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A large scale industrial furnace Lattice-Boltzmann study

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Recent developments on the Lattice Boltzmann Method (LBM) have established this approach as an alternative to traditional CFD methods for combustion applications. However, application to industrial burners remains challenging due to the large range of scales involved. The geometry is also much more complex than classical academic benchmarks and burners. In this study, we present large-eddy simulations of a partially premixed CH4-air industrial burner using a hybrid Lattice-Boltzmann method. Due to the large burner size and the burnt gases content, radiative heat transfer is fundamental here, and taken into account for the first time in this framework. As a first attempt to couple Lattice-Boltzmann modelling of reacting flows and radiative heat transfer, an optically thin approximation is adopted for its relative simplicity and low computational cost. The approach consists in assuming the medium optically thin for all wavelengths, thus the absorption phenomenon will be neglected and only emission will be considered. The numerical results are compared to experimental data of the O2, CO and NOx fields.

Keywords: *Combustion, Lattice Boltzmann Method, Radiation, Industrial Burners*

Acoustic characterization and imaging of Carrara marble degradation

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Carrara marble is a well-appreciated and well-known marble variety which has been used since Antiquity in statuary and built heritage. It can undergo diverse deterioration during its ageing such as sugaring, thermal expansion, bowing, microcracks generation, loss of mechanical resistance, etc. Previous studies have shown that these degradation phenomena can result from exposure to cyclical thermal fluctuations and that they can be enhanced when thermal variations are combined with relative humidity variations. However, these works usually use destructive testing methods, which limits the understanding of the evolution of marble mechanical properties during combined thermal and hygric cycling. Thus, this study aims at following the evolution of mechanical parameters of marble samples during thermo-hygric cycles by means of a nondestructive method. To this end, Nonlinear Resonant Ultrasound Spectroscopy (NRUS) is employed on samples conditioned in the laboratory. This technique allows extracting mechanical properties such as resonant frequency and hysteretic nonlinear parameter. The latter assesses the material damage at the mesoscopic scale. The evolution of these parameters is followed during thermo-hygric cycling at mild temperature to better grasp degradation mechanisms of marble exposed outdoors. The evolution of the linear and nonlinear parameters is studied in view of the material microstructure through microscopic observations (optical and electron) and through porosimetry analyses (mercury intrusion porosimetry) in order to bring to light the mechanisms at stake (microcracking, grain boundary dissolution, etc). Lastly, this study aims at developing acoustic imaging of existing cultural artefacts by means of a technique suitable for cultural preservation requirements (non-destructive, contactless).

Keywords: *Nonlinear resonance, degradation mechanisms, ultrasound imaging, laser ultrasonics, heritage conservation*

Advanced numerical modelling for the simulation of turbulent transport in tokamak plasma and confrontation to experiments

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In the modern world with predicted shortage of fossil fuel and climate change, research on new sources of energy is of great importance. Nuclear fusion seems to be a promising long-term candidate. It is more reliable than conventional ”green” solar or wind energy and on the other hand, it is less dangerous than nuclear plants, with much less chance of catastrophic incidents. One of the milestones on the way to fusion will be the ITER machine. Among a variety of issues to succeed in its operation, reducing the heat and particle fluxes at the tokamak walls is one of the most challenging. This requires the development of new numerical tools to provide plasma parameters prediction in a reasonable computational time. The transport code SolEdge3X-HDG which is under development in our laboratory already has exceptional advantages allowing it to accurately describe the simulation domain and provide full plasma discharge simulations. However, its description of plasma physics is still rather simplified. During my PhD research I am now working on implementing a self-consistent turbulent transport model, which captures the ballooning feature of the transport observed experimentally. Together with newly implemented spatially non-constant diffusion coefficients this will allow better prediction of the fluxes onto the plasma facing components. To compare the HDG simulations with the experimental data of the WEST tokamak, we have developed a set of synthetic diagnostics simulating experimental measurements. The bolometer signals modelled from simulation background are being compared with the experimental data. Moreover, it has been employed for the tomographic inversions study. A synthetic pinhole camera has also been developed which may further help the design of fast-camera on the WEST tokamak.

Mots-Clés: *fusion, transport modelling, synthetic diagnostics, tokamak, plasma*

Amplitude-dependent modal coefficients accounting for localised nonlinear losses in a time-domain integration of woodwind model

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This work develops the design of a sound synthesis model of a woodwind instrument by modal decomposition of the input impedance, taking into account viscothermal losses as well as localised nonlinear losses at the end of the resonator. This formalism has already been applied to the study of forced systems. It is now implemented for self-oscillating systems. The employed method extends the definition of the input impedance to the nonlinear domain by adding a dependance on the RMS acoustic velocity at a geometric discontinuity. The poles and residues resulting from the modal decomposition are fitted as a function of this velocity. Thus, the pressure-flow relation defined by the resonator is completed by new equations which account for the dependence with the velocity at the end of the tube.To assess the ability of the model to reproduce a real phenomenon, comparisons with experimental results on reed instruments were carried out. Simulations show that the model reproduces these experimental results qualitatively and quantitatively.

Keywords: *Musical acoustics, nonlinear losses, reed instruments, modal decomposition*

An improved passive scalar model for hazardous hydrogen/air ignition prediction

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With an increasing interest in hydrogen as an alternative fuel for transportation, there is a need to develop tools for the prediction of ignition events. A cost-effective passive scalar formulation has been recently developed to predict hydrogen auto-ignition. A self-reacting scalar without heat release is used to model the branching of the ignition process. The scalar branching rate is analytically deduced from the kinetic Jacobian matrix. This method was found to reproduce with fidelity the ignition delays obtained by detailed chemistry for temperatures above crossover, where the branching is the leading process. For temperatures below the crossover temperature, where other phenomena such as the thermal runaway are important, the scalar approach fails to correctly predict ignition events. Thus, modification to the scalar framework has been performed to extend its validity over the entire temperature range. Furthermore, a simple way to approximate the molecular diffusion of the scalar has been developed based on the analytically obtained eigenvector of the Jacobian. This accounts for large differences of composition in the radical pool and non-unity Lewis number effects. The complete modified framework is presented and its capability is assessed in canonical scenarios and more complex simulations relevant to hydrogen safety.

Keywords: *Auto, ignition, Hydrogen, Hydrogen safety, reduced chemistry*

Characterization and modelling of the porous network of UO2 ceramic microstructures for the computation of their thermal conductivity

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By altering the standard manufacturing process of UO ceramics, it is possible to obtain ceramics with large-scale porosity located at the interfaces between granules. The interconnection of these inter-granules pores leads to a complex porous network that strongly impacts the thermal behaviour of these ceramics. Thus, to understand the effects of temperature on the thermal properties of the fuel, the variations of influence of the porosity at high temperature and the phenomena which are responsible must be determined. From an experimental point of view, measurements up to a temperature of 500◦C have been performed. However, it is not possible to go beyond this temperature and it was therefore decided to develop a numerical model to evaluate the thermal behaviour of these ceramics beyond 500◦C. A model taking into account the porosity at different scales has been developed. Particular importance was given to the modelling of the inter-granules porosity which has a major impact on the thermal conductivity of the ceramics. This model is based on full field numerical simulations (FFT) performed on virtual microstructures that mimic some morphological properties of the ceramics of interest which have been previously characterised from 2D optical microscopy images. To go further in the characterization of the porous network and thus be able to validate, and eventually improve, the developed model, a 3D characterization of the studied ceramics by micro-tomography was carried out. Finally, the developed model was used to simulate the thermal behaviour of ceramics of interest and a comparison with the experimental results obtained in the range of achievable temperatures was performed.

