28th French-Polish Seminar of Mechanics

October 14-15, 2021
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Book of Abstracts

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LAboratory of Mathematics and PhySics
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avec la participation de

in collaboration with

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Preface

The French-Polish Seminar in Mechanics is organized since 1992, alternatively in France and in Poland. Its purpose is to explore new developments and to intensify scientific interactions between groups of french and polish researchers working in the broad field of Mechanics and their applications in Engineering Sciences.

After the 27th edition organized in Besançon in June 2019, the 28th edition of the French-Polish Seminar in Mechanics is held in Perpignan, France, October 14-15 2021. It is organized by the LAboratoire de Modélisation Pluridisciplinaire et Simulations (LAMPS) of the University of Perpignan Via Domitia, in collaboration with the Warsaw University of Technology, INSA Val de Loire and the University of Bourgogne Franche-Comté. It brings together more than fourty distinguished Mathematicians, Engineers and Scientists from France, Poland, Brazil, Germany, and United States. This edition of the meeting was made possible thanks to the financial support of the University de Perpignan Via Domitia.

This booklet contains the abstracts of twenty oral presentations which include a large variety of results in the following topics: Dynamics of Mechanical Systems, Solid Mechanics, Fluid Mechanics, Contact Mechanics, Rheology, Granular Materials, Numerical Methods, Mathematical Modelling, Thermal Transfers. In the name of the organizers of this conference, I would like to thank all the authors for their valuable presentations as well as for their contribution to the success of this seminar.

I wish to express my gratitude to Prof. Dr. Jerzy Bajkowski, Dr. Robert Zalewski, Pr. Eric Florentin and Pr. Philippe Nardin for their help in the scientific coordination of the seminar as well as for their assistance in the organization of this meeting. Special thanks go to Joëlle Sulian for her countless hours of work, for the typeset of this volume as well as for her patience with the last minute changes. I am also grateful to Sylvia Munoz for her work on the financial management of this seminar. I extend my thanks to all members of the organizing committee for their cooperation and to all members of LAMPS for their interest in this conference.

I wish all participants a fruitful joint work and a very pleasant stay in Perpignan and in our region. Moreover, I express my hope that there will be many other editions of this event in the future, in order to promote and extend the collaboration between researchers in Mechanics in France and Poland.

Stéphane Abide

28e Séminaire Franco-Polonais de Mécanique
14 et 15 octobre 2021
Université de Perpignan Via Domitia

Program

Thursday, October 14

AMPHI 5

13:30 Welcome of participants - Registration
14:00 Opening Ceremony
14:30 Conferences: oral presentations

14:30–18:35 Chairman : Françoise Bataille

14:30	**U. Harlander**	Using the differentially heated rotating annulus experiment to understand changes in climate variability
15:15	**S. Viguier-Pla**	Dimension reduction of cyclostationary random functions
15:40	**M. David**	Study of anisothermal channel flow physics with direct numerical simulations

16:05 - 16:30 : Coffee Break

16:30	**C. Brouzet**	Fragmentation of brittle bres in turbulence: A laboratory model for plastic fragmentation in the ocean
16:55	**G. Meletti**	Amplitude Modulations in Strato-Rotational Instabilities (SRI)
17 :20	**L. Caban**	A generalization of the compact difference schemes to very high-order approximations of differential equations containing high-order derivatives
17:45	**S. Cherkaoui**	Primal-Dual Active Set methods for multi-contact problems solving in granular media
18:10	**P. Bartkowski**	Temperature and strain rate effects of jammed granular systems

19:00 : Dinner

Names in burgundy color: virtual presentation

Friday, October 15

AMPHI 5

09:15-12 :05 Chairman : Mircea Sofonea

9:00	**E. Florentin**	Uncertainty propagation using polynomial chaos expansion for robust conception: industrial application
9:45	**JM. Bajkowski**	Rheological model and parameter identifying of a smart beam with sand core
10:10	**Q. Serra**	Stochastic modeling in the context of structural vibrations

10:35 - 11:00 : Coffee Break

11 :00	**C. Bajer**	Massive computations with the simplex-shaped space-time finite element method in structural dynamics
11:25	**G. Labrosse**	C^∞ Mathematical modeling of multiphase components
11:50	**K. Szepietowska**	Strain field of the living abdominal wall subjected to intraperitoneal pressure

