transformations and Thermomechanical Phenomena**
Co-chairs: Samantha Daly, Alexander Freidin

**SM10** **Sizescale Effects in Materials**
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**SM12** **Nanostructures and MEMS**
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**SM13** **Plasticity, Viscoplasticity and Creep**
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**SM14** **Stability of Structures**
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**SM15** **Computational Solid Mechanics**
Co-chairs: Stefan Hartmann, Ricardo Lebensohn

**SM16** **Vibrations and Control of Structures**
Co-chairs: Felix Chernousko, Ilmer Santos

**SM17** **Other Topics in Solid Mechanics**

## Fluids / Solids Topics

**FS01** **Acoustics**
Co-chairs: Christophe Bailly, Jakob Jensen

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**FS03** **Experimental Methods in Mechanics**
Co-chairs: Stuart Dalziel, Yilan Kang, Philippe Petitjeans, Arun Shukla

**FS04** **Chaos and Pattern Formation**
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**FS07** **Actuating and Smart Materials**
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**FS08** **Granular Materials and Flows**
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**FS09** **Foams and Cellular Materials**
Co-chairs: Isabelle Cantat, Stelios Kyriakides

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## Book of Papers


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**MS04 - Nonlinear Dynamics of Engineering Systems**



24th International Congress of Theoretical and Applied Mechanics

# VIBRO-IMPACT DYNAMICS IN SYSTEMS WITH TRIGGER OF COUPED THREE SINGULAR POINTS: COLLISION OF TWO ROLLING BODIES

Katica R. (Stevanović) Hedrih[1,2]
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[2]*Faculty of Mechanical Engineering, University of Niš, Serbia*

*Summary* Under the author's use Petrović's elements of mathematical phenomenology, especially mathematical analogy, new expressions of post-collision outgoing angular velocities of two rolling rigid bodies are determined. Advances to theory of collision between two bodies are generalized to collision of two rolling rigid bodies. Using these results, nonlinear dynamics in the vbro-impact system with trigger of coupled singular points and homoclinic trajectory in phase trajectory portraits is study. Use phase portraits of two nonlinear dynamical systems in which appear central collision of thin rolling different size disks are studied. In first vibro-impact system disks is in rolling along straight line and coupled by springs, and in second rolling disks are moving along a circle line rotate with constant angular velocity around vertical central axis. In both considers system dynamics exist a trigger of coupled singular points.

## ADWANCES TO THEORY OF COLLISION OF TWO RIGID ROLLING BODIES

Advances to theory of collision between two bodies are generalized to collision of two rolling rigid bodies. Under the authors' use Petrović's elements of mathematical phenomenology [1,2,3,4], especially mathematical analogy, new expressions of post-collision outgoing angular velocities of two rolling rigid bodies are determined in following forms (see Figure 1.a*):.

$$\omega_{P1}(t_0+\tau)=\omega_{P1}(t_0)-\frac{1+k}{1+\frac{\mathbf{J}_{P1}}{\mathbf{J}_{P2}}}(\omega_{P1}(t_0)-\omega_{P2}(t_0))$$

$$\omega_{P2}(t_0+\tau)=\omega_{P2}(t_0)+\frac{1+k}{1+\frac{\mathbf{J}_{P2}}{\mathbf{J}_{P1}}}(\omega_{P1}(t_0)-\omega_{P2}(t_0))$$

where $k=\frac{\omega_r(t_0+\tau)}{\omega_r(t_0)}=\frac{\omega_{P2}(t_0+\tau)-\omega_{P1}(t_0+\tau)}{\omega_{P1}(t_0)-\omega_{P2}(t_0)}$

$$\mathbf{J}_{P1}\vec{\omega}_{P1}(t_0)+\mathbf{J}_{P2}\vec{\omega}_{P2}(t_0)=\mathbf{J}_{P1}\vec{\omega}_{P1}(t_0+\tau)+\mathbf{J}_{P2}\vec{\omega}_{P2}(t_0+\tau)$$

Kinematical plans of pre- and post-collision angular velocities are composed for different cases of collisions.

