1) Models and Method for variation and uncertainty management in Micro-manufacturing during the design phase.

Background

For the purpose of this study, the term micro-manufacturing refers to the creation of high-precision three dimensional (3D) products using a variety of materials and possessing features with sizes ranging from tens of micrometers to a few millimeters. While microscale technologies are well established in the semiconductor and microelectronics fields, the same cannot be said for manufacturing products involving complex 3D geometry and high accuracies in a range of non-silicon materials. At the same time, the trends in industrial and military products that demand miniaturization, design flexibility, reduced energy consumption, and high accuracy continue to accelerate -- especially in the medical, biotechnology, telecommunications, and energy fields. By and large, countries with traditional strengths in manufacturing have continued to invest heavily in recent years in micromanufacturing R&D for several reasons. First, the demand from the global market for ever-smaller parts and systems at reasonable cost and superior performance is strong. This demand tends to drive the high-end research. Second, the prospects of multidisciplinary research are causing companies increasingly to blend material science, biology, chemistry, physics, and engineering to speed up technology innovation and thereby new applications based on microtechnology.

The technologies used to design NLBMM (non-lithography-based meso- and microscale) parts and the processes and equipment used to fabricate them are in a nascent stage. These technologies have been, for the most part, borrowed from the design practices of macroscale engineering and very large-scale integration (VLSI). At present, most designers have difficulty ascertaining the appropriate time to use pre-existing design knowledge, theory and tools. Designers must be able to assess the suitability of pre-existing technology for the design of NLBMM parts. Otherwise, design processes will be long and iterative, with the result that the products' benefits will be either delayed or lost.
Fabrication processes are often scale dependent. For instance, traditional macroscale techniques such as milling are not generally applicable at the nanoscale. Likewise, the nanoscale processes used by nature to build biological systems are not generally applicable to the fabrication of some large-scale parts. The range of utility for a specific fabrication process generally terminates within the meso- or microscale. This is an important point for designers to realize; designers must "design for" compatibility of microscale parts with parts that were fabricated using a macro- or nanoscale fabrication processes. Microelectromechanical systems (MEMS) and very large scale integration (VLSI) designers encounter this issue in the form of packaging challenges.
The link between design and manufacturing has led to design for X (DFX) methods (Boothroyd et al., 1994) and concurrent design practices (Syan and Menon, 1994) that are used to help designers select appropriate design-fabrication process combinations. Although the general idea of DFX and concurrent engineering may be considered scale-independent (the design of parts to be made with fabrication processes that are cost and/or time appropriate), the implementation of these practices depends upon the fabrication processes that are to be used. The small-size scale of NLBMM parts makes it necessary to use new or adapted versions of existing manufacturing technology. As a result, new DFX rules will be needed to help designers make design-process choices that ensure scale-specific manufacturability and cross-scale compatibility.
Standards for NLBMM parts are currently in a nascent stage and require better definition. Of particular importance are the standards for measurement and evaluation of part characteristics. Without these standards, designers will have difficulty talking with vendors, customers, and others about the specifications that drive the design and fabrication of their parts. These standards should cover geometry, material properties, optical properties, electromagnetic properties, and other related characteristics. Designers need to understand how to design NLBMM parts so that they are compatible with standard measurement methods. The existing techniques for measuring the characteristics of NLBMM parts are far from ideal. Many of these techniques are slow, provide only 2D information, and require destructive evaluation. Clearly, improved measurement tools are needed, as will be explained in a later chapter of this report. A set of rules that govern the design of NLBMM parts "for measurement" does not exist. As a result, most designers use intuition and advice from metrology vendors to design parts that may be measured in a way that does not affect the rate of manufacturing and does not lead to long time constants for manufacturing processes control. Metrology technology is traditionally slow to develop. As such, early designs must be compatible with available technology. "Design for Standard Measurement" will be important to the rapid adoption of NLBMM parts.