12:15 – 14 :00 : Lunch

14:00-16:35 Chairman : Eric Florentin

14:00	**M. Shillor**	Models for Dynamic Contact with Friction, Heat Exchange, and Debonding
14:45	**P. Klosowski**	Safety accepts of human orbit region shocks by finite element method
15:10	**S. Dumont**	Interface models in coupled thermoelasticity
15:35	**A. Jaskot**	Modeling of the motion of the mobile platform with four-wheel drive taking into account wheel slippage
16:00	**D. Danan**	Body-tted topology optimization with the Equivalent Radiated Power criterion

16:25 Clôture

Plenary : 35 mn + 10 min of questions **Talk : 15 min + 10 min of questions**

Abstracts

Massive computations with the simplex-shaped space-time finite element method in structural dynamics

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[2] Faculty of Production Engineering, Warsaw University of Technology, Warsaw, Poland

[3] Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland

An efficient algorithm for parallel computing for large scale structural vibration problems is proposed. The presented original direct method uses simplex-shaped space-time finite elements that enable a direct decoupling of the variables while assembling global matrices. The method uses the consistent stiffness, inertia and damping matrices, and can operate with non-symmetric matrices. The computational cost is independent of the bandwidth of the matrix in the classical meaning since only non-zero coefficients are retained. The algorithm was successfully implemented. The computational gain increases with the number of nodes and the dimensionality of the problem and can reach thousands of times even in the case of moderate discrete meshes. A large size 3-D example and comparison prove the efficiency of this space-time approach.

The computational time is significantly shorter than for other methods. The well known commercial application ANSYS requires a time proportional to the number of degrees of freedom in the analysed structure. The proposed space-time simplex element method only requires a time independent of the number of degrees of freedom since the distributed solution is carried on in parallel threads. The size of the problem that can be solved during a single computational stage depends on the number of nodes and blocks on the GPU card. The further technical evolution of GPU card architecture together with the CUDA environment will allow both increasing the number of nodes treated in parallel and decreasing the time of a single computational step.

Graphic adapters should be designed taking into account the elaborated algorithms for particular real-time dynamic simulations. Also, special algorithms should be developed for matrix computations. Iterative methods are not so promising here as direct methods are. Generally, the GPU card used with the space-time finite element method is even more efficient for 3-D tasks with complex meshes compared with classical computational methods than it is for 2-D tasks. The proposed efficient solver for various physical problems is universal and can be successfully applied to simulations, although more detailed further analysis of the leading idea could significantly improve the proposed computer procedure.

Rheological model and parameter identifying of a smart beam with sand core

J. M. Bajkowski[1], B. Dyniewicz[2], C. Bajer[2], J. Bajkowski[3]

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[3] *Polish Air Force University, Poland*

The prototype beam explores the properties of a dilatant sand in a quasi-solid phase, also called the jammed state. The sand composition consists of an ultrafine sand mixed and dispersed in a hydrophobic silicone that helps sand grains to agglomerate. The granular material was placed in an elastic PVC envelope merged between two aluminum beams. The envelope restricts the movement of sand and allows pressurizing grains by evacuating the air, allowing for some "smart material" behaviour.

During the experiment, the beam was fixed in a horizontal cantilever position and initially deflected. After releasing, the beam was free to vibrate, while displacement was recorded until the lateral oscillations ceased. Setting various underpressure values results in different intensities of the jamming. A proper model of the system and the identification of its parameters are necessary to answer the question, whether it is possible to use pressurized grains in semi-active vibration damping as an alternative to casual smart materials?

The considered model describes the global behavior of the system and combines nonlinear oscillators with frictional elements connected in series, which activate springs and the accompanying dashpots (Fig. 1). The full rheological model is described with 12 unknowns depending on underpressure. Thus, the inverse problem that leads

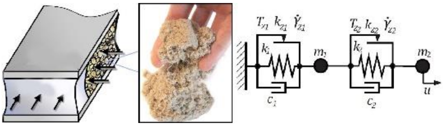

Figure 1: Experimental beam with a sand core and rheological model.

to minimization of the norm of differences between the measured and computed response becomes significant. Identification of parameter values allowed to decide which parameters may be reduced or assumed constant, and which depends heavily on the underpressure value. A fair agreement backed up by the low value of error was observed for broad range of initial deflections and different underpressure values.

