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Guest Editorial

Special Issue: Dynamics of Systems With Impacts

A system undergoing impacts can have strong nonlinear characteristics and the system response can experience unique qualitative changes. Impacts can occur in a wide range of systems, and the wide interest in them has spurred researchers to explore different tools for analyses and simulations and experiments with real, physical systems.

In single degree-of-freedom oscillators, impacts can occur with a barrier, while in a system with multiple degrees-of-freedom, one can additionally observe impacts among interacting bodies. On the one hand, impacts are intrinsic for the operations of many engineering devices. On the other hand, impacts may induce dangerous forces or perturb operations in systems where we expect to have smooth dynamics. In both situations, a deep understanding of the system dynamics can help predict the system behavior and also form a picture of the implications of impacts. Systems experiencing impacts are part of a large group of systems modeled by discontinuous differential equations; their dynamics is also interesting from a theoretical standpoint. Finding accurate numerical solutions of a discontinuous system of equations remains a challenging task in the field of nonlinear dynamics. There are many open problems associated with numerical and analytical investigations of impact oscillators, for example, the current toolboxes for continuation can only be used to determine the bifurcation diagrams for specific types of equations and constraints.

Systems with impacts are used to model drilling in hard materials, milling, impact print hammers, as well as shock absorbers and much more. In these systems, there are still lot of challenging practical problems to solve, one of them being downscaling of drilling rigs used for installation of underground cables and pipes. Another application of impacting systems is in the modeling of gear transmissions, wherein interactions between gears involve impacting and sticking events. Thus, to reach high efficiency and reliability, one has to reduce these events to a minimum.

Impact may cause the following effects: severe forces and stresses, rapid transfer of energy, and large acceleration impulses. These effects are associated with complex system dynamics, and in many cases, control of these systems is difficult to do. Sophisticated control algorithms may be needed to address all of the aforementioned effects. Damage caused by impacts is a topic of many studies in civil and materials engineering, where the trend to introduce lighter materials has to be reconciled with the resistance of systems made with them. Similar considerations are needed for ships whose collisions with floating objects cannot be ignored. In many structures (e.g., buildings, siloes, containers, scaffoldings, and free-standing power transformers), hazardous external excitations (e.g., earthquake and rogue waves) may lead to overturning through rocking instabilities involving impacts.

In the paper "An Improved Mathematical Model of Galton Board With Velocity-Dependent Restitution," the author introduced a new model of a Galton board. It is a box with a glass front and many horizontal nails or pins embedded in the back and a funnel. The small balls are dropped via funnel and collide with the nails, as they fall through to the bottom of the Galton board, under the influence of gravity to the slots into which the balls are collected. The main novelty in this study is taking into account a velocity-dependent coefficient of restitution between pin/nail and ball. The obtained results show that the ball follows a deterministic trajectory rather than performing a random walk and the Galton board cannot be correctly described as a statistical model only.

The paper "Experimental and Simulation Results of a Cam and a Flat-Faced Follower Mechanism" is devoted to study of a cam and a flat-faced follower system with impacts and friction at the contact points. The authors performed numerical analysis as well as experimental investigations. They calculated the largest Lyapunov exponents to obtain the information about the stability of the cam and the flat-follower system.

The paper "A New Design of Horizontal Electro-Vibro-impact Devices" is focused on dynamics of a vibro-impact moling device. The authors introduced a new design of the considered system. The numerical as well as the experimental investigations are performed. The proposed system is able to obtain the higher collision velocity and significantly increases the impact momentum in comparison to existing devices.

The authors of the paper "Planar Multibranch Open-Loop Robotic Manipulators Subjected to Ground Collision" considered a tree-type robotic system with floating-base. The motion of the system is divided in to two stages, i.e., first, when it has no contact with the ground or any object in its environment (flying phase) and second when the system collides with the ground (impact phase). The authors derived a systematic algorithm that is used to divide any tree-type robotic system into a specific number of open kinematic chains and calculated the forward dynamic equations of each chain.