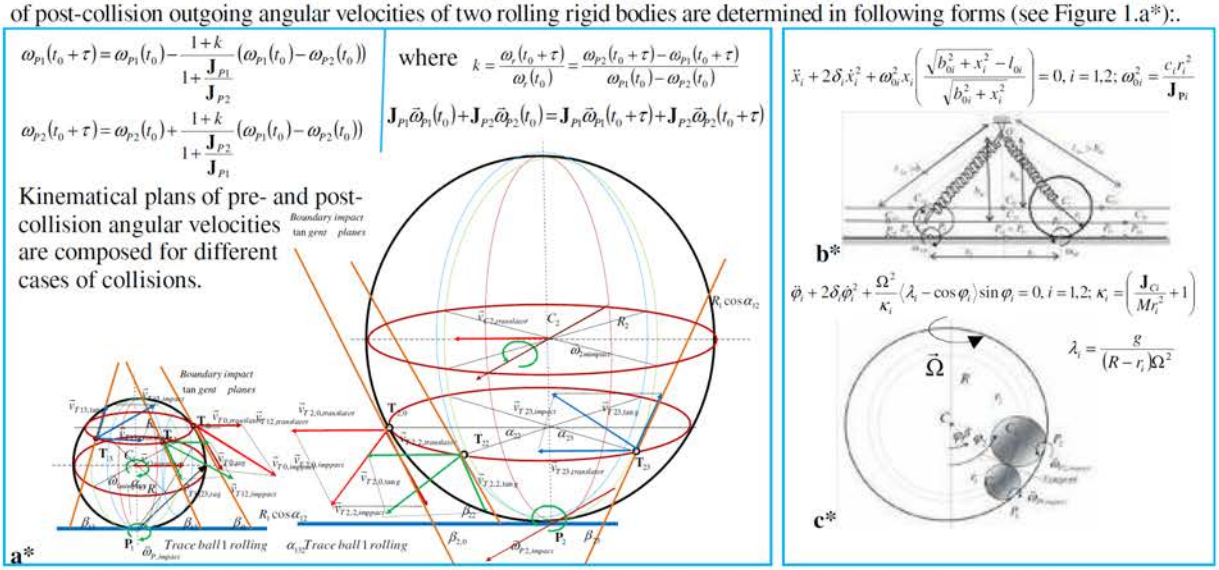


**Figure 1**. a* Plans of the impact velocities of possible points at corresponding circles at same height of balls in central a nd skew collisions of two rolling heavy balls different radiuses: left for first smaller ball and right for second bigger ball. b* and c* Two vibro-impact systems each containing two rolling thin different radiuses disks in central successive collisions.

## NON-LINEAR DYNAMICS OF TJE VIBROIMPACT SYSTEMS WITH T RIGGESR OF COUPLED SINGULAR POINTS AND HOMOCLINIC ORBITS IN FORM NUMBER EIGHTIN PHASE PORTRAITS

In Figure 1.b* and c* two mechanical vibro-impact syst ems containing two rolling thin different size disks are presented. Each disks, in both considered systems dynamic s, a corresponding trigger [5,6] of coupled three singular po ints and homocclinic orbit in the form of number "eight" pos ses in corresponding phase portraits for corresponding rel ation of parameters of system, In both system exists a bifurcati on parameter and with its variation in the phase portrait s layering of phase trajectories appear, as well as appearance and disappe arance of trigger of coupled singular points. Kinetic para meters and phase portraits of each vibro-impact system (in Figu re 1. b* and c*) in ideal constraints as conservative and, also, in the field of turbulent damping as no conservative, an d of each of the rolling disks are determined and graphic ally presented. in Figure 2 a* and b* phase trajectory branches in phase portraits of two rolling disks for motion in interval be tween configurations of the initial condition configurations and configurations of pre-first-collision and post-first-co llision between two rolling disks for corresponding conservativ e systems are presented. On the phase portraits alterna tions of the pre-collision impact velocities of the disks into post-col lision corresponding translator or angular velocities are visible.