The experimental research shows the efficiency of the kinetic sand used as fillings for the damping core. The phenomenological model turned out to provide good parameter estimation, however some simplifications should be worth considering, to make it less computationally expensive for further optimization. Due to its conceptual simplicity, effectiveness and low cost, the proposed solution for controlling the damping properties with granular material is an interesting alternative to classic damping systems.

Temperature and strain rate effects of jammed granular systems

P. Bartkowski

Faculty of Automotive and Construction Machinery Engineering, Warsaw University of Technology, Warsaw, Poland

Jammed granular systems, also known as Vacuum Packed Particles (VPP), have begun to compete with the well-known group of smart structures already widely applied in various fields of industry, mainly in civil and mechanical engineering. However, the engineering applications of VPP are far ahead of the mathematical description of the complex mechanical mechanisms observed in these unconventional structures. As their wider commercialization is hindered by this gap, in the paper the authors consider experimental investigations of granular systems, mainly focusing on the mechanical responses that take place under various temperature and strain rate conditions. To capture the nonlinear behavior of jammed granular systems, a constitutive model constituting an extension of the Johnson-Cook model was developed and is presented. The extended and modified constitutive model for VPP proposed in the paper can be simply implemented into any commercial Finite Element Analysis code, making it possible to carry out fast and reliable numerical simulations of innovative structures.

Fragmentation of brittle fibres in turbulence: A laboratory model for plastic fragmentation in the ocean

C. Brouzet,
Aix-Marseille University, France

While marine plastic pollution is ubiquitous and represents a global environmental threat, fundamental questions related to the fate of plastic debris in oceans remain poorly understood. In particular, the fragmentation process of marine plastic items, at the origin of the dispersion of microplastic de- bris across the globe, remains qualitatively described in the literature and a quantitative description is therefore needed. For instance, the fragmentation model currently used considers impact between solids, which is not relevant for a turbulent fluid environment. Here, I will present a physical model for the fragmentation of plastic debris in the turbulent upper layer of the ocean. Using laboratory experiments on the fragmentation of brittle fibres in a turbulent flow complemented by numerical simulations and theoretical analyses, our results demonstrate that the fragmentation process is limited at small scales by a physical cut-off length. This length originates from the fluid-structure interactions between the debris and the surrounding turbulent flow field, and is shown to be independent of the brittleness of the fibres. Such limitation mechanism of the fragmentation process at small scales is able to reproduce the size distribution of floating plastic debris measured in the ocean and therefore paves the way for a thorough understanding of marine plastic fragmentation.

A generalization of the compact difference schemes to very high-order approximations of differential equations containing high-order derivatives

L. Caban[1], A. Tyliszczak[1], B. Geurts[2]

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[2] *University of Twente (UT)*

High-order discretization methods are extensively used in solving high-order differential equations occurring in mathematical and engineering problems. Among others, they find applications in modeling of wave propagation equations (second, third, fourth, fifth and higher order derivatives), fluid mechanics (second and fourth order derivatives), thermal instability (sixth and eighth order derivatives), magnetohydrodynamics and astrophysics (tenth and twelfth order derivatives). In this work we generalize the compact difference schemes and formulate a general framework of discrete representations of arbitrary order derivatives up to the approximation order limited only by the overall number of nodes in the computational meshes, K. In results, the derived discrete schemes involve large number of mesh points. Their accuracy is demonstrated based on 1D and 2D benchmark problems: a linear dispersive wave equation, the Korteweg-de Vries equation, the Kuramoto-Sivashinsky equation, the Taylor-Green flow, a convected vortex and double shear-layer flow. The last three problems are typical test cases in CFD. The obtained results are compared with analytical solutions and solutions obtained by the Fourier pseudo-spectral method. It is shown that applying very high-order compact schemes allows us to obtain the approximation accuracy at the level of 30^{th} - 40^{th} order and in some cases we even reach the spectral accuracy with the error decrease proportional to h^K , where h is the mesh spacing.

