30th French-Polish Seminar of Mechanics

organized by

LAMPS

LAboratory of Pluridisciplinary Modelling and Simulations

of

University of Perpignan Via Domitia

BOOK OF ABSTRACTS

.

Organizing Committee

Serge Dumont and Mircea Sofonea (Perpignan, France - **Chairs**)
Mikaël Barboteu (Perpignan, France)
Francesco Bonaldi (Perpignan, France)
Michel Cayrol (Perpignan, France)
Sylvia Muñoz (Perpignan, France)
Joëlle Sulian (Perpignan, France)

Scientific Committee

S. Abide (Nice, France)
C. Bajer (Warsaw, Poland)
J. Bajkowski (Warsaw, Poland)
M. Barboteu (Perpignan, France)
G. Domek (Bydgoszcz, Poland)
S. Dumont (Perpignan, France)
B. Dyniewicz (Warsaw, Poland)
E. Florentin (Bourges, France)
F. Jourdan (Montpellier, France)
P. Kłosowski (Gdansk, Poland)
F. Lebon (Marseille, France)
I. Lubowiecka (Gdansk, Poland)
H. Piotrzkowska-Wróblewska (Warsaw, Poland)
Q. Serra (Bourges, France)
M. Shillor (Rochester MI, USA)
M. Sofonea (Perpignan, France)
R. Zalewski (Warsaw, Poland)

.

Preface

The French-Polish Seminars on Mechanics are yearly scientific events marking the French-Polish collaboration in the wide field of mechanics and its applications. For more than 25 years, the seminars have been organized alternately in France and Poland, allowing French and Polish researchers to further consolidate and extend a successfull cooperation. The last edition of the Seminar took place in Gdánsk (Poland) on September 21 and 22, 2023.

This volume contains the abstracts of the oral presentations at the 30^{th} edition of the Seminar, hosted by the University of Perpignan Via Domitia. Its topics include but are not limited to: solid mechanics, fluid mechanics, mechanics of materials, contact mechanics, numerical methods, biomechanics, heat transfer, viscoplasticity, two-phase flow, mechanical systems dynamics, identification of parameters for modelling mechanical processes.

We are grateful to the University de Perpignan Via Domitia for the financial support that made possible the organization of this edition of the Seminar.

We would like to thank all the speakers for their valuable presentations and all the participants for turning this conference into a great succes. Furthermore, we wish to express our gratitude to the members of the Scientific Committee for their help in the scientific coordination and logistic assistance.

Special thanks go to Joëlle Sulian for managing the web page as well as the conference program, and to Sylvia Munoz for managing the financial aspects.

We wish all participants a fruitful time and a very enjoyable stay in Perpignan.

Serge Dumont and Mircea Sofonea

On behalf of the Organizing Committee

Contents

Exploring the performance of a composite microsphere-modified magneto-rheological fluid, *Jacek Mateusz Bajkowski et al.* 9

An energy-consistent discretization of hyper-viscoelastic contact models for soft tissues, *Francesco Bonaldi et al.* 10

Analysing discrete and continuous spectrum and dimension reduction for thermal fields, *Mélanie Dreina et al.* 11

DNS of turbulent natural convection flows in a differentially heated cavity with conjugate heat transfer, *Mélanie Dreina et al.* 12

Large Eddy simulation of a turbulent round impinging jet with conjugate heat transfer, *Cédric Flageul et al.* 13

Approximations and associated quality of mechanical stochastic problems, *Éric Florentin et al.* 14

A Fourier term and Bernstein polynomial collocation method for nonlinear fractional order partial differential equations, *Cundi Han et al.* 15

Study of the mechanical and functional behaviour of stents, *Franck Jourdan* 16

Topological optimisation of simplified hernia implant with particle swarm method, *Szymon Kalinowski et al.* 17

Hanging roof - theoretical and constructional problems, *Paweł Kłosowski* 18

On some mechanical aspects of abdominal hernia repair,
Izabela Lubowiecka et al. 19

An improved normal compliance method for non-smooth contact dynamics,
Vo Anh Thuong Nguyen et al. 20

Mathematical model of breast cancer based on mechanical and biological properties of tissues developed for computer-aided personalized neoadjuvant therapy, *Hanna Piotrzkowska-Wróblewska et al.* 21