[a)] Corresponding author. Email: khedrih@sbb.rs,khedrih@eunet.rs.

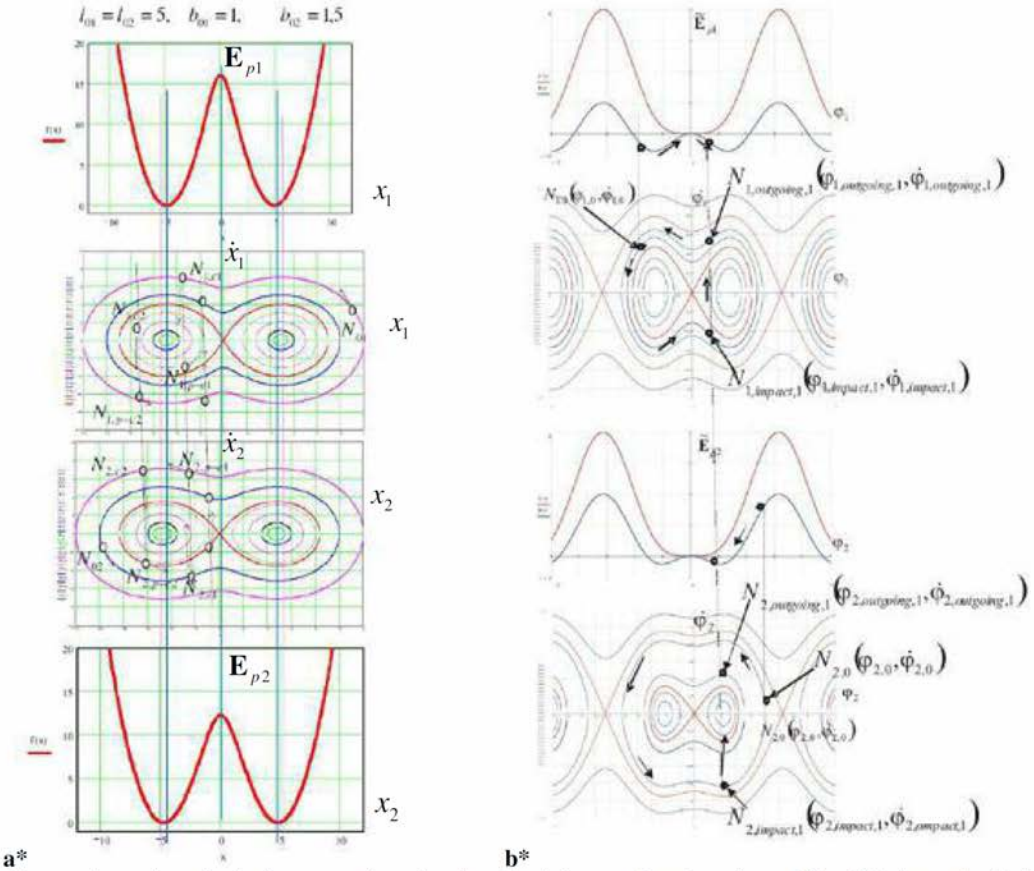


**Figure 2.** Phase trajectory branches in phase portraits and total mechanical energy branches of two rolling disks for motion in interval between initial condition configuration and configurations of pre-first-collision and post-first-collision between two rolling disks with vibro-impact dynamics (a*) along a line and (b*) on rotate circle trace with constant angular velocity around vertical central axis for the conservative systems presented in Figure 1,b* and 1.c*.