Primal-Dual Active Set methods for multi-contact problems solving in granular media

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[2] *University of Nîmes*

The understanding of granular media and the complex character of the interactions governing their dynamics is a major issue for industries in several sectors. The recurrent and growing need to simulate them requires adapted tools, mainly grouped under the term of Discrete Element Method (DEM). Granular dynamics is then governed by Newton's second law of motion combined with a regular contact model. Later, other discrete element based strategies have been developed, especially the Non-Smooth Contact Dynamics (NSCD) approach, which consists of taking into account the frictional contact inter- actions collectively during a time step, without using a regularization process, and whose management of the non-smooth dynamics equations is done through the Non-Linear Gauss-Seidel algorithm (NLGS). The literature is full of numerical methods to solve these equations, but recently, Primal-Dual Active Set (PDAS) methods have emerged as simple to implement and efficient methods to solve these kinds of problems. These methods are based on the following principle: the frictional contact conditions are reformulated in terms of non-linear complementary functions, whose solution is provided by Newton's semi-smooth iterative method. On the basis of these prerequisites, we provide an algorithm for solving contact and friction laws in the non-smooth framework of NSCD in granular media. Numerical experiments are reported to evaluate the efficiency and assess the performances of PDAS methods compared to other numerical methods. Finally, in order to assess the relevance of the NSCD-PDAS approach in an application framework, the implementation has been carried out in an open source solver, allowing to inherit the massive parallelism specific to the solver, to simulate fluid-granular coupled flows, and to compare the performances with the DEM approach specific to the solver.

Body-fitted topology optimization with the Equivalent Radiated Power criterion

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[1] *IRT SystemX*
[2] *Alter Ego Engineering*
[3] *Renault*

The Equivalent Radiated Power (ERP) criterion focuses on the vibration of structural panels; as such, in automotive applications, it can be used to estimate the acoustic performance of vehicles without modeling the fluid as well as the computationally expensive fluid-structure coupling. As a matter of fact, such a computationally intensive effort may not even be required in an early design phase. In practice, the spatial averaging version of the ERP criterion is evaluated through a post-processing of the solution arising from an harmonic response problem of a visco-elastic body. In order to solve such a problem, we rely on the modal frequency response analysis.

In the broad sense, shape and topology optimization aims at finding an optimal shape among a set of admissible shapes $\mathcal{O}_{ad}$, constrained in a design space $D \subset \mathbb{R}^3$, with respect to a set of prescribed criteria. As of now, density-based optimization methods, which describe the optimization variable via a density field which takes intermediate values between the material and the void densities, are used to a significant extent in the literature and the industry. However, it leads to the introduction of ficticious material densities and may therefore produce non-physical modes in intermediate densities. On the other hand, the level-set method is based on a sensitivity analysis from the shape optimization framework and is used to enforce a descent direction and advect a structural interface and also provides a clear definition of the shape.

Therefore, in the present work, we opt for a level-set based topology optimization method for the ERP minimization on three dimensional test cases. Note that it is coupled with a remeshing routine, in order to enables the reconstruction of a body-fitted mesh at each step of the iterative process. Such a choice allows us to handle naturally the topology changes and provides high quality meshes for the physical evaluations inherent to the optimization process.

Study of anisothermal channel flow physics with direct numerical simulations

M. David, A. Toutant, F. Bataille
University of Perpignan Via Domitia PROMES-CNRS

Anisothermal channel flows are of particular interest in many of the engineering fields. Particularly, in concentrated solar power towers, the irradiated wall of the receiver is subjected to a very strong solar flux which leads to asymmetric heating of the fluid. The flow passing through the solar receiver is very complex and is characterized by a strong asymmetric heating of a highly turbulent gas flow. Deepen understanding of the encountered flows will further permit the solar receiver optimization. The academic geometry of the bi-periodic channel is well adapted to reproduce thermal and dynamic phenomena encountered in the receiver, see figure 1. The streamwise (x) and spanwise (z) directions of the channel are periodic. The flow is bounded by two plane walls in the wall-normal (y) direction.