Keywords: *Porous solids, Pore network, Inter, granules porosity, Morphological descriptors, Virtual microstructures generation, Thermal conductivity, Homogenisation, FFT computation, Optical microscopy, X, ray tomography, UO2 ceramics*

Combination of Adaptive Mesh Refinement and High Performance Computing for Accurate Solution of Elastostatics Contact Mechanics Problems

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As contact mechanics problems are locally highly non-linear, their numerical simulation is computationally challenging. Efficient numerical solutions of such problems often rely on adaptive mesh refinement (AMR). Even if efficient parallelization of standard AMR techniques as h-adaptive methods appear (1), their combination with contact mechanics problems remains a challenging task. This work introduces a High Performance Computing (HPC) strategy for solving 3D contact elastostatics problems with AMR on hexahedral elements. The contact is treated by a node-to-node algorithm with a penalization technique. Concerning the AMR strategy, we rely on a non-conforming h-adaptive refinement solution. An estimate-mark-refine approach with a local detection criterion based on a Zienkiewicz-Zhu (ZZ) type error estimator and a geometric-based stopping criterion is applied to perform the AMR process (2). In this contribution, we extend the combination of these contact mechanics and AMR strategies to a parallel framework. We place ourselves in the MFEM software (3) environment. The proposed scalable algorithm is first based on a mesh partitioning that guarantees the contact paired nodes to be on the same processes. The contact stiffness matrix is locally built. The combined AMR-contact algorithm is ruled by two nested iterative loops. The external loop concerns the AMR process while the internal one deals with the contact solution. The penalised contact problem is solved thanks to a dedicated iterative solver. The contact solution process is performed until the set of active contact nodes does not vary. Once this loop converges, the AMR strategy is locally applied and the mesh decomposition is rebalanced with the previously discussed partitioning contact constraints. The external process ends once the AMR stopping criterion is satisfied. To perform scalable AMR on MFEM, the currently implemented method is enriched with our own estimate-mark-refine approach. The proposed strategy is evaluated on the 3D Hertzian contact problem with millions of unknowns. Our HPC approach turns out to be well scalable for dozens of cores.

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Keywords: *High Performance Computing, Adaptive Mesh Refinement, Contact Mechanics Problems, Elastostaticity*

Innovative smoke control for railway and metro stations

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The design of a smoke removal system in case of fire in a metro station is very time consuming. The objective of the thesis entitled Innovative Smoke Removal System in Subway Stations is to conduct studies in order to find solutions for the pre-sizing of equipment to reduce this study time in the preliminary design phase. As station designs are multiple and interactions with tunnels are complex, we limited ourselves to the case of platforms equipped with integral edge doors in order to dissociate the station part from the tunnel part. We carried out 3D numerical simulations in different configurations in order to make a parametric study; the aim being to determine the air flow rates to be extracted as well as the positions of the extractors in order to guarantee the safety of users in the event of a fire. At the beginning of the research work, it became clear that a transverse and homogeneous smoke extraction along a platform is not an optimal solution, especially for platforms of great length. In addition, it was shown that the emptying filling box model used in the zone codes was not valid for aspect ratios that were too large. Nevertheless, the results of the simulations are used to study the behaviour of two variables, namely the efficiency and the yield of the system as a function of the fire power and the length of the platform.

Keywords: *Smoke extraction, mechanical ventilation, effectiveness, efficiency, containment screen*

Design of an ultra-wideband transmitter for short-range pulse communications

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Unlike conventional communicating devices, ultra-wideband (UWB) communications explore short pulses instead of a modulated carrier to transmit information data. This allows to : • turn-off transmitters and receivers at the bit scale, • have a power consumption proportional to the data rate, • and enable compatible devices real-time location with a precision of 5 cm. Therefore, UWB communications can target healthcare, wellness, safety, and sports applications. This work deals with the design of a transmitter for short-range pulse communications in the 3.1 GHz - 10.6 GHz frequency band. The research goals are to obtain a device able to generate short pulses that respect radiofrequency masks imposed by IEEE standards and regulatory commissions for all the 3.1 - 10.6 GHz frequency band. The transmitter is built around a fast oscillator and an envelope-shaping circuit designed in 28 nm CMOS technology.

Keywords: *Transmitter, Ultra, wideband, Short Pulses*

Discrimination d’intensité et adaptation de la gamme dynamique

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Response functions of auditory neurons represent the mean activity of a neuron as a function of the stimulation level : neurons get activated at a low threshold level, and increase their activity with the level until they saturate. This measure is generally performed in silence : a certain sound level is played and the neuronal activity in response is measured, without noise between stimulations. Judging it unnatural, a research group decided to reproduce this measure but with a continuous stimulation called context, its level fluctuating around a certain mean. They found that the response function then shifted : the range of levels to which a neuron reacts (from threshold to saturation) adapts to the context, favouring the levels close to the mean level. This dynamic range adaptation (DRA) has not yet been found in humans, only in small animals in studies using electrodes directly implanted in the auditory system. This study aims to find the consequences of DRA in human sound perception. Intensity discrimination performance (smallest perceptible intensity difference) tests have been carried out on nine normal-hearing people with different context and test signal levels : a soft and a loud signal were tested in silence, in a soft context and in a loud context. The hypothesis was that performances should be better when context level and test signal level are matching, because small differences between test levels yield greater differences in neuronal activity, when the response function is close to the context level. The results were only in agreement with the hypothesis for the soft test signal. To have a better control on the test conditions, another noise was added, but its effect was not the one expected. Competing mechanisms might be preventing the observation of dynamic range adaptation and other tests are planned to explore the possibilities.