The next contribution "Global Behavior of a Vibro-Impact System With Multiple Nonsmooth Mechanical Factors" is focused on a nonlinear mechanical model of a vibro-impact system subjected to double nonsmooth mechanical factors that combine elastic and rigid impact. The mechanism of a sticking motion, chattering motion, and the periodic cavity induced by the gazing bifurcation is analyzed. The authors showed the coexistence of periodic motions and the extreme sensitivity of the initial value within the high-frequency region.

In the paper "Process Parameter Optimization of a Mobile Robotic Percussive Riveting System With Flexible Joints," the authors proposed a method for process parameter optimization of a mobile robotic percussive riveting system with flexible joints to guarantee the rivet gun alignment during the operation. During the riveting, the impacts are induced and they not only deform the rivet but also induce forced vibration to the robot; hence, the robot must hold the gun firmly during the operation. The authors performed a global optimization to demonstrate the practical application of the proposed method for the planning of the robotic percussive riveting system.

The paper "Cartilage Stiffness and Knee Loads Distribution: A Discrete Model for Landing Impacts" includes simulations of the motion of the musculoskeletal to determine loads experienced by the ligaments and cartilage during athletic motions such as impact from a drop landing. The authors performed a forward dynamic simulation of the impact phase of the drop landing with varying cartilage's stiffness and mass. This study agrees with the literature that the drop landings are high risk movements for injury.

The authors of the paper "Numerical Location of Painlevé Paradox-Associated Jam and Lift-Off in a Double Pendulum Mechanism" investigated the phenomenon known as the Painlevé paradox. They analyzed under what conditions the Painlevé paradox can occur for a general two-body collision using a framework that can be easily used with a variety of impact laws. Finally, the occurrence of the considered phenomenon is shown in double pendulum system.

In the paper "Analytical and Numerical Investigations of Stable Periodic Solutions of the Impacting Oscillator With a Moving Base and Two Fenders," the authors considered the dynamics of the cantilever beam with a mass at its end and two-sided impacts against a harmonically moving frame. The objective of the study is to determine in which ranges of parameters of the system, its motion is periodic and stable. Investigations are performed analytically using the Peterka's approach and confirmed by numerical calculation.

The study shown in "Numerical Study of Forward and Backward Whirling of Drill-String" is devoted to the undesired lateral vibrations (whirling) occurring in drill-strings, which is one of the main sources of losses in drilling applications. The presented model has been calibrated based on a realistic experimental drilling rig. The study reveals the coexistence of various types of whirling motion for a given set of parameters and their sensitivity to initial conditions. The obtained theoretical predictions confirm previous experimental studies carried out by the authors.

In the paper "A Preliminary Experimental Study About Two-Sided Impacting SDOF Oscillator Under Harmonic Excitation," the authors considered the pounding phenomenon between a mass and two-sided shock absorbers, subject to sinusoidal excitation. They tested the effectiveness of such an impact mitigation strategy. Different measures have been applied to detect the ranges where the pounding phenomenon occurs in steady state and for varying excitation's frequency. The good agreement of numerical and experimental results is achieved.

The next contribution "A Comprehensive Set of Impact Data for Common Aerospace Metals" showed two sets of an impact experiment. The first part of the study is focused on determination of the restitution coefficient using a 2-m long pendulum for eight different materials. In second part of the paper, the authors performed a series of compliance measurements for the same set of materials. Good agreement is seen for load levels spanned by both machines and the data set provides a unique insight into the transitionary region.

The authors of the paper "Dynamic Model for Free-Standing Fuel Racks Under Seismic Excitation Considering Planar and Nonslide Rocking Motion" considered the dynamics of a free-standing rack (FS rack), which is a type of a spent nuclear fuel rack under the seismic excitation. The model includes two submodels: a translation model, which simulates the planar translational and rotational motion, and a rocking model, which simulates nonslide rocking motion. The validation of the model is performed by a miniature experiment. The main outcome from this paper is that the friction force plays a significant role in a motion of FS rack so the estimation and control of friction coefficient are important in the design of FS rack.