## CONCLUDING REMARKS

Advances to theory of collision of two rolling rigid bodies open new possibilities for progress in knowledge of vibroimpact system dynamics. Obtained results are related to different ceases of conservative as well as no conservative vibro-impact dynamics. Emery analysis for turbulent damping with generalized function of energy dissipation $\Phi = b\dot{x}^3/3$ gives rate of total mechanical energy degradation in the form: $d\,E_k + E_p\,/dt = -3\Phi$.

**Acknowledgment:** Parts of this research were supported by the Ministry of Sciences and Technology of Republic of Serbia through Mathematical Institute SANU Belgrade Grant ON174001 "Dynamics of hybrid systems with complex structures. Mechanics of materials.". and through Faculty of Mechanical Engineering University of Niš.

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Palais des congrès de Montréal

Embassy of Canada in Vienna, Austria
Embassy of Canada in Belgrade

Dear Madame/Sir,

Professor Dr Katica R. (Stevanovic) Hedrih, the leader of the Project ON174001 "Dynamics of hybrid systems with complex structures" supported by Ministry of Education, Sciences and Technology Republic of Serbia, and realized by Mathematical Institute SANU, Belgrade, is accepted as a participant The 24th International Congress of Theoretical and Applied Mechanics (ICTAM 2016) Montreal, Canada, from 21 to 26 August, 2016.

We will be grateful if you grant the visa of Canada to Professor Dr Katica R. (Stevanovic) Hedrih, for travelling to Montreal, Canada, for participation in ICTAM Montreal 2016, organized by International Union of Theoretical and Applied Mechanics.

Director of Mathematical Institute

Dr. Zoran Ognjanovic, Research Professor
Mathematical Institute of the Serbian Academy of Sciences and Arts
Kneza Mihaila 36, 11000 Belgrade, Serbia
tel: 381-11-2630-170 / fax: 381-11-2186-105
http://www.mi.sanu.ac.rs/~zorano
email: zorano@mi.sanu.ac.rs


04/28/2016

Katica Hedrih (Stevanovic)
Mechanical Institute SANU Belgrade
ul. Vojvode tankosica 3/22
NIS N/A - OTHER 180000
Serbia

Dear Katica Hedrih (Stevanovic),

You are cordially invited to attend the International Congress of Theoretical and Applied Mechanics (ICTAM), which will take place in Montréal, Canada from August 21 - 26, 2016.

We hope that you will be able to attend and participate in this exciting program, either by presenting scientific data or taking part in the discussions.

This Letter of Invitation is to facilitate your visa application only for attending the Congress and does not imply any different relationship or financial assistance. The Citizenship and Immigration Canada's Special Event Code for this event is "16ICTA".

We recommend that you proceed with the normal visa application as soon as possible.

We look forward to the possibility of meeting you in Montréal, Canada.

Sincerely,

Michèle Bourgeois-Doyle
Congress Manager
**Congress Management Office**
National Research Council of Canada
1200 Montréal Road, Building M-55
Ottawa, ON
Canada K1A 0R6
Tel: (613) 998-9488
Fax: (613) 993-7250
Email: ICTAM2016@nrc-cnrc.gc.ca


## REGISTRATION RECORD

### Attendee Information

| | |
|---|---|
| Confirmation Number | 17864976 |
| Email | khedrih@sbb.rs |
| ADMIN-Abstract Number | 126637<br>Admin field used from E-Select (LC) |
| First Name | Katica |
| Last Name | Hedrih (Stevanovic) |
| Job Title | Project Leader - Full University Professor and Researcher |
| Company | Mechanical Institute SANU Belgrade |
| Department/Faculty | Mechanics |
| Address Line 1 | ul. Vojvode tankosica 3/22 |
| City | Nis |
| Province / State | N/A - Other |
| Postal / Zip Code | 180000 |
| Country/Economy | Serbia |
| Work Phone | (+381) 0184241663<br>*Select Country code, for Canada/US go to "United States / Canada" in the dropdown menu. Then enter number as xxxxxxxxxx (No spaces)* |
| Fax | +3814241663<br>*Enter as xxxxxxxxxx (No spaces)* |
| cc email | khedrih@sbb.rs<br>*Please complete if you wish to include an alternate email address(s) to receive a copy of your registration confirmation.* ***Instruction:*** *please separate the email addresses with a semicolon and* ***NO*** *spaces.* |
| LOI - Yes or No | Yes<br>**IMPORTANT!** We recommend that you begin your visitor visa application process at least 3 months prior to arrival into Canada to ensure a timely approval process. Read all available guidelines (http://www.ictam2016.org/side_general_information/entry_formalities_e.shtml) and ensure that you include ALL required supporting documentation. |
| Cancel Policy | Checked |