Keywords: *Perception sonore, Psychoacoustique, Discrimination d’intensit´e, Adaptation de la gamme dynamique*

Dynamic stall models for post flutter analysis of an aeroelastic wing section

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Aeroelastic phenomena are a major concern for aircraft designers because of the dramatic consequences on the aircraft structure they can engender. Recent solar-powered HALE (High Altitude Long Endurance) drones are designed with lightweight structures and flexible high aspect-ratio wings that are vulnerable to this phenomenon. Efforts must still be done to improve engineering tools combining, beam models, unsteady and nonlinear aerodynamics, and flight mechanics. Kirsch's thesis led to the computational code (GEBTAero) for the anisotropic composite flexible wing simulation allowing to determine the flutter critical airspeed for different configurations using aeroelastic tailoring. The model is based on a geometrically exact beam theory coupled with a two-dimensional unsteady finite state aerodynamic model. Currently, It doesn't consider nonlinear unsteady aerodynamics. My work aims to implement and assess dynamic stall models that will be convenient for aeroelastic modelling of HALE drone wings with GEBTAero, the nonlinear effect of the dynamic stall changing drastically the way the wing moves in the airflow. Before implementing nonlinear aerodynamics in the full code, the first step is to employ a simplified 2D aeroelastic model to compare formulation, accuracy and robustness of different dynamic stall models considering low and high reduced frequency movements. Using a typical 2D aeroelastic model combined with a dynamic stall model, the resulting formulation is solved in the frequency domain to predict the flutter critical airspeed and in the temporal domain to exhibit the airfoil movement and limit cycle oscillations (LCO) that could be observed. Dynamic stall models existing in the literature were implemented and first assessed by comparison with experimental data and test cases available. The different models were evaluated by comparing LCO's prediction. Results show that using Snell model, rather than Oye or Riso models, can lead to divergent pitch or plunge displacement, particularly for high reduced frequency motion.

Keywords: *Aeroelasticity, nonlinear aerodynamics, HALE Drones, Dynamic stall*

Proximity effects in matrix-inclusion composites: elastic effective behaviour, phase moments and full-field computational analysis

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This work focuses on the effects of inclusion proximity on the elastic behaviour of dilute matrix-inclusion composites. Rigid or soft monodisperse spherical inclusions are considered, with moderate volume fraction. To conduct this study, Representative Volume Elements (RVE) with an effective local minimum distance between inclusions varying between the spheres' radii and one tenth of this radius are built. Numerical finite elements calculations on RVE are performed. The obtained homogenised elastic properties, as well as phase stress moments (first and second), are compared to Mori-Tanaka estimates, well established for this kind of composites. The behaviour of local fields (stresses) in the microstructure with respect to inclusion proximity is also analysed. It follows that the effective properties and phase stress moments converge asymptotically to the Mori-Tanaka estimates when the minimal distance between spheres increases. The asymptote seems to be reached around a distance equal to the spheres' radii. Effective and phase behaviours show a deviation that can achieve and even exceed (for the second moments) ten percent when inclusions are close. The impact of inclusions proximity is even more important on local stress fields. The maximum stress values (hydrostatic or equivalent) can be more than twice as high locally.

Keywords: *heterogeneous materials, dilute matrix, inclusion, proximity effect, homogenization, first and second moments, local behaviour*

Experimental analysis of wind turbine wake effects on aerodynamics loads of downstream wind turbine blade

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In wind farms, wake flows developing downstream of wind turbines impact the aeroelastic loads of the wind turbines subjected to them. It leads to a decrease in energy production and an increase in mechanical loads due to the related specificities to the shear and turbulence of these flows. To bring new insights on such wake effects, the French ANR MOMENTA project has for main objective to improve the estimation of the aeroelastic loads in the specific case of a wind turbine subject to the wake turbulence characteristics of another wind turbine. Due to the improvement of the wake-induced turbulence description, this project aims to provide a first step toward optimised wind farm layouts in dense configurations, in terms of energy yield and load reduction. It involved 6 partners with different skills: in-field measurements, CFD and experimental studies. My PhD thesis relies on an experimental approach to study turbulence effects on local and global aerodynamics of a simplified wind turbine model. Experiments are performed in the low Reynolds wind tunnel of the PRISME laboratory with a cross-section area of 5x5 m2. The wind bench was equipped with strain gauges, pressure taps, torque and thrust sensors and a Pitot tube. With the help of 3 passive turbulence grids, a rate of 3.8, 8 and 13.3% of turbulence could be obtained at the rotor position. The first analyses show that the higher the speed of rotation, the more a slight effect of turbulence can be observed. Indeed, global variables such as thrust and power coefficients have less amplitude when the tip-speed ratio increases. This phenomenon is verifiable at the local scale thanks to the bending moment and the distribution of the pressure coefficients. Results will be later compared with CFD simulations. The second campaign is in preparation: new sensors and positioning are discussed.

Keywords: *wind turbine blade aerodynamics, turbulence effects, wind tunnel experiment*

Experimental and 3-D numerical thermal studies of a new single-cell calorimeter prototype

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Research reactors are tools used in the nuclear field to address current and future challenges. They allow the realisation of experiments under irradiation with high photon and neutron fluxes. Thus, thanks to these studies, characterizations of materials can be carried out (accelerated ageing of inert material, nuclear fuel behaviour ...). For that, it is necessary to know the irradiation conditions present in these reactors to dimension experiments. One of the key quantities to be quantified is the absorbed dose rate, also called the nuclear heating rate. This need is reflected in the continuous innovation of sensors and associated measurement methods. Consequently, since 2009, the joint laboratory LIMMEX (AMU, CEA, CNRS) has been working on the study of non-adiabatic calorimeters to estimate the nuclear heating rate. These studies are part of a complete design process, from laboratory characterizations to validations in nuclear conditions. The improvement of these sensors is achieved through innovative advances in terms of design, miniaturisation, and adaptation of their metrological characteristics according to the needs. Thanks to this work, several prototypes of calorimeters, such as the CALORRE type, have already been designed and tested in real conditions. Based on these previous conclusive results, a new prototype of a single-cell calorimeter named Mono-CALO is currently under study. In the perspective of increased miniaturisation, this prototype is a technological breakthrough compared to the previous ones due to microelectronics techniques used. This poster will present studies performed on this new prototype. After a detailed description of the sensor, the first part will be dedicated to results (sensitivity, response time...) obtained by the coupling of experiments realised via a test bench and 3-D thermal numerical simulations with the COMSOL Multiphysics software. The second part will focus on the numerical development of a new thin heating-element integrated into the calorimeter for its calibration.

Keywords: *Calorimetry, Calibration, Nuclear heating rate, 3, D numerical simulations, thin layer*

Experimental Investigations of Rod Bundle Creep in Fluid-Structure Interaction

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Pressurised water reactors (PWR) have increased in size and operations requirements. To ensure their safe and efficient operation, the understanding of the fuel assembly (FA) behaviour inside the core during irradiation is of primary importance. FAs are subjected to different phenomena including mechanics, thermal, and hydraulics under irradiation. The complex reciprocal interactions between these physics cause a modification of the FA geometry, more specifically, permanent elongation and lateral deformations. Since the irradiation creep of FAs occurs over several months or years, experimental studies seem unfeasible. The proposed work offers an alternative to this burden by relying on similarities and focusing on macroscopic coupling rather than the micro-structural response of the material. The proposed experimental approach presented in this paper consists of taking advantage of the rapid thermal creep of materials in a reduced-scale assembly mock-up at low pressure and moderate temperatures. Particle Image Velocimetry (PIV), an optical measurement method, is used to characterise the flow around mock-up rods as they deform. To support experiments, Computational Fluid Dynamics (CFD) modelling is used to simulate turbulent flow within the rod bundle. Numerical simulation results are compared to experiments. Thanks to simulations, it is possible to determine equivalences between the experimental conditions and the realistic in-core conditions. Thus, it is possible to have a better understanding of the interaction between fluid forces, structural deformations, and the creep response of fuel assemblies in PWR environment.