A rotation-free finite element formulation for anisotropic elastoplasticity of textiles and fiber-embedded composites, *Roger A. Sauer et al.* 22

The new Damped Normal Compliance (DNC) contact condition, *Meir Shillor* 23

Analysis of the effect of straight arch technique parameters on loads in the periodontium, *Kamil Sybilski et al.* 24

Randomized neural network methods for solving mechanics problems,
Fei Wang 25

Multi-layer elastic contact system and its finite element agorithm design,
Zhizhuo Zhang et al. 26

List of participants 27

Conference Program 29

Exploring the performance of a composite microsphere-modified magnetorheological fluid

Jacek Mateusz Bajkowski [1], Warsaw University of Technology
Czesław I. Bajer, IPPT, Polish Academy of Sciences
Bartłomiej Dyniewicz , IPPT, Polish Academy of Sciences
Jerzy Bajkowski, Polish Air Force University

Abstract: The use of magnetorheological (MR) fluids in engineering applications has garnered significant attention due to their ability to transition between liquid-like and solid-like behaviour under the influence of a magnetic field. While conventional MR fluids have been extensively studied, our exploration into a novel formulation, diverging from conventional compositions, opens new possibilities for designing devices with a controllable elasticity.

This study synthesised a novel MR fluid formulation diverging from conventional compositions by incorporating compressible microspheres filled with gas and ferromagnetic iron particles into a polyalphaolefin. Including lightweight polymeric particles allows for compression of the non-Newtonian fluid, altering its apparent viscosity and yield strength, all while maintaining control over the fluid's state through the magnetic field. This novel composite microsphere addition not only amplifies compressibility beyond typical MR fluids but also reduces the required concentration of iron particles to achieve equivalent yield stress.

The rheological characteristics of the custom MR fluid are intriguing. The modified fluid was used in a prototype translational vibration damper and tested under dynamic conditions for different excitation frequencies. Surprisingly, the characteristic of the fluid did not directly translate into the dynamic characteristic of the device. The activated magnetorheological fluid obstructs the flow and promotes the damper's elastic rather than viscotic response, presenting a unique and complex challenge for further modelling and understanding.

This innovative fluid composition could potentially be used in a device that acts as a liquid spring, with the remaining possibility of controlling material characteristics.

[1] Speaker: jm.bajkowski@gmail.com

An energy-consistent discretization of hyper-viscoelastic contact models for soft tissues

Francesco Bonaldi[2], Université de Perpignan Via Domitia
Mikaë Barboteu, Université de Perpignan Via Domitia
Serge Dumont, Université de Perpignan Via Domitia
Christina Mahmoud, Université de Montpellier

Abstract: We propose a mathematical model of hyper-viscoelastic problems applied to soft biological tissues, along with an energy-consistent numerical approximation. We first present the general problem in a dynamic regime, with certain types of dissipative constitutive assumptions. We then provide a numerical approximation of this problem, with the main objective of respecting energy consistency during contact in adequacy with the continuous framework. Given the presence of friction or viscosity, a dissipation of mechanical energy is expected. Moreover, we are interested in the numerical simulation of the non-smooth and non-linear problem considered, and more particularly in the optimization of Newton's semi-smooth method and Primal Dual Active Set (PDAS) approaches. Finally, we test such numerical schemes on academic and real-life scenarios, the latter representing the contact deployment of a stainless-steel stent in an arterial tissue.

[2]Speaker: francesco.bonaldi@univ-perp.fr

Analysing discrete and continuous spectrum and dimension reduction for thermal fields

Mélanie Dreina[3], Université de Perpignan Via Domitia
Sylvie Viguier-Pla, Université de Perpignan Via Domitia
Stéphane Abide, Université Côte d'Azur

Abstract: The aim of this work is to compare three methods of data reduction in the context of heat transfer. This follows the well-known practice of observing unsteady phenomena according to space or time energetic arguments. Especially, the present study focuses on the efficiency of the Proper Orthogonal Decomposition (POD), Spectral Proper Orthogonal Decomposition (SPOD) and Principal Components Analysis in the Frequency domain (FPCA). In several previous works, both POD and SPOD have been proposed in the context of fluid mechanics while FPCA is been newly applied to this domain. Thus, in this work we provide a discussion on the contribution of the FPCA to deal with multiscale physics.