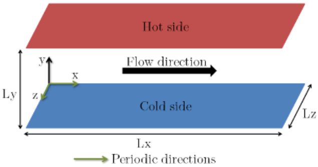

Figure 1: Bi-periodic channel.

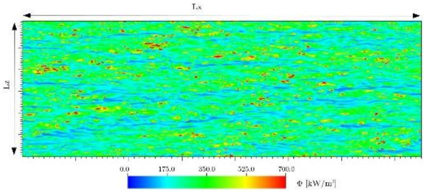

Figure 2: Instantaneous wall heat flux

This study investigates the turbulence and the temperature effects on channel flows thanks to Direct Numerical Simulations (DNS). The DNS is a computational fluid dynamic approach which aims to solve the quasi-integrality of the turbulence scales. These simulations are extremely costly but provide rich and accurate information on the flow physics. The results of 5 DNS are analyzed. To achieve these simulations more than 12 millions of computational hours have been required. The mean friction Reynolds numbers of the simulations are 180, 395, 800, 820, and 930. The effects of the turbulence level and the temperature distribution are investigated. The Navier-Stokes equations are solved under the low Mach number approximation and the thermal dilatation is taken into account. The variations of the fluid properties are considered. Particularly, the dynamic viscosity is computed thanks to the Sutherland's law. The equations are solved with the finite difference method in a staggered grid system. The streamwise and spanwise directions are discretized with a uniform grid spacing. In the wall-normal direction, which is submitted to high velocity and temperature gradients, the mesh is nonuniform. The wall-normal grid points are given by a hyperbolic tangent law. The software used to perform the simulations is TrioCFD. The instantaneous fields (see figure 2) as well as the first- and second-order statistics of the turbulence are presented and discussed. The results highlight the high Reynolds number effects observed on the velocity fluctuations and the strong coupling between the dynamic and the temperature.

Interface models in coupled thermoelasticity

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During the last decades, the interest in bonded structures, obtained by assembling different parts made of possibly different materials to compose a unique construction, is strongly increased. For example, bonded structures are manufactured for civil, marine and aeronautic applications.

In this work, we propose new transmission conditions at the interfaces between the layers of a dynamical three-dimensional composite structures.

More precisely, the mechanical behavior of two linear isotropic thermoelastic solids, bonded together by a thin layer, constituted by a linear isotropic thermoelastic material, is analized by means of an asymptotic analysis.

After defining a small parameter ε, which will tend to zero, associated with the thickness and the constitutive coefficients of the intermediate layer, different limit models and their associated limit problems, the so-called thermoelastic interface models, are characterized, according to the different dependences of the constitutive coefficients to the small parameter. The asymptotic expansion method is reviewed by taking into account the effect of higher order terms and by defining a generalized thermoelastic interface law which comprises the above aforementioned models.

Numerical examples are presented to show the efficiency of the proposed methodology, based on a finite element approach.

Uncertainty propagation using polynomial chaos expansion for robust conception: industrial application

J. Salloum[1], B. Bergeot[1], Q. Serra[1], N. Gallienne[2], N. Richet[2], S. Berger[1], E. Florentin[1]

[1] INSA CVL
[2] Air Liquide

Variability of the parameters is taken more and more into account in the design phase. Different stochastic methods can be used to predict possible values of the response of a system when the in- put parameters vary. This numerical tool is of interest to several industrial applications such as risk management, optimization and robust design. Scanning the stochastic space is generally very expensive from a numerical point of view and constitutes the major difficulty of stochastic approaches. Monte Carlo simulations, considered as a reference approach: it involves evaluating the results of the system studied on a large sample of realizations. Simple to implement, a large amount of realizations is necessary to obtain a quality result. Different variants have been introduced to improve convergence (Latin Hypercube sampling, quasi Monte Carlo ...).

Several methodologies based on a spectral expansion have been developed to tackle the cost associated with sampling methods. Perturbation methods are based on a Taylor series expansion around the mean value of parameters. They are limited to the case of small variations of the random field around its mean value, and they cannot be applied to non-smooth functions. The Polynomial Chaos expansion is a spectral method, consisting in searching an approximation of the stochastic response in the space spanned by a finite basis of orthonormal polynomials.