Keywords: *PWR, Fluid, structure, Creep, Fuel assembly bow*

Fibre aggregation in flows

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When fibres are suspended in flows, they can collide and sometimes hang together to create balls. This aggregation process has been observed in natural systems (1) but also in industrial processes (2)(3). We are currently running laboratory experiments to reproduce this phenomenon in order to analyse and model fibre aggregation. Recently, we have succeeded in generating nearly spherical aggregates in a turbulent von Karman flow. After exploring the conditions where our synthetic balls can form, we now study the impact of the different parameters on the number and size of the aggregate, such as the turbulent intensity of the flow or the mechanical properties of the fibres and their concentration. We then characterise the aggregate with X ray tomographic images. We are able to reconstruct each fibre and the network of entangled fibres. The formation of aggregates is expected to be a dynamical process with a balance between aggregation and fragmentation. Therefore we are also studying the fragmentation of balls by immersing a single aggregate within a turbulent flow in order to observe and analyse its destruction.

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***Keywords:** Fluid mechanics, fibres, aggregation, fragmentation*

Finite Element Simulation of artillery projectile shrinking

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The loading of an artillery projectile aims to shrink the shell into the gun barrel to ensure good positioning before firing. This shrinking fit assembly is made possible by the driving band attached to the projectile. This band is made of softer metal than the one of the barrel. Most of the simulations for projectile/gun barrel interaction focus on the interior ballistics' phenomena after the ignition of powder (1). Major simulations on the loading of artillery and tank shells were made by Balla (2). This work aims to go further by focusing on understanding the assembly made by the projectile and barrel while properly loaded through analysis of the behaviour of the driving band during finite elements simulation. The simulated assembly is an elastic-plastic copper made driving band shrinked between an indeformable cone illustrating the barrel and the rigid projectile body. We simulate the three phases of the assembly: penetration (static or dynamic), springback and extraction. During each phase, we track the macroscopic variables of the assembly (displacements, external forces, interaction forces, ...) and the local variables (pressure, contact surface, ...) at the interface between barrel and the driving band. At the macroscopic scale, we observed that the extraction force is always smaller than the penetration force. Moreover, the springback has a significant effect on the performance of the assembly especially on the normal force. Therefore, a comprehension of the assembly through shrinking table only is not sufficient. At the local scale, we observe a heterogeneous distribution of the normal force along the contact that evolves during the three phases due to springback and loading direction evolution. This distribution is heavily impacted by the shape and material of the band.

Keywords: *Finite element modelling, contact, elastoplastic, shrinking fit assembly modelling, static and dynamic analysis*

Fluid-structure interaction using lattice Boltzmann method with applications to rupture and fragmentation

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Fluid-structure interaction (FSI) is a complex phenomenon of growing interest in academia and industry, with significant implications for engineering fields, particularly in situations involving shocks, impacts, explosions, or wave propagations which could lead to mechanical failure. In this context, the topic of the PhD thesis is the exploration of innovative methods for the simulation of FSI in highly compressible flows with rupture and fragmentation of the solid. The goal is to associate efficient computing codes from M2P2 and CEA to study the capacities of a unified solver. Three main topics are explored in this thesis work. First, the Lattice Boltzmann Method (LBM), is considered for the simulation of the fluid domain. LBM is one of the most recent developments in computational fluid mechanics, which is associated with high-performance and very good dissipative properties. In this context, the M2P2 laboratory is a leading research lab with the development of a state-of-the-art tool, proLB, for the simulation of compressible flows. Second, the use of Europlexus is considered for the simulation of solid structure with large displacement, rupture and fragmentation. This code has been developed by the CEA for the simulation of complex mechanical systems with rapid transients' dynamics, using a finite element method. Finally, the coupling interactions between fluid and solid will be addressed. The most recent works have been focused on the use of the Immersed Boundary Method (IBM), which represents a real challenge in the context of highly compressible flows. Overall, the ambition of this thesis is to build a unified solver for the simulation of compressible flows with FSI, and solid rupture modelling, which will be beneficial for engineers and scientists.

Keywords : *fluid, structure interaction, lattice Boltzmann method, immersed boundary, compressible, rupture, fragmentation*

Heat losses in Hele-Shaw burner with lattice Boltzmann solver

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Carbon footprint reductions drive the development of hydrogen technology as an energy carrier. Refuelling stations, storage units, and hydrogen production plants are spread over the world while hydrogen applications expand for transport and electricity/heat production. Hydrogen combustion safety issues need to be addressed as a new system is designed. Computational fluid dynamics (CFD) for hydrogen needs a mesh size one order of magnitude lower compared to methane to achieve mesh convergence due to the smaller flame thickness. Consequently, 2D and 3D simulations require two and three orders of magnitudes more points, respectively. An efficient numerical method like lattice Boltzmann solver (1) is necessary to overcome this obstacle. Fundamental 2D flame shapes between plates are computed by taking into account heat losses at the walls. No-slip isothermal wall boundary conditions show better predictions of flame shape between plates spaced by a few millimetres. The isothermal boundary condition is implemented by imposing fixed external wall temperature while the internal wall (flame side) temperature is adjusted by assuming steady heat transfer, a similar method has been used in (2). An effective wall thermal thickness is used to tune the cooling of burned products with experimental data for one gap thickness and equivalent ratio (ϕ). We aim to recover the experimental symmetric and asymmetric flame shapes by expanding the range of gap size and equivalent ratio tested numerically with the same effective wall thickness. Gap size has an important effect on thermal and momentum losses. Equivalence ratio, on the other side, affects flame speed, sensibility to hydrodynamic, thermodiffusive, and thermoacoustic instabilities. Stationary results are obtained with a lattice Boltzmann solver and validate the model with experimental results in Hele-Shaw burner. An efficient tool supported with experimental data allows us to validate simulations and could help to develop strategies to model the 3D phenomenon in 2D simulations. Additionally, a combination of the Lattice-Boltzmann method and detailed chemistry kinetic mechanism provides a robust and accurate numerical approach for simulating flame propagation in microchannels, which can be extended to other combustion systems.