The paper "Soft Impact in a Biomechanical System With Shape Memory Element" is devoted to the analysis of the shape memory prosthesis of the middle ear which permits the adjustment of its length to individual patient needs. Sometimes, the prosthesis cannot be properly fixed to the stapes; hence, the impact between the prosthesis and stapes becomes the crucial issue. The results of the study provided an answer in terms of how the prosthesis length, which produces the ossicular chain tension, influences the system dynamics and its implication in medical practice.

The authors of the paper "Complex Dynamics of Bouncing Motions at Boundaries and Corners in a Discontinuous Dynamical System" started from the local theory of flow at the corner in discontinuous dynamical systems and obtained analytical conditions for switching impact-alike chatter at corners. They investigated the dynamics mechanism of border-collision bifurcations in discontinuous dynamical systems. Finally, numerical simulations of periodic motions are presented for illustrations of motions complexity and catastrophe.

The paper "Interaction Between Coexisting Orbits in Impact Oscillators" showed that impact oscillators exhibit an abrupt onset of chaos close to grazing due to the square root singularity in their discrete time maps which cause the large-amplitude chaotic vibrations. The chaotic oscillations do not appear if the ratio of the natural frequency of the oscillator and the forcing frequency is an even integer. The authors showed that in systems with square root singularity, the range where the chaotic orbit does not exist is much broader then in the theoretical prediction. It is caused by interaction between the main attractor and coexisting orbits.

The authors of the paper "A Comparison of Ordinary Differential Equation Solvers for Dynamical Systems With Impacts" introduced a method that helps in selecting the best ordinary differential equation solver and its parameters, for a class of nonlinear hybrid system with impacts. As an exemplary system, they selected a monopod interacting compliantly with the ground. The evaluation of solvers is based on time of calculation and their accuracy. Interestingly, the best solver for a realistic test case turned out to be a solver recommended for numerically nonstiff ODE problems.

In the paper "Path-Following Bifurcation Analysis of Church Bell Dynamics," the authors performed a path-following bifurcation analysis of church bell to gain an insight into the governing dynamics of the yoke–bell–clapper system. Numerical analysis is performed both by a direct numerical integration and path-following methods using a new numerical toolbox ABESPOL based on Coco. The presented analysis allows to locate the regions in the parameters space ensuring robustness of bells effective performance.

The paper "Interplay Between Dissipation and Modal Truncation in Ball-Beam Impact" presented a ball-beam impact and, in particular, the interplay between dissipation and modal truncation. The Hertzian contact model between a solid ball and an Euler–Bernoulli beam model are used to describe the motion of the system. The authors found that the contact dissipation (either viscous or hysteretic) has only a slight effect while the contact location plays a significant role in convergence. However, even small modal damping speeds up convergence of the net interactions.

Thus, this special issue provides a wide spectrum of current research on systems with impacts. We hope that it will help in sharing information on recent studies, helping in solving new problems and in proposing new ideas. The Guest Editors would like to acknowledge the kind support of JCND Editor Balakumar Balachandran and Assistant to the Editor Amy E. Suski. We wish to express our appreciation to the authors of all the papers in this special issue for the excellent contributions as well as many reviewers for their high-quality work on reviewing the manuscripts.

Przemyslaw Perlikowski
Associate Professor
Division of Dynamics,
Faculty of Mechanical Engineering,
Lodz University of Technology,
Stefanowskiego 1/15,
Lodz 90-924, Poland
e-mail: przemyslaw.perlikowski@p.lodz.pl

Ko-Choong Woo
Associate Professor
Faculty of Engineering,
The University of Nottingham Malaysia Campus,
Jalan Broga,
Semenyih 43500, Selangor Darul Ehsan, Malaysia
e-mail: woo.ko-choong@nottingham.edu.my

Stefano Lenci
Professor
AE
Department of Civil Engineering,
Polytechnic University of Marche,
via Brecce Bianche,
Ancona 60131, Italy
e-mail: s.lenci@univpm.it

Tomasz Kapitaniak
Professor
Division of Dynamics,
Faculty of Mechanical Engineering,
Lodz University of Technology,
Stefanowskiego 1/15,
Lodz 90-924, Poland
e-mail: tomasz.kapitaniak@p.lodz.pl