Application:
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Scientific issue:

This proposal focuses on design for variation and uncertainty management of the micro-manufactured product and its micro-manufacturing process. At the most basic level, “design” is a process that is used to generate, evaluate and select a solution for a given problem. Uncertainty and risk are unavoidable when designing in the absence of full knowledge. Uncertainty stems from the lack of knowledge required to model performance. The risk that is associated with a particular design may be ascertained if one is able to use models to define a probability of success. In short, it is better to be in a position to ascertain risk than to be in a position of uncertainty. Throughout this assessment, little evidence has been found to suggest that stochastic methods have been employed during the design of NLBMM parts. Given the nascent state of the NLBMM technology, one finds variation in fabrication processes, metrology tools, material properties, and other aspects which must to be considered during the design process. The ability to model these variations and use such models to assess risk is important for two reasons:

- Knowing the risks may help to prevent the stifling of design concepts in the face of erroneously perceived high risks.
- A good understanding of risks may be used to guide the distribution of resources toward designs that have a higher probability of success.

The scientific main objective is to improve methods for variation and uncertainty management during this design phase. This proposal will focus on a contribution in developing:

- Models to predict the quality of micro-manufactured part (Prediction of surface roughness and dimensional deviation). Prediction of surface finish and dimensional deviation is an essential prerequisite for developing a micro-manufacturing process. Two main attributes of job quality are surface roughness and dimensional deviation. Surface finish has a great influence on the reliable functioning of two mating parts. A reasonably good surface finish is desired for improving the tribological properties, fatigue strength, corrosion resistance, aesthetic appeal of the product, ... Excessively better surface finish may involve more cost of manufacturing.

- Methods for risk assessment. There is a need for modeling and simulation tools that link the performance of components to variations in the characteristics of the part and the variations in the performance of a system to variations in the performance of its parts. In many cases, the preceding may be addressed by custom-made, stand-alone simulations (e.g., Monte Carlo simulations). Unfortunately, many of these tools are difficult to learn and they are not integrated with existing geometric and behavioral modeling tools. This is perhaps the reason that stochastic design tools are not widely used in engineering design.

- Methods for parts tolerancing. Micro-manufacturing processes are characterized by high process variability and an increased significance of measurement uncertainty in relation to tight tolerance specifications. Therefore, it is important to take into account not only the micro manufacturing process capabilities but the measurement uncertainty.

Key Words: Design, Tolerancing, Micro-manufacturing, Uncertainty management and propagation
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2) Colloids transport in porous media: Direct numerical simulation at the microscopic scale.

Natural porous media such as soils or aquifers contain colloidal particles. These particles in suspension in the fluids present in the pore-space can be of different nature (bacteria, clay particles, pollutants …). In the case of aquifers, according to geochemical and hydrodynamic conditions, colloids can be transported by water, develop a high reactivity and a high mobility and act as vehicles to pollutants. Some colloidal particles such as bacteria are also likely to present a risk to the environment and health by altering the quality of drinking water.

Particle transport is also known to be of particular interest in the petroleum industry, since the release and adsorption of natural particles present in reservoirs may alter the petrophysical properties of the porous rocks and lead to additional loss or gain in oil production.

In order to better understand the behavior of colloidal particles in porous media, experimental and numerical studies have been conducted in our laboratory.

Since the behaviour observed during laboratory experiments can not be easily analysed by classical theories, during a recent PhD thesis, a special effort has been put into direct simulation of transport, deposition or detachment of a particle near a rough surface. New numerical modules have been implemented in order to take into account lubrication forces and physicochemical forces between moving particles and rough pore-surfaces. Test cases, chosen on the basis of experimental results presented in the literature, have been limited for the moment to the transport of isolated particles near a solid surface for given hydrodynamic conditions (a given Reynolds number) at different values of ionic strength and the influence of various surface roughness types were analysed.