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Keywords: *Hydrogen safety, Combustion instabilities, Lattice Boltzmann method*

Influence of context recognition on the representation of acoustic horizon

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Distance perception in an audio content has long been investigated as sources' distance, how far the source is from the perspective of a listener. Yet, an audio spatial scene is not only perceived as a sum of punctual audio entities but it also takes into account a broader aspect, based for example on shape or textures. Moreover, in the domain of soundscape studies, researchers describe soundscapes as a sonic environment with emphasis on the way it is perceived and understood by an individual. This leads to the existence of an interaction between the recognition of the sonic environment and its perception. Based on this framework, how does the auditory distance perception, defined as acoustic horizon, is influenced by the recognition of the environment? For that, we designed an experiment which showed that there exists an interaction between the recognition and the perception of the acoustic horizon. In addition, we discussed how this interaction could be linked to multiple factors. We will present our results and the leads for a better perceptual characterization of the acoustic horizon.

Keywords: *soundscape, acoustic horizon, perceptual experiment, spatial audio*

Instabilities around a differentially rotating spheroid embedded in a rotating stratified fluid

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To better predict Earth's climate evolution, the CO2 and heat fluxes between the oceans and the atmosphere must be taken into account. These fluxes are governed by the vertical mixing in the ocean. But the measured mixing rate is 10 times smaller than necessary to balance the energy budget of the oceans: this calls for new, local mechanisms of mixing. At the edge of meso-scale eddies, an horizontal layering is observed, corresponding to density steps [1]. This is a local signature of an increased vertical mixing. To quantify its influence we need to determine the origin of the underlying instability/ies.
To model this geophysical flow, a heated solid ellipsoid differentially rotates anticyclonically in a rotating stratified medium. We numerically and experimentally study this setup to assess the intensity and the structures of instabilities around the ellipsoid in the different regions of the Rossby, Froude, Ekman, Prandtl and Schmidt numbers space.
The numerical analysis is conducted using the pseudo-spectral eigenvalue problem solver Dedalus [2]. The experimental apparatus uses a rotating cylindrical tank of 1 m in diameter. The base flow is analytically computed for any aspect ratio from 0 to infinity. Various types of instabilities are observed, including baroclinic, double diffusive, convective and centrifugal ones. Their efficiency and relevance to explain the observed mixing are systematically assessed.

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Keywords: *Geophysical Flows , instabilities , rotation , stratification , mixing*

Integration of virtual sound sources in electric vehicle interior

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The rise of electric cars has presented new challenges for automotive sound design. One of these challenges is creating a pleasant and appropriate soundscape for the vehicle's interior. Because electric cars don't have a dominant engine sound, drivers perceive their car's dynamics differently. Previous studies have suggested using synthetic auditory cues to recreate the sensation of vehicle dynamics, but users have reported that these sounds don't blend well with the car's existing soundscape. Our study explores the acoustic and perceptual characteristics of the car soundscape and demonstrates that creating a coherent environment depends on the spatial attributes of sound sources. Timbral attributes are less crucial, which gives sound designers more freedom to shape the sound of their vehicle.

Keywords: *Automotive Audio, Augmented Reality, Spatial Audio*

Internal shear layers in librating spherical shells

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Internal shear layers generated by the longitudinal libration of the inner core in a rotating spherical shell are analysed asymptotically and numerically. The forcing frequency is chosen within the inertial range such that the internal shear layers issued from the inner core at the critical latitude form a well-defined pattern of concentrated wave beams. Asymptotic solutions for these layers are constructed by using the famous viscous self-similar solution of Moore & Saffman function with two undefined parameters (amplitude and singularity strength). Depending on the aspect ratio and forcing frequency, various wave patterns, such as periodic orbits and attractors, can be obtained. For the simplest periodic orbit that is obtained when the wave propagation direction is inclined at 45◦, the asymptotic solution is obtained by propagating the self-similar solutions from the critical latitude on the inner core, for which the amplitude and singularity strength are known in the literature. The similarity solutions are traced along the critical ray paths until they decay to zero. The comparison of the velocity profiles with the direct numerical solutions performs well and converges with decreasing Ekman number. For the attractors, the asymptotic solutions can still be obtained by propagating the self similar solutions from the critical latitude. However, another type of the self-similar solution appears around the attractors and the two parameters of it are obtained by asymptotic matching with the logarithmic-singular inviscid solution. The comparison between numerics and asymptotics shows that these two asymptotic solutions perform well close to the critical latitude and attractors respectively at low Ekman numbers pertaining to geophysical applications.

Keywords: *rotating flows, inertial waves*

Micromechanical modelling of nuclear fuel oxide creep for predictive simulation of reactor behaviour

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A UO2 crystal plasticity model (1) has been improved to take into account the thermally activated plasticity and the hardening/recovery creep at high temperature. The proposed improvements allow a physically based modelling of a double-kink mechanism for the computation of the thermally activated slip strain rate. Concerning the hardening/recovery creep, an effective strain rate is introduced in link with the travelling time of dislocations during their interactions, with multiplication and dynamic/static recovery mechanisms. These mechanisms are induced by the unpinning of dislocations (Frank-Read source) and the annihilation of dislocations with climb and cross-slip. The dislocation climbing velocity is computed with a vacancy diffusion model in the statistically stored dislocations and the associated self-diffusion coefficient. The two inelastic strains, thermally activated plasticity and hardening/recovery creep, are coupled with an assumption of addition of travel times (2). This model has been implemented with a finite transformation formalism, integrated by an implicit Newton-Raphson method, using the MFront tool. A first application of the new model has been performed to simulate compression tests on single crystals at high temperature. These results compared to the experiments allow to obtain a first validation/calibration of the model. This model illustrates its predictive capacity thanks to the physical parameters identified independently of the tests used for the validation. The effects analysed concern the impact of temperature, strain rate, crystal orientation and deviation from stoichiometry. The limits of the validation are also discussed with in particular the strong dispersion of the experimental data and the question of the structural effects related to the representation of the compression displacement loading in the simulation. This work is supported financially in the context of the PLEIADES platform co-developed by the French Alternative Energies and Atomic Energy Commission (CEA), Electricité de France (EDF) and Framatome

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Keywords: *Multi, Scale Problems, Plasticity, dislocations, Climb, recovery, creep*

Modélisation et simulation thermo mécanique de la propagation de fissure dans les élastomères

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Dans ce poster, nous présentons une nouvelle approche pour résoudre les problèmes de propagation de fissure par des modèles à gradient d'endommagement . Cette approche est basée sur la construction d'une formulation variationnelle espace-temps en Galerkin continu en espace et discontinu en temps. Le problème variationnel est traité aussi bien en IGA que en éléments finis. A travers quelques exemples numériques, nous discutons de l'intérêt de cette approche par rapport aux approches existantes.

Mots-Clés: *Champs de phase, espace, temps, Galerkin discontinu en temps, Analyse Iso, géométrique*

Motion assessment of the thoracic aorta and flow numerical modelling

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One of the goals of blood flow numerical modelling inside pathological aortic geometries is to predict their evolution at an early stage. This modelling has to be biomimetic in order to be relevant. Computational times of the few simulations including fluid-structure interactions are currently incompatible with the clinical practice. Moreover, these works generally consider a wall mechanical behaviour which is not patient-specific. The ”prescribed displacement” approach can tackle these two issues. We propose a reconstruction of in vivo aortic wall motion, based on MRI acquisitions on 4 volunteers. Comparing the reconstructed geometries with 4DFlow MRI shows that errors remain of the order of magnitude of the spatial resolution. Then, this procedure is applied to patients with thoracic aortic aneurysms. The motion determined on patients will be imposed as a structural boundary condition in numerical simulations representative of their aneurysmal pathologies. This type of biomimetic modelling allows the implementation of digital twins.