In this presentation, the basics of Polynomial Chaos Expansion is introduced and we illustrate different results obtained with this tool to study the response of models subjected to parametric uncertainties. We focus on an industrial application to illustrate the interest for dimensioning purpose. Mastering the quality of such a tool is not so easy in this context.

Using the differentially heated rotating annulus experiment to understand changes in climate variability

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Recently there have been a large public interest on the question whether the mid-latitude jet stream changes due to climate change. This mid-latitude jet is responsible for a number of weather extremes like heat waves and cold spells but also so called cut-off lows that can bring heavy rainfall and flooding. Surprisingly, the mid-latitude jet can be modeled using a rather simple laboratory model. We report on a set of laboratory experiments to investigate the effect of Arctic warming on the amplitude and drift speed of the mid-latitude jet stream. Our results show that a progressive decrease of the meridional temperature difference 1) slows down the eastward propagation of the jet stream, 2) complexifies its structure, and 3) increases the frequency of extreme events. Extreme events and temperature variability show a clear trend in relation to the Arctic warming only at latitudes influenced by the jet stream, whilst such trend reverses in the equatorial region south of the subtropical jet. Despite missing land-sea contrast in the laboratory model, we find similar trends of temperature variability and extreme events in the experimental data and the National Centers for Environmental Prediction (NCEP) reanalysis data. We think that with respect to fundamental features of the mid-latitude jet stream and climat change, laboratory experiments form a useful supplement to numerical models.

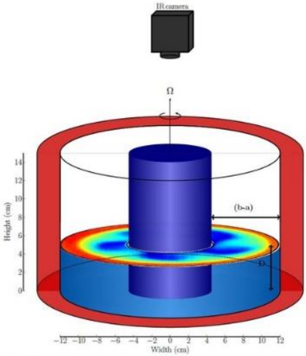

Fig. (1) Schematic drawing of the experimental apparatus. The inner cylinder is cooled using a thermostat. The outer wall is heated by fluid surrounding the outer wall. The surface temperature of the fluid in the gap between the walls is measured by an infrared camera aligned with the axis of rotation.

Modeling of the motion of the mobile platform with four-wheel drive taking into account wheel slippage

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The paper describes the issue of modeling the motion of mobile platforms taking into account slip. The motion dynamics model is presented on the basis of a four-wheeled mobile platform with four-wheel drive. The proposed platform dynamics model is based on the description of the platform motion as a rigid body subjected to active and passive forces resulting from the drive of the wheels and the interaction of these wheels with the ground during motion. In the description of the interaction of wheels with the ground, a model of dry friction was adopted, with the possibility of wheel slip when the value of the developed friction force was exceeded by the active forces of the drive wheels.

The formulated initial problem of the platform motion was solved using the Runge-Kutta 4th order method. By adapting the solution algorithm proposed by the authors, a computing program was developed in the Matlab environment to determine the parameters of motion. Simulation tests were performed to verify the usability of the model when the platform is moving, taking into account the occurrence of skid and without. Examples of motion simulation results are described in this work. The presented dynamic model can be adapted to study the motion of wheeled mobile platforms also with a different number of drive wheels, through a mathematical description of the driving forces of the wheels and their interaction with the ground, appropriate to the number of wheels.
The paper also presents a computational algorithm that allows to track the relationship between the active forces caused by the driving torque and the reactive forces during motion at the contact point of the wheel with the ground. If the value of the developed friction forces by the driving forces is exceeded, the drive wheels slip.

The adopted computational model of the platform motion was subjected to experimental verification in relation to the real four-wheeled mobile robot LEO Rover. By comparing the results of simulation and experimental tests, it was confirmed, in the tested range of drive force configurations, that the simulation results were consistent with the relevant real robot motion parameters.

Further plans include the development of a computational model to enable mobile platform motion studies in more complex motion cases, e.g. bypassing or hitting obstacles. The model is a good basis for research when models built on the kinematic relationships are insufficient, such as in the case of skidding during platform movement.

Safety aspects of human orbit region shocks by finite element method

P. Klosowski
Gdańsk University of Technology

Safety aspects of injuries of the human orbital area are the subject of the research. The research is divided into several stages.