[3]Speaker: melanie.dreina@univ-perp.fr

DNS of turbulent natural convection flows in a differentially heated cavity with conjugate heat transfer

Mélanie Dreina[4], Université de Perpignan Via Domitia,
Stéphane Abide, Université Côte d'Azur
Sylvie Viguier-Pla, Université de Perpignan Via Domitia

Abstract: Conjugate heat transfer refers to the heat transfer that occurs at the interface between a fluid and a solid. The study of this phenomenon can help in understanding the thermal wear of materials, such as pipes. However, there are still questions regarding the modelling of turbulence at the interface. This work presents a numerical method for direct numerical simulation of conjugate heat transfer in the case of natural convection in a cavity. With our numerical method, the Navier-Stokes equation is discretized using Thcebychev polynoms in the vertical and horizontal directions while the periodic direction is discretized with Fourier series expansion. This numerical approach ensures a high level of accuracy. Conjugate heat transfer is handled using a matrix influence technique to prescribe the continuity of temperature and heat flux at the fluid/solid interface. This work applies the matrix influence technique with a parallelization process based on pencil decomposition to allow jobs on massively parallel computers and reduce simulation time. Some preliminary simulations will be presented in order to illustrate the efficiency of the proposed method and to discuss the regularity of the temperature fluctuation dissipation at the interface.

[4]Speaker: melanie.dreina@univ-perp.fr

Large Eddy simulation of a turbulent round impinging jet with conjugate heat transfer

Cédric Flageul[5], Université de Poitiers
Éric Lamballais, Université de Poitier
Thibault Dairay, Michelin
Sofiane Benhamadouche, EDF R&D

Abstract: Fluid-solid thermal coupling associated with the impingement of a jet on a heated solid plate is investigated by means of Large Eddy Simulation (LES) using the open-source code Incompact3d. High-order compact schemes and realistic inflow conditions are used to improve the fidelity of the simulation. The sponge layer near the lateral faces allow the fluid to leave the domain smoothly with a limited influence upstream. In case of fluid-solid thermal coupling, the temperature field in the fluid and solid domains are weakly coupled. Cases with conjugate heat transfer are compared with idealized cases (imposed temperature or heat flux). Temperature and heat-flux behavior around the fluid-solid interface show the fundamental difference between the aforementioned cases. Advanced statistics associated with second-order RANS turbulence models are presented. The topic will be deepened later using Direct Numerical Simulation, and the resulting database will be publicly available. The Reynolds number based on the impinging jet diameter is 10^4.

[5]Speaker: cedric.flageul@univ-poitiers.fr

Approximations and associated quality of mechanical stochastic problems

Éric Florentin[6], INSA CVL, Université d'Orléans, Université de Tours
Quentin Serra, INSA CVL, Université d'Orléans, Université de Tours

Abstract: In mechanical engineering, addressing stochastic models often involves employing Monte Carlo simulations grounded in a deterministic framework of finite element computation. However, a notable limitation of this method lies in its computational cost. Methods where one aims to represent randomness in a simplified manner by reducing the dimension of the stochastic model are an interesting path from a computational cost perspective. Different numerical techniques have been developped using this principle. Ensuring the introduced approximation maintains a high level of fidelity is a challenge. To address this, we study in this presentation different approximations and their associated verification techniques. Verification is to estimate the distance between the approximated solution and the reference one.

[6]Speaker: eric.florentin@insa-cvl.fr

A Fourier term and Bernstein polynomial collocation method for nonlinear fractional order partial differential equations

Cundi Han[7]**, INSA CVL, Université d'Orléans, Université de Tours,**
Quentin Serra, INSA CVL, Université d'Orléans, Université de Tours
Hélène Laurent, INSA CVL, Université d' Orléans
Éric Florentin, INSA CVL, Université d'Orléans, Université de Tours

Abstract: A novel and highly accurate numerical method, utilizing Bernstein polynomials and Fourier terms, is proposed in this study. This method addresses the challenging task of numerically processing nonlinear fractional partial differential equation models, which pose significant difficulties due to their nonlinear terms and fractional orders. To overcome these challenges, fractional order operator matrices for multi-dimensional unknown functions are derived. This innovative approach enables the effective processing of nonlinear terms within the numerical examples and enhancing accuracy. Through these concerted efforts, the obstacles inherent in solving such equations are effectively mitigated.By leveraging the combined power of Bernstein polynomials, Fourier terms, and fractional order operator matrices, this method stands poised to significantly advance the numerical processing of nonlinear fractional partial differential equations, offering enhanced accuracy and efficiency in their solution.