Keywords: *Aortic Wall Motion, MRI, Geometrical Reconstruction, Numerical Modeling*

Multiphysics modelling of adhesive interface with damage and friction

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The nuclear fuel elements of fast reactors are formed of cylindrical fuel pellets made of (U, Pu)O2 nested inside their stainless steel cladding. Pellets are initially separated from their cladding by a small radial gap of about 100 µm that can be closed during neutron irradiation because of physical, mechanical and chemical phenomena activated by the very high temperature level (up to 2000 ◦C) imposed on the materials. On top of that, a bonding phenomenon can be observed at pellets cladding interface during neutron irradiation and under specific conditions : a minimum contact time between pellet and cladding, a temperature gradient between 500 and 700 ◦C, a closed gap with a low contact pressure (about 10 MPa), the presence of fission products and a corrosion layer (1). The different power cycles and stresses they impose induce a repetition of formation and rupture of a bonded interface. Regarding the nuclear reactor safety, bonding phenomenon modelling and its implementation in the simulation software environment (2) are required. We propose here a multiphysics approach to model this adhesive interface. In the framework of finite elements modelling, we propose to use cohesive elements and contact algorithms with a continuum approach (3). Constitutive relations between strain and stress in the cohesive elements are defined from thermodynamic potentials with the help of supplementary internal variables, in order to take into account damage and chemical conversion (4). The chemical conversion allows to model the adhesive bonds formation and it is coupled to the thermo-mechanical state. Damage is taken into account by a progressive continuum damage. Damage is also coupled to the thermo-mechanical state and friction, it only takes place in traction or shear of the interface. The friction and the thermal flux at the interface depend on the damage, the adhesive bonds and the compressive state. The constitutive model is implemented in a finite element software.

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Keywords: *Adhesive interface, Multiphysics, Damage, Cohesive zone model*

Nuancing Stability for Self-Sustained Musical Instruments: Transient Duration and Basins of Attraction

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We study models of self-sustained musical instruments, such as wind instruments and bowed string instruments. Those dynamical systems can be modelled by autonomous equations. The quasi-static analysis of those equations is thoroughly represented in the literature. In this framework, stationary solutions are calculated, along with their stability. However, those systems may be multistable: multiple stable solutions coexist for identical parameter values. Transient analysis notions are then needed to predict the actual regime obtained. This work aims at proposing analysis tools and graphical representations to complement the quasi-static analysis. On the one hand, we nuance the notion of stability using basins of attraction (determined with Support Vector Machines). On the other hand, we propose to enrich bifurcation diagrams with information about transient duration. Those methods are applied to a fifth order Van der Pol oscillator, which is an archetype of a self-sustained musical instrument model.

Keywords: *Self sustained musical instruments, Stability analysis, Basins of attraction, Basin stability, Transient duration*

Numerical modelling of explosion attenuation by aqueous foams

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Various experimental studies have shown the capability of dry aqueous foam to mitigate blast effects of explosions. Moreover, foam seems appropriate to capture micrometric particles potentially projected by the explosion. These micrometric particles can be pollutant elements whose dispersion needs to be prevented. This work aims to reproduce numerically the explosive projection of particles and their capture by aqueous foam as well as blast mitigation. The numerical approach is based on a multiphasic flow model in pressure, velocity and temperature disequilibrium. Four phases need to be considered: gaseous detonation products, air, liquid of the foam and solid particles. Mitigation effects are caused by the various interactions between phases. Indeed, drag effects between gases (detonation products and air) and water droplets as well as solid particles attenuate the leading shock through momentum exchanges. Heat and mass exchanges together with evaporation also attenuate blast wave effects. Those interactions are considered through source terms and resolved individually. Several experimental test cases of explosions with or without foam and with or without particles are computed with the multiphase flow model. Numerical results show excellent agreement with experimental data for pressures at various locations. The shock pressure drastically decreases when the explosive is confined by aqueous foam. Projected micrometric particles are also captured by the foam’s liquid phase. The blast wave pushes the foam and forms a liquid cap which stops particles. Consequently, their dispersion in the environment is greatly reduced by the foam.

Keywords: *Multiphase flow, Relaxation, Hyperbolic*

Numerical modelling of coated silicon nanoparticles during lithiation and core-shell carbon coating optimization

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Lithium ion batteries (LIBs) using silicon as the anode active material have high energy density and are used in many pieces of electronic equipment. A major issue for improving the performance of LIBs is understanding their degradation mechanisms that lead to capacity fade. In this work, we consider that the anode is composed of spherical nanoparticles of silicon in a soft electrolyte media. We are interested in the mechanical behaviour of a single nanoparticle without interaction with the others. Experimental results (1, 2) indicate that three main phenomena occur during the lithiation of silicon nanoparticles. First, the formation of an advancing lithiation front separating two phases: a pure silicon core and a silicon lithium alloy outer shell. Second, large volume transformation of about 300 % and finally, particle fracture. In order to take into account those phenomena, semi-analytical and finite element mechanochemistry models were established. The lithiation is treated similarly to a thermomechanical problem, where the lithium concentration drives the differential swelling within the particle. The semi-analytical model is an extension of the composite model of a sphere subjected to a radial loading in the case of elasto-viscoplastic constituents (3). The finite element model takes into account large deformation via the logarithmic strain framework. The solution in both cases shows that the lithiation front and the viscoplastic deformation of the outer shell are essential ingredients in modelling the lithiation. Moreover, the viscoplastic deformation relaxes the significant internal stresses, induced by the swelling of the silicon lithium alloy, which leads to the formation of a residual tangential traction of the shell. This traction is likely to cause the nanoparticle fracture. Some experiments show that mitigation of nanoparticle mechanical failure can be achieved by using a carbon coating that has several benefits, such as stress alleviation and swelling restriction. In this work, we analyse the mechanical impact of coating with different thickness.

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Keywords: *Lithium ion batteries, Finite Element, carbon coating*

Numerical simulation of Fluid-structure interaction phenomena in the aortic valve. Application to the Ross procedure.