1. The laboratory tests on mechanical properties of selected tissues were performed and the most important mechanical properties like the elasticity modulus or the ultimate strength were calculated.
2. Computer tomography scans of the orbital region of a skull were used to obtain the finite element model of a skull.
3. Several models of impact were analyzed
4. The finite element model of the orbital region was analyzed under impact from different directions

During the presentation, the most important assumptions of the performed analysis will be presented. The problem of modelling human tissues having a large range of stiffness or being incompressible will be discussed. Results on the initial tests enabling proper construction of the final model will be shown.

The final analysis points out the places on the human orbital region and the eyeball which are especially exposed to damage. Such analysis is important also in reverse analysis when according to recorded damages of the orbital region, or the eyeball the reasons for the damage are detected.

The research has been performed with the support of the National Science Center (NCN) in Cracow, Poland within grant No. 2016/23/B/ST8/00115 „Analysis of the mechanical properties of the eye orbital wall and the numerical nonlinear dynamic analysis of the orbital blow-out trauma type verified by clinical observations”.

C^∞ Mathematical modeling of multiphase components

G. Labrosse
TchebyFlow & LAMPS, University of Perpignan

Multiphase components is a generic concept. As examples, it stands for solid objects immersed in a fluid flow, or for parts of a material whose thermal conductivity and density are significantly different from those of the base material. These situations are usually numerically treated by a multi-domain approach, a cumbersome technology when many multiphase components are to be considered. The proposed modeling allows the problem to be posed as a mono-domain configuration, which is, by the way, much closer to Physics. Illustrations will be given from the 1D/2D heat equation, the RLC-network problem, the 2D wind tunnel configuration, and the 3D Maxwell equations.

Amplitude Modulations in Strato-Rotational Instabilities (SRI)

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In geophysical and astrophysical flows, stratified vortices can be found from small to large scales, and they are relevant in the distribution of heat and momentum in stably stratified systems such as the atmosphere or oceans. In the astrophysical context, accretion disks (from which solar systems are formed) can be seen as stratified vortices. In such systems, understanding the mechanisms that can result in an outward transport of angular momentum is a central problem. For a planet or star to be formed in a disk, angular momentum has to be carried away from its center to allow matter aggregation by gravity; otherwise, its rotation speed would be far too large, avoiding this matter aggregation (and the consequent
star formation) to happen. In such gas systems, turbulence is the most likely mechanism to achieve such a large angular momentum transport. However, it was shown that the flow prole of accretion disks is
stable with respect to purely shear instabilities, and the question arises about how the turbulence can be generated. Among other candidates, the strato-rotational instability (SRI) has attracted attention in recent years. The SRI is a purely hydrodynamic instability that manifests itself as non-axisymmetric spirals and can be modeled by a classical Taylor-Couette (TC) system with stable density stratification. The density stratification causes a change in the marginal instability transition when compared to classical non-stratified TC systems, making the flow unstable in regions where, without stratification, it would be stable. This characteristic makes the SRI a relevant phenomenon in planetary and astro-physical applications, particularly in accretion disk theory In this work, we will present confrontations of experimental data with non-linear High-performance numerical simulations of strato-rotational flows that reveal non-linear interactions of SRI modes leading to periodic changes in the SRI spirals axial direction of propagation. These spiral patter changes lead to low-frequency velocity amplitude modulations related to two competing spiral wave modes. We will then show how two different spirals linearly interacting could lead to these pattern changes, but related to the non-linear transfer of energy from the base flow to these secondary instabilities. We will also show how the presence of amplitude modulations impact the momentum transfer regime and the net momentum flux driven by the SRI, that might represent strong in fluences on star formation regimes in accretion disks.