[7]Speaker: cundi.han@insa-cvl.fr

Study of the mechanical and functional behaviour of stents

Franck Jourdan[8]**, Université de Montpellier**

Abstract: Endovascular surgery has made spectacular progress in the treatment of a number of cardiovascular pathologies. This progress is mainly due to the minimally invasive nature of the procedure, which reduces the risk of morbidity. This presentation will focus on endovascular devices such as stents. These are expandable mesh structures that are applied to the vascular walls. Different types of stents, treating pathologies such as stroke or aortic dissection, will be studied, both from the point of view of their mechanical and functional behaviour. Particular attention will be paid to the material properties of shape memory alloy stents, but also to the importance of the structural aspect of these implants. The presentation will be based on medical, experimental and numerical work.

[8]Speaker: franck.jourdan@umontpellier.fr

Topological optimisation of simplified hernia implant with particle swarm method

Szymon Kalinowski[9]**, Gdańsk University of Technology**
Katarzyna Szepietowska, Gdańsk University of Technology
Éric Florentin, INSA CVL, Université d'Orléans, Université de Tours,
Izabela Lubowiecka, Gdańsk University of Technology

Abstract: The study refers to topology optimisation of surgical implant used in treatment of abdominal hernia. This research aims to solve a frequently occurring medical problem with high recurrence rate of abdominal hernia. It's believed that by achieving mechanical compatibility between substituted tissues and implant will help avoiding recurrences. This research is aiming to achieve this by obtaining reduced and uniformly distributed reaction forces in the connections between native tissue and the implant by manipulating topology of implant. Combination of commercial finite element software (Marc Hexagon) with in-house code in Python for optimisation and control is applied in the analysis. In the study the implant is modelled as a decagonal membrane by means of finite element method (FEM). It consists of 1152 4-node membrane finite elements with 3 degrees of freedom in each node. The load is amplified for the tests and is applied as displacements. The material model is assumed as linear elastic and isotropic with Poisson's ratio 0.3 and Young's Modulus of 16.155 MPa. The optimised surface is described using 3rd and 4th polynomial expansion of quadratic surface equation for lowering the number of unknowns during optimisation. The proposed optimisation examples v1 and v3 have significantly reduced differences between reactions while v2 and v4 reduced the overall reactions compared to unoptimised model with uniform thickness of 0.5mm as shown in Table 1.

Table 1: Reaction forces (N) in implant connections

	R1	R2	R3	R4	R5
unoptimised	251.83	38.78	94.07	136.91	145.79
optimised v1	53.63	38.57	45.22	42.78	31.87
optimised v2	50.97	7.94	22.43	27.47	29.75
optimised v3	54.89	34.11	43.09	36.72	31.19
optimised v4	52.11	8.84	26.37	30.70	30.43

[9]Speaker: szykalin@pg.edu.pl

Hanging roof - theoretical and constructional problems

Paweł Kłosowski[10], Gdańsk University of Technology

Abstract: Roofs made of technical fabrics are now becoming more and more popular structures. The construction materials are most often technical fabrics and ropes. The design of such a structure requires a thorough knowledge of mechanics in the geometrically and physically nonlinear range. In addition, manufacturers of technical fabrics usually do not provide the most important parameters for design. Technical fabrics have different properties in the weft and warp directions, and in addition, these properties change as the deformation increases. The properties of fabrics also depend on the technology of their production and often, despite similar parameters given by manufacturers, their behavior after incorporation is different. Therefore, laboratory tests are necessary to make a correct design.