| | Selection | | Cost |
|---|---|---|---|
| Registration Category | Participant | | $CAD750.00 |
| | Welcome Reception - Monday, August 22, 2016 | | |
| | | **Total** | **$CAD750.00** |

| Date | Transaction Type | | |
|---|---|---|---|
| 04/27/2016 | Transaction Amount | | $CAD750.00 |
| 05/05/2016 | Online Credit Card Payment(xxxxxxxxxxxx6888) | | $CAD-750.00 |
| | | **Balance** | **$CAD0.00** |

**For Registration Inquiries:**
Laura Chajkowski, CMP CMM
Director, Registration
ictam2016registration@legendconferences.com

ICTAM 2016 Management Office - ICTAM2016@nrc-cnrc.gc.ca
1200 Montreal Road, Building M-19, Room 274 Ottawa, Ontario Canada K1A 0R6


**ICTAM 2016 - Conference Services Office**
National Research Council Canada
Tel: + 1 (613) 226-9988
Email:
ictam2016registration@legendconferences.com

**MUST BE PRESENTED AT REGISTRATION DESK**

# RECEIPT

**Date:** 05/06/2016
**DUE UPON RECEIPT**

Registrant Name: Katica Hedrih (Stevanovic)
Andjelka Hedrih
Bill To:Mechanical Institute SANU Belgrade
Trg Ucitelj Tase 3, Nis, N/A - OtherSerbia
*khedrih@sbb.rs*
Confirmation #: 17864976

**PAID**

**Abstract Number:**126637

| **Selection** | **Quantity** | **Cost** |
|---|---|---|
| Katica Hedrih (Stevanovic): Participant | 1 | $CAD750.00 |
| | **Paid** | **$CAD750.00** |
| | **Balance** | **$CAD0.00** |

*This amount includes taxes where applicable*
NRCC GST Registration No.: 12149 1807 RT 0275
NRCC QST Registration No.: 1006178088 (Québec Resident)

Please advise if any of the above details are incorrect. If you have any queries **please quote your ID Number - 17864976 in any future correspondence.**

**Registration Record Link:**
https://www.eiseverywhere.com/ereg/record.php?id=sGCM3m8YIqXxk2VQWJaALA%3D%3D

Per: *Laura Chajkowski, CMP CMM*
ICTAM 2016 - Director, Registration - +1 (613) 226-9988
ictam2016registration@legendconferences.com

**Cancellation/Refund Policy:**
Cancellations received in writing **on or before Friday, June 17, 2016** will receive a full refund less $100.00 administration fee. After this date, there will be no refunds. ALL REQUESTS MUST BE IN WRITING.


TOMOMASA TATSUMI D.Sc.

Professor Emeritus, Kyoto University
Professor Emeritus, Kyoto Institute of Technology

26-6 Chikuzendai-machi Momoyama
Fushimi-ku Kyoto 612-8032 Japan
TEL.:(075)611－4720
FAX.:(075)611－4846


По позиву председника ICTAM Montreal 2016, професора Н. Флориана, била сам гост на коктелу канадских учесника Конгреса и тамо сам упознала **директорку Natural Science and Engineering Research Council of Canada, Памелу Мос,, која је изразила жељу да се оствари сарадња са Министарством науке у Србији.**