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The heart consists of two chambers (the ventricles), which are separated by valves, whose role is to ensure that the blood flows in the correct direction through the heart and the body. The aortic valve is one of these four valves, located between the left ventricle and the aorta and has for particularity to be the most subjected to degeneration. The Ross procedure is a cardiac surgery that involves replacing a patient's diseased aortic valve with their own pulmonary valve. Subsequently, the pulmonary valve is substituted with either a donated or synthetic valve. This procedure is primarily performed on young patients diagnosed with aortic valve disease and anticipated to have a long lifespan. Despite its favourable long-term outcomes, the Ross procedure remains a contentious surgery owing to its complexity when compared to prosthesis implantation, and the unknown long-term effects. In recent decades, numerical methods and high-performance computing have progressed significantly and are now ready to be used to understand the coupling between blood flow and the aortic valve. In particular, fluid-structure interaction frameworks based on immersed boundary and lattice Boltzmann methods are now able to capture two-way coupling phenomena occurring in the aortic valve. The purpose of this PhD thesis is to develop, validate and use these numerical methods to simulate and characterise the impact of the Ross procedure on the hemodynamics (turbulence, pressure loss, etc.) and the mechanical properties of the aortic valve (peak stresses, tissue fatigue, etc.), assisting cardiac surgeons in better understanding this technique. This presentation will introduce the fluid and structure interaction (FSI) solver developed during this thesis and its application to a realistic model of an aortic valve dynamically deformed under physiological conditions. The 3D results will be presented and compared for the first time to the behaviour of a pulmonary valve in the context of the Ross procedure.

Keywords: *FSI, LBM, IBM, FEM, Aorte, Valve*

Realisation of resistive memories (CBRAM) and co-integration of nonlinear selection elements printed on flexible substrate functionalized by pressure sensor

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Conductive Bridge Random Access Memory (CBRAM) device has been considered as a good candidate for applications on flexible substrates. In this study, CBRAM memory cells were fabricated through a heterogeneous process combining vacuum-free, low cost and fast processing techniques such as sol-gel for the SiO2 mesoporous electrolyte and inkjet-printing for silver lines acting as active electrodes. We demonstrate the non-volatile behaviour of the cells, that arises from the formation and dissolution of conductive Ag filaments within the mesopores of the SiO2 thin film. The cells feature low switching voltages, a high ratio between high and low resistance states of 104, and reasonable bipolar switching behaviour with more than 103 write-read-erase-read cycles. This work constitutes a step toward the elaboration of crossbar memory arrays on flexible substrates with low cost and vacuum free techniques.

Keywords: *CBRAM, mesoporous SiO2, inkjet, printing, memristor*

Setting up the first mechanical creep tests on irradiated nuclear ceramics to understand spent fuel viscoplastic behaviour

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The mechanical integrity of the nuclear fuel cladding is critical for the safety of pressurised water reactor fuel elements. Stresses in the cladding are mostly driven by its mechanical interaction with the ceramic fuel. Hence, a comprehensive description of the mechanical behaviour of the fuel is crucial. This viscoplastic behaviour is characterised by tests on a virgin material for reasons now discussed. Aside from the intrinsic constraints associated with testing irradiated materials (which requires usage of dedicated hot cells), a severe difficulty is to extract suitable samples from irradiated fuel pellets, which are highly damaged during the irradiation. Our objective is to prove the feasibility of a mechanical test on irradiated ceramics. To do so, we will address all the technical challenges and present our solutions in order to implement the world's first creep experiment on spent fuel in a hot cell. Initially, the extraction of an intact sample from cracked irradiated fuel conditions the feasibility of a compression experiment. Multiple methods will be tested in order to establish a modus operandi. Then, the ceramics will be machined into millimetre thick cylindrical samples. The tests will be carried out in a unique induction furnace under a controlled atmosphere, equipped with a load line that is instrumented to control displacement and load. The development of our device extends over three ” twin platforms ”, to qualify each step independently, starting with inert materials, then non-irradiated nuclear ceramics to compare with a large available database. Finally, we will introduce the experimental loop in a hot cell to set up the first database on spent fuel. To support our experimental efforts, we use a micrometric scanner technology on our samples and integrate them in a digital twin. Such a device will allow us to enrich the viscoplastic behaviours within fuel performance codes.

Keywords: *Light water reactor, nuclear fuel, Power transient, High temperature, creep test, Pellet, cladding interaction, Fuel performance code, irradiated fuel, UO2, Uranium Dioxide*

Simulation and modelling of hydro-acoustic properties of SONAR antenna

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Wall-pressure fluctuations resulting from a turbulent boundary layer cause radiated noise and structural vibration. In naval applications, these fluctuations affect the performances of towed sonar and sonar domes. Hence, the knowledge of this hydrodynamic noise is important to better calibrate acoustic antennas. In practice, this noise is evaluated from the wavenumber-frequency (w-f) spectra of wall-pressure fluctuations. The present work proposes a new model and a new methodology to compute the w-f spectra of wall-pressure fluctuations.

Keywords: *Turbulence, Wall, pressure, RANS, LES, LBM, Poisson equation*

Study of combustion regimes in vitiated and high temperature environment

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In the nuclear industry, facilities consist of closed and mechanically ventilated rooms. When a fire occurs in these compartments, it can spread to the upper part of the room, such as cable trays fires. In this case, it evolves in a high temperature under-oxygenated volume, because of the vicinity of the ceiling and the smoke, which acts on combustion in two antagonistic ways by reducing the amount of oxidiser (and then the heat release rate) and increasing pyrolysis (the mass loss rate). However, the coupled and opposite effects of these two phenomena are not yet fully understood. Elevated fire scenarios are therefore a key issue for fire risk assessment. This is why the objective of the PhD is to study the combustion regimes in a vitiated and at high temperature environment. This work focused on a small-scale experimental campaign. Its aim is to study the influence of the fire elevation on the combustion and the production of chemical species. For a first series of tests, the compartment was well ventilated to avoid under-oxygenation effects. Then the atmosphere was deliberately vitiated. The results show a strong effect of external heat fluxes on the mass loss rate when the flame impinges on the ceiling. Two combustion regimes are thus highlighted, whether or not the fire is affected by the vitiation. Also, the effects of the compartment vitiation were highlighted on the whole range of elevation, but their influence is weak on the combustion compared to that of external heat fluxes. Under-oxygenation effects are far more visible on the production of toxic species such as carbon monoxide which shows a very strong increase with the vitiation of the compartment. Scaling parameters are proposed, showing the generality of the results and that the physical phenomena involved have been well understood.

Keywords: *Elevated fires, Compartment, Under, oxygenation, Pool fires*

Study of the durability of aortic valve bioprostheses by a coupled in-vitro / in-silico approach

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The PhD topic is on the numerical simulation of the prosthetic heart valves, focussing on the durability. There are two types of prosthetic heart valves : the mechanical valves and the biological valves. The mechanical valves (made with metallic parts) have a longer durability and dont' need to be replaced during the life of the patient but suffer from major drawbacks such as anticoagulation treatments. The bioprosthetic heart valves (BHVs) are made of bovine pericardium or porcine aortic valves and don't require anticoagulation, have superior hemodynamic properties but a limited life span in comparison with the mechanical valves. The two mechanisms involved in the structural valve degeneration of the BHVs are the calcification and the mechanical degeneration. The main way to estimate the durability of bioprosthetic valves is to perform an accelerated wear testing. But these tests are time-consuming and do not accurately represent the functioning of a real heart because of the accelerated frequencies. These tests allow mainly to observe a mechanical wear but not calcification (because calcification is a biological process). The aim of the thesis is to develop a numerical fatigue model of bioprostheses, taking into account the progression of calcification, and based on mechanical stresses on the leaflets of the BHV. These stresses are computed numerically using a fluid-structure interaction simulation code, and validated on experiments realised at the University of Laval. As numerical simulations are time-consuming, especially for fatigue tests where many cycles are repeated, we plan to develop a fairly fast and efficient numerical method to estimate the durability of many different valve models. To achieve this goal, metamodels can be developed based on clinical data and data obtained from numerical simulations to estimate the lifetime of a new valve without having to perform a new numerical simulation.