During the presentation, laboratory tests, which are used to determine the construction parameters of the fabrics, will be shown. Single- and double-axis experiments on testing machines and with the use of the so-called creeper will be discussed. It will be described how to determine the mechanical parameters of the tested fabric on the basis of such tests (least squares method) and how to statistically develop the obtained results. Technical fabrics also change their properties under the influence of weather conditions, which is why it is necessary to adopt appropriate safety factors when designing to consider these adverse long-term changes.

The basic method used to analyse hanging roofs is the finite element method. Modelling must begin with determining the geometry and tension state of the fabric under its own weight (form finding). Already at this stage, significant numerical difficulties arise, which require the use of special calculation techniques. A model of the dense network will be presented, which, together with the membrane finite element, well reflects the behaviour of the fabric in covers with complex shapes. The basic loads of such structures are wind load (mainly suction) and possibly snow load in year-round structures. In addition, a sufficiently high degree of tension of the fabric should be maintained over the entire roof surface to prevent it from wrinkling or flapping under the influence of wind. Examples of such analyses will be shown, as well as examples of failures of real covers, additionally the causes of catastrophes will be discussed.

[10]Speaker: klosow@pg.edu.pl

On some mechanical aspects of abdominal hernia repair

Izabela Lubowiecka[11], Gdańsk University of Technology
Mateusz Troka, Gdańsk University of Technology
Katarzyna Szepietowska, Gdańsk University of Technology

Abstract: The study concerns some mechanical aspects of the medical problem of ventral hernia in humans and its repair with the use of synthetic implants. Implants typically do not mimic the mechanical properties of the human tissue they replace. This causes a state of stress, which may lead to the implant detaching and thus to the recurrence of the hernia. The complex, multi-layered structure of the abdominal wall causes differences in the mechanical behavior of its various regions, which are easy to observe e.g., through different ranges of strains under physiological loads. This causes difficulties in adjusting the appropriate properties of implants used as substitutes for healthy tissue in the area of the defect (hernia). In this work, we propose a methodology based on experimental data collected in vivo and analyse the impact of changes in the mechanical properties of various abdominal regions on the forces in the connection between the implant and the tissue. In the research we define and analyse a numerical model of human abdominal wall with and without a surgical implant. We relate the results of numerical studies to experimental data based on digital image correlation. We use neural networks (self-organizing maps) in the analysis, which helps to determine regions with similar mechanical behavior under the influence of intra-abdominal pressure.

[11] Speaker: lubow@pg.edu.pl

An improved normal compliance method for non-smooth contact dynamics

Vo Anh Thuong Nguyen[12]
Stéphane Abide, Université Côte d'Azur
Mikaël Barboteu, Université de Perpignan Via Domitia
Serge Dumont, Université de Perpignan Via Domitia

Abstract: Based on the growing importance of understanding granular media and their behaviors in various industries, this work proposes a new method different from the Discrete Element Method (DEM) and the Non-Smooth Contact Dynamics (NSCD) approach to model granular dynamics. We focus on a discontinuous Moreau second-order sweeping process for modeling contact dynamics, incorporating the Moreau-Yosida regularization with parameter α to develop a regular contact model. We propose the Improved Normal Compliance (INC) method to ensure energy conservation and employ a combination of the Newmark method and Primal-Dual Active Set (PDAS) to address nonlinearity. The main aim of the present work is to improve an implicit regularization method for which energy conservation and non-penetration are quite similar to NSCD-NLGS along with a suitable computational cost. Several numerical experiments are reported for verification and validation purposes, and also to evaluate the efficiency and assess the performances of Newmark-PDAS-INC method compared to other numerical methods (DEM, NSCD-NLGS). In this talk, we propose different simulations including the restitution coefficient and the friction, and we will make comparisons between the mentioned methods focusing on energy conservation, penetration and CPU time.