The objective of this PhD project is to further develop the numerical fluid mechanics code in order to take into account a large number of colloidal particles and carry out a statistical analysis of particle behaviour in porous media. The relative importance of hydrodynamic forces vs physico-chemical interactions on the deposition and release of particles in a pore space for different types of pore-surface roughnesses will be thoroughly analysed.

Required competencies: a good knowledge of fluid mechanics and numerical analysis and a real will to invest in direct numerical simulations in fluid mechanics.

Supervising team: Azita Ahmadi – Henri Bertin – Aziz Omari

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3) Detection and treatment of inconsistent or locally over-constrained configurations during the manipulation of 3D geometric models made of free-form surfaces

Subject description:

The evolution of the manufacturing technologies and the advances in the domain of new materials have significantly increased the degree of freedom when defining the shape of a product that can now become very complex. Today, free form shapes are not only used to answer needs related to aesthetic criteria but also to be able to satisfy to functional criteria. The dashboard, the wings or the optics of a car, a turbine blade, a lemon squeezer and so on, are so many products that can be made of very complex free form shapes whose design is not always easy with actual CAD/CAS software.
To enable the modelling of the free form shapes of a product, actual CAD modellers mainly use NURBS curves and surfaces. Subdivision surfaces also enable the representation of free form surfaces through a recursive subdivision at the infinity of a control polyhedron. But their use in mechanical engineering is still limited.
During the last decades, numerous methods have been proposed to ease the definition and manipulation of NURBS surfaces without going back to the underlying mathematical models. Most of these methods try to modify an initial model while satisfying a set of user-specified constraints. The constraints can be indirectly specified on the control points of the control networks/polygons, or directly onto the surface potentially made of multiple trimmed patches connected together with continuity conditions (Pernot04). Some of these approaches enable the specification of higher level constraints enabling the insertion of discontinuities inside the patches (Cheutet06). Some constraints may also be defined directly onto the trimming curves lying in the surface parametric space to enable simultaneous deformation of the patches and their trimming lines (Pernot08). But constraints may also be defined through the use of different supports such as the digital images that can be easily taken with a digital camera (Panchetti09). The common denominator to all these approaches lies in the fact that they all suppose that there are enough Degrees of Freedom (DOF) to enable the desired modifications without encountering locally over-constrained or inconsistent configurations. This hypothesis is very restrictive since it does not optimize at best the NURBS model description capabilities. Its satisfaction often requires the insertion of numerous DOF through the use of the Boehm's knot insertion algorithm. This uncontrolled increase of the DOFs impacts the quality of the final model which becomes heavier than the initial one. Some approaches try to improve this process while defining hierarchical NURBS surfaces (Qin01).
This thesis aims at defining models, methods and tools to detect and treat locally over-constrained and/or inconsistent configurations that may occur when defining and/or modifying NURBS surfaces. The detection module should produce an analysis of problematic configurations, i.e. a set of areas where either some new DOFs or some local changes in the constraints are mandatory. The treatment module should enable the definition of mechanisms to help the decision on modifications. On the basis of actual 2D sketchers, the idea is to be able to propose some appropriate tools to analyse the constraints and suggest some modifications in 3D. Thus, the number of DOFs will be optimized and there will be no systematic insertion of new DOFs.
Through the tools already developed and available within the INSM team of the LSIS laboratory, the candidate will have to analyse some critical configurations to identify the logical structures of some over-constrained configurations, thus enabling their analysis and post-treatment (identification of corrective solutions). The candidate will take advantage of the work of D. Lesage (Lesage02) that has been working on the definition of models and methods for the detection of such configurations on planar curves within a 2D sketcher.

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Keywords: geometric modelling, numerical optimisation, local over-constraints, inconsistent configurations, bipartite graphs.

Candidate profile: computer graphics, applied mathematics, C/C++ programming.
Application:
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If selected, you should then apply for scholarship to the Chinese Scholarship Council (CSC) through your University International Office.

Candidature: send CV + motivation letter to the above mentioned contacts.

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4