Stochastic modeling in the context of structural vibrations

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Structural vibrations is an active domain in mechanics, which have many practical applications, we can cite for example energy harvesting or minimization of vibrations for structural safety and comfort enhancement. Thus, many engineering studies aim at designing systems having prescribed properties in the frequency domain.
However, the variability of the parameters, such as material parameters, geometric parameters, environment parameters, implies a variability in the quantity of interest of the system. This fact has been confirmed experimentally by a large dispersion of the vibration levels, especially in a domain called the mid-frequency range, where the variability is high and not yet reduced by mass and damping effects. Thus, it is of major importance to take into account this variability in the design process.
The complexity of the numerical models, associated to the high dimension of the space of the parameters, leads to prohibitive computational costs for someone who wants to estimate the mean, the variance or even the distribution of the quantity of interest with brute force. Thus, several metamodeling techniques have been proposed in the literature recently to estimate these quantities at a lower cost, for example using a relatively small number of observations.
As a consequence, the properties predicted by the metamodel are not exact, and the associated error needs to be estimated to have an indicator of the efficiency of the metamodel.
In this presentation, we will focus on a discrete model in linear structural vibrations, to investigate the main tendencies of the error in the frequency domain. Limits of classical error estimates will be discussed and a strategy based on error metamodeling will be proposed and discussed.

Models for Dynamic Contact with Friction, Heat Exchange, and Debonding

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The talk presents a few additional aspects of modeling the processes involved in dynamic contact between 2D bars that may include friction, frictional heat generation, heat exchange and also, possible debonding of bonded 2D bars. We first describe a model for thermoelastic contact between a 2D bar and a rigid or reactive foundation when friction and frictional heat generation are included. Then, we present a model for the dynamic contact of two thermoelastic 2D bars with Barber's heat exchange condition. The motivation for such problems comes from various settings in MEMS devices which will be presented in some details. Finally, we describe the process of debonding of a bonded system when the deterioration of the adhesive is caused by vibrations, thermal eff and the humidity in the environment. Since the models are new, their analysis and computer simulations are needed.

Strain field of the living abdominal wall subjected to intraperitoneal Pressure

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The biomechanical approach has been used to address ventral hernia repair issues related to recurrences, postoperative pain, and discomfort of patients with operated hernias. It is believed that mechanical biocompatibility between surgical meshes used in the treatment, and the abdominal wall needs to be achieved. Therefore, an understanding of mechanical behaviour of both the implants and abdominal wall is required. In this study, we focus on the latter aspect. The abdominal wall is a multi-layered complex structure. Until now, the entire abdominal wall samples or its separate components were studied mainly postmortem. The current study addresses the need for further investigation of living human abdominal wall.

Noninvasive in vivo measurements of patients suffering from end-stage kidney disease were performed during standard peritoneal dialysis. Digital Image Correlation (DIC) technique is used to perform fullfield optical displacement measurements of the external abdominal wall surface of the patient during introduction of dialysis fluid. During the medical procedure, the intra-abdominal pressure is measured after the introduction of the fluid. The strains of the human living abdominal wall subjected to intraperitoneal pressure are calculated. The principal directions of the strains characterising various regions of the abdominal wall are analysed.

The study provides data for further identification of the material properties of human living abdominal wall.

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Dimension reduction of cyclostationary random functions

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Cylclostationary random functions, also refered as periodically correlated random processes, have been explored since the 1960's, are widely explored, on one hand for theoretical developments of their properties and treatment, and on another hand for modelizations of concrete applications. Indeed, cyclostationarity occurs in processes where some statistics present periodicity. These periodic phenomena are encountered in various situations, due for example to modulation in signal theory, rotation in mechanics, revolution of planets, sanguine pulse in medicine, seasonality in economics, or pulsation of stars in astronomy.
In this talk, we consider a random function $(X_t)_{t\in\mathbb{R}}$. We say that it is cyclostationary when $\mathrm{cov}(X_t, X_{t'}) = \mathrm{cov}(X_{t+\Delta}, X_{t'+\Delta})$, for a given Δ of $\mathbb{R}$, and for any (t, t') of $\mathbb{R}\times\mathbb{R}$. We transform it into a stationary series, and then we proceed to the dimension reduction of this stationary series, with the Principal Components Analysis in the frequency domain (cf. Brillinger [1] and Boudou and Dauxois [2]). Then we show how to reconstruct a summary of the intitial cyclostationary function.
We give an example on simulated data. The set of indices can be extended to $\mathbb{R}^k$ (cf. Boudou and Viguier-Pla [3]).

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