[12]Speaker: vo-anh-thuong.nguyen@univ-perp.fr

Mathematical model of breast cancer based on mechanical and biological properties of tissues developed for computer-aided personalized neoadjuvant therapy

Hanna Piotrzkowska-Wróblewska [13], IPPT, Polish Academy of Sciences
Czesław I. Bajer, IPPT, Polish Academy of Sciences
Bartłomiej Dyniewicz, IPPT, Polish Academy of Sciences
Mateusz Jacek Bajkowski, Warsaw University of Technology

Abstract: The paper presents a mathematical and numerical model of a breast cancer and proposes its use in predicting the growth rate of tumor and his response to applied neoadjuvant treatment. The following physical and biological properties of cancer tissue were taken into account in the mathematical model: V_T - concentration of cancer cells in the tumor, V_E - stiffness of the tumor and surrounding tissues (shear wave elastography), degree of tissue vascularization V_K - expressed as a percentage of the area of the tumor section occupied by blood vessels, p - percentage of cancer cells in during division (proliferation coefficient Ki-67) and the vector v, containing components of the apparent velocity of the movement of the field of active cancer cells. The model takes into account the relationships between all the variables mentioned above. The parameters values were the values obtained on the basis of the results of histopathological examinations of breast tumors (V_T and p) and ultrasound assessment (V_K vascularization - color Doppler, V_E stiffness - shear wave elastography).

Two stage of tumor evolution were considered. The first phase - longer - concerned the period of growth and the second one - shorter - included the time of treatment. It was assumed that time of growth of tumor lasting 36 months. This phase may to be shorter or longer, depending on the characteristics of the cancer The assumed treatment period of time was 20 weeks. However, the duration of therapy depends on the frequency of administration and the type of drug.

A computer program, was utilized to simulate the process of tumor development and phase of treatment based on clinical data. Numerical simulations of monitored variables derived from clinical data, have been presented. The proposed mathematical and numerical model can be applied to prediction the effects of treatment after particular phases of chemotherapy individually for every patient.

[13] Speaker: hpiotrzk@ippt.pan.pl

A rotation-free finite element formulation for anisotropic elasto-plasticity of textiles and fiber-embedded composites

Roger A. Sauer[14] **Gdansk University of Technology, Ruhr University Bochum, IIT Guwahati**
Thang X. Duong, Bundeswehr University Munich

Abstract: We present a general, nonlinear, rotation-free finite element formulation for 2D solids and 3D shells with embedded fibers that resist in-plane and out-of-plane bending and exhibit angle plasticity. The formulation allows for the simulation of heterogeneous and fibrous materials either with or without matrix, such as textiles, biomaterials, composites, and pantographic structures. Fibers can be initially straight or curved.

To describe their bending kinematics, a so-called in-plane curvature tensor – which is symmetric and of second order – is proposed. The corresponding stress couple tensor – also symmetric and of second order – can then be derived from the mechanical power balance.

This balance also leads to suitable constitutive equations and the weak form for the proposed finite element formulation. The formulation requires only displacement degrees-of-freedom to capture in-plane and out-of-plane bending. To this end, isogeometric shape functions are used in order to satisfy the required C1-continuity for bending across element boundaries. The proposed formulation admits a wide range of material models. In particular, a nonlinear elastoplasticity model is proposed for the angle change between fibers.

The computational behavior of the proposed formulation is illustrated by several benchmark examples including the classical picture frame and bias extension tests for textiles.

[14]Speaker: roger.sauer@pg.edu.pl

The new Damped Normal Compliance (DNC) contact condition

Meir Shillor [15], Oakland University, Rochester MI, USA

Abstract: We describe the new contact condition, which generalizes the normal compliance condition, and that takes into energy dissipation during the contact process.

We describe the impact of a mass and then a rod on a reactive foundation.

We provide the models, analysis and simulations.

Then, we describe a dynamic membrane which is restricted by an obstacle above it on the boundary, the Boundary Obstacle Problem, and then the when the Interior Obstacle Problem.

[15] Speaker: shillor@oakland.edu

Analysis of the effect of straight arch technique parameters on loads in the periodontium

Kamil Sybilski[16], Military University of Technology, Warsaw
Jerzy Małachowski, Military University of Technology, Warsaw
Anna Ewa Kuc, Wroclaw Medical University
Michał Sarul, Wroclaw Medical University

Abstract: The present work is concerned with the modelling of the stomatognathic system and of orthodontic brackets. A model was constructed based on CT and 3D scanning to accurately represent the structure of the internal structures. The DICOM image obtained from the CT scan was used to extract cortical bone, compact bone, and teeth. 3D scanning was used to determine the exact geometry of the dental arch with brackets in place. The periodontium was obtained based on Boolean operations. All geometries were combined into a single model based on the image data, and in the next step the orthodontic wire, hooks and mini implant were modelled. All structures were assigned appropriate material properties. The Ogden hyperelastic model was used to model the periodontium.