Keywords: *bioprosthetic heart valves, durability, fatigue, numerical simulation*

Study of Thermoacoustic Combustion Instabilities using the Lattice Boltzmann Method

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In the ongoing pursuit to meet the stringent requirements for cleaner and quieter fuels, the solutions put forth suggest switching to lean premixed combustion and/or using hydrogen either as a replacement for traditional fuels or to enrich them. Though the emissions of CO2 can be significantly reduced by doing so, the disruption to the stability of the combustion systems has been identified to be a major issue. One of the widely recognized factors for these instabilities is the ”Thermoacoustic Combustion Instability” caused by the resonance between the noise produced by the flame and the burner acoustic (eigen) modes, following which the pressure oscillations in the chamber tune in onto the resonant frequency (eigenmodes here) and grow in amplitude. Sometimes the amplitudes are so high that they pose a serious hazard to the combustion systems; The destructive implications of this form of instability were memorably demonstrated in the Saturn V program's rocket engines. The study deals with analysing the mechanisms for these kinds of instabilities with a novel numerical method called the ”Lattice Boltzmann Method” (LBM). Unlike the conventional Navier-Stokes-based CFD methods, the LBM solves the Boltzmann equation projected onto a lattice. First, the feasibility of using such a method is studied on a simple case of Flames propagating in a channel, following which the mechanisms of noise generation and the implications of hydrogen enrichment to Methane air combustion are studied on a micro Gas Turbine (mGT) called ”Preccinsta”.

Keywords: *Combustion, Thermoacoustic Instabilities, Lattice Boltzmann Method*

Supersonic, Rarefied Flow Simulations using OpenFOAM, for High-Speed Vehicle

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New transportation modes, as alternatives to highway and airline travel, have come under increased focus due to the climate change context. Electrically powered mass transportation is a strong alternative, to be able to move significant numbers of passengers and cargo. One such proposal is the TransPod system, which is being researched and industrially developed. The TransPod system consists of vehicles designed for > 1000 km/h speeds, travelling in a reduced-pressure guideway (1). This is a type of low-pressure ”tube transportation”(LPTT) - of which examples include ”Vactrain”, ”Hyperloop”, and ”TransPod” (1). Several research studies have been done on LPTT, considering it as the fifth mode of aerospace transportation, where fundamental fluid dynamics becomes necessary to improve technical feasibility. Simulating flows in low-pressure tube transportation is important for the design and optimization of these systems. The two main difficulties in simulations are (1) the low ambient pressure, requiring robust numerical schemes, and (2) high-speed compressible flow, due to the vehicle speed and relatively high blockage ratios (2). Our work investigates the flow around the pods at steady transonic speeds. In this work, a hyperbolic solver using MUSCL-HLLC (Harten-Lax-Van Leer-Contact) schemes (3) is adapted for the configuration. First, the solver is validated with academic test cases, such as low-pressure shock tubes and bluff body flows. Then, a low pressure NACA flow study in a channel is presented before proceeding to the actual TransPod case study, to estimate the aerodynamic coefficients(4) as well as its moments

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Keywords: *low, pressure tube transportation, fluid dynamics, HLLC solver, Euler equations, Blockage ratio*

Thermomechanical behaviour of a bed of immersed particles: comparison between experiment and simulation

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Under certain extreme accidental conditions like Loss Of Coolant Accident, nuclear fuel may fragment, may relocate and may be expelled outside of the cladding. This leads to a modification of its thermal properties. In order to compute its behaviour during the whole accidental scenario, it is necessary to evaluate the thermal conductivity of the fragment bed thus formed. However, the estimation of equivalent thermal properties in granular media is complex and remains widely discussed in the literature. The results given by the semi analytical models usually used suffer from an important dispersion linked to the lack of knowledge of the microstructure at the local scale and the heat transfers at the interfaces. Approaches based on the Discrete Element Method such as thermal DEM, DEM/FFT or DEM/LBM allow a better description of the microstructure but are sensitive to interface description. In order to better understand their influence and to validate the models and simulation methods, the challenge of this thesis is to set up and operate experimental devices to measure the equivalent thermal conductivity and to quantify the weight of the different heat transfer modes in the medium. One of our main results was to show the existence of a critical transition of the thermal conductivity as a function of the inter-particle porosity. Our model allows us to predict the thermal conductivity of a powder bed under ambient conditions by taking into account microstructural parameters: from the crystalline scale (grain-size) to the macroscopic scale (intra-particle porosity and inter-particle porosity).

Keywords: *Thermal conductivity, microstructural parameter, multiscale model, intraparticle porosity, interparticle porosity, grain size, measurement, transient hot plate, x-ray, tomography*

Towards High-Fidelity Computations for Natural Circulation Loop in the Framework of System Scaling Uncertainty Evaluation

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To enhance safety, nuclear power plants under conception rely on passive mechanisms such as natural convection for decay heat removal. Simulation consists of solving a system of equations written to model the nonlinear physics that drives flow dynamic start-up and stability. Different spatial and time resolutions can be considered, and a classical engineering question arises about those achieving a fine balance between the accuracy of a targeted figure of merit and CPU cost. Regarding code qualification for nuclear safety, this question should actually be extended by considering the ability of the numerical approach for system scaling that could indeed jeopardise the reliability of a reactor case simulation. This study focuses on the stability analysis of a natural circulation loop featuring a horizontal heater and horizontal cooler (HHHC). Direct Numerical Simulations (DNS) and various turbulence models are carried out using the CEA in-house code TrioCFD, following the Boussinesq approximation and the flow incompressibility hypothesis. For high-fidelity simulations, particular attention is given to numerical solution uncertainty and model uncertainty to obtain the coupled modelling uncertainty. Specifically, the Grid Convergence Index (GCI) method is applied for solution convergence related to spatial and temporal discretizations. While the Polynomial Chaos Expansion (PCE) is implemented through the CEA in-house uncertainty platform URANIE to generate surrogate models for further quantile computation, sensibility analysis and calibration. Ultimately, the figures of merit (FoMs) and modelling uncertainties will be investigated in the context of scale change. Next, methodological intentions regarding scaling uncertainty evaluation are provided.

Keywords: *Natural Circulation, Scaling, CFD, Uncertainty Quantification*