The bony structures were connected using a TIED type contact. A contact based on the penalty function was defined between the brackets and the wire. The hook fused to the arch and mini implant were modelled as a constrained nodal rigid body (CNRB). In real conditions, the load is realised by an elastic element connecting the mini-implant and the hook. Depending on the expected load value, this element is tensioned accordingly. In the numerical model a coordinate system was defined between the mini-implant and the hook, with the x-axis passing through the elements. A force vector was defined along the x-axis. The entire model was constrained at the top of the skull to avoid the effect of the constraint on the behaviour of the periodontium.

In this work, the effects of different hook heights and different values on the loads occurring in the periodontium were analysed. The result of the numerical analyses carried out is a data set showing stresses and pressures. Based on the results, it is possible to determine the character of tooth displacement, as well as the risk of root resorption associated with the closure of the lumen of fine blood vessels.

[16]Speaker: kamil.sybilski@wat.edu.pl

Randomized neural network methods for solving mechanics problems

Fei Wang[17], Xi'an Jiaotong University, Xi'an, P.R. China

Abstract: Deep neural networks (DNNs) are widely utilized in artificial intelligence, scientific computing, and machine learning tasks due to their ability to construct a broad range of nonlinear functions through compositional methods. The remarkable universal approximation capability of DNNs has made them popular for solving partial differential equations (PDEs). While several DNN-based methods have been proposed for PDEs, challenges concerning accuracy and training time still persist. Randomized neural networks (RNNs) have emerged as an alternative approach to fully parameterized neural network models. In RNNs, the parameters of the links between hidden layers are randomly selected and then fixed during training, while the parameters for the links between the last hidden layer and output layer are determined using a least-squares method.

In this presentation, we introduce the application of randomized neural networks combined with the Petrov-Galerkin method for solving mechanics problems such as linear elasticity and Navier-Stokes equations. Numerical experiments demonstrate that RNN-PG methods can achieve high accuracy with a reduced number of degrees of freedom. Moreover, RNN-PG offers several advantages including being mesh-free, easy handling of different boundary conditions, enabling efficient solutions to time-dependent problems using a time-space approach, and providing numerical solutions at any desired resolution. These results highlight the significant potential of RNN-PG methods in the field of numerical methods for PDEs.

[17]Speaker: feiwang.xjtu@mail.xjtu.edu.cn

Multi-layer elastic contact system and its finite element agorithm design

Zhizhuo Zhang[18], Southeast University, Nanjing, P.R. China
Mikaël Barboteu, Université de Perpignan Via Domitia
Jinde Cao, Southeast University, Nanjing, P.R. China

Abstract: Multi-layer elastic system is an important type of physical model in engineering mechanics, which has key and broad application prospects in the study of mechanical response of pavement. However, the lack of interlayer contact conditions may be a potential reason for the insufficient accuracy of finite element numerical simulations based on this model, which was also verified in pavement experiments. Therefore, it is a reasonable and feasible method to construct a mathematical model of a multi-layer elastic system with contact conditions based on variational inequality theory and conduct numerical simulations. In this talk, starting from the research background of pavement mechanics, the research motivation and the construction of mathematical models based on variational inequality of multi-layer elastic contact systems with interlayer Tresca friction conditions will be introduced. Due to the coupling characteristics of the displacement fields on both sides of the contact zones, the finite element numerical solution of this variational inequality is difficult to obtain directly. Thus, based on the two ideas of domain decomposition method and global method, the layer decomposition algorithm and the mixed finite element method will be introduced, both of which can decouple the displacement fields on the contact zones and be used to solve the numerical solution of the multi-layer elastic contact system. Finally, numerical simulation experiments based on the three-layer elastic contact system will be performed. In this experiment, we not only compared the numerical solutions obtained by the two algorithms, but also verified the convergence properties of the algorithms.

[18]Speaker: zhizhuo_zhang@163.com

List of participants

- Abide, Stéphane
- Bajer, Czesław
- Bajkowski, Jacek Mateusz
- Barboteu, Mikael
- Blaise, Paul
- Bohatier, Claude
- Bonaldi, Francesco
- Briec, Walter
- Brouzet, Robert
- Cayrol, Michel
- Dejardin Pierre-Michel
- Dreina, Mélanie
- Dumont, Serge
- Dyniewicz, Bartłomiej
- Flageul, Cédric
- Florentin, Eric
- Han, Cundi
- Huynh Van-Cong
- Jabri, Samah

- Jourdan, Franck
- Kalinowski, Szymon
- Kiéma, Benjamin
- Kłosowski, Paweł
- Lubowiecka, Izabela
- Muñoz, Sylvia
- Nguyen, Thuong
- Piotrzkowska-Wróblewska, Hanna
- Sauer, Roger
- Serra, Quentin
- Shillor, Meir
- Sofonea, Mircea
- Sulian, Joëlle
- Sybilski, Kamil
- Viguier-Pla, Sylvie
- Tarzia, Domingo
- Wang, Fei
- Zhang, Zhizhuo
- Zeghmati, Belkacem

Conference program

Thursday, May 30

10:00–10:30 Registration

10:30–11:00 Opening Ceremony

Chairperson : C. Bajer

- 11:00–11:40 *Meir Shillor*, The new Damped Normal Compliance (DNC) contact condition (keynote lecture)
- 11:40–12:20 *Hanna Piotrzkowska-Wróblewska*, Mathematical model of breast cancer based on mechanical and biological properties of tissues developed for computer-aided personalized neoadjuvant therapy (keynote lecture)

12:30–14:00 Lunch

Chairperson : I. Lubowiecka

- 14:00–14:40 *Paweł Kłosowski*, Hanging roof - theoretical and constructional problems (keynote lecture)
- 14:40–15:20 *Éric Florentin*, Approximations and associated quality of mechanical stochastic problems (keynote lecture)

15:20–15:40 Coffee Break

Chairperson : M. Shillor

- 15:40–16:00 *Cédric Flageul*, Large Eddy simulation of a turbulent round impinging jet with conjugate heat transfer
- 16:00–16:20 *Jacek Mateusz Bajkowski*, Exploring the Performance of a composite microsphere-modified magnetorheological fluid
- 16:20–16:40 *Zhizhuo Zhang*, Multi-layer elastic contact system and its finite element agorithm design

16:40–17:00 Coffee Break

Chairperson : S. Abide

- 17:00–17:20 *Izabela Lubowiecka*, On some mechanical aspects of abdominal hernia repair
- 17:20–17:40 *Szymon Kalinowski*, Topological optimisation of simplified hernia implant with particle swarm method
- 17:40–18:00 *Cundi Han*, A Fourier term and Bernstein polynomial collocation method for nonlinear fractional order partial differential equations
- 18:00–18:20 *Kamil Sybilski*, Analysis of the effect of straight arch technique parameters on loads in the periodontium

19:00–23:00 Dinner

Friday, May 31

Chairperson : É. Florentin

- 9:40–10:20 *Franck Jourdan*, Study of the mechanical and functional behaviour of stents (keynote lecture)

- 10:20-11:00 *Fei Wang*, Randomized neural network methods for solving mechanics problems (keynote lecture)

11:00–11:20 Coffee Break

Chairperson : F. Bonaldi

- 11:20–12:00 *Roger A. Sauer*, A rotation-free finite element formulation for anisotropic elastoplasticity of textiles and fiber-embedded composites (keynote lecture)

- 12:00–12:20 *Vo Anh Thuong Nguyen,* An improved normal compliance method for non-smooth contact dynamics

12:30–14:00 Lunch

Chairperson : P. Kłosowski

- 14:00–14:40 *Francesco Bonaldi,* An energy-consistent discretization of hyper-viscoelastic contact models for soft tissues (keynote lecture)

- 14:40–15:00 *Mélanie Dreina*, Analysing discrete and continuous spectrum and dimension reduction for thermal fields

- 15:00–15:20 *Mélanie Dreina*, DNS of turbulent natural convection flows in a differentially heated cavity with conjugate heat transfer

15:20–15:30 Closing Ceremony

17:30–18:30 Sightseeing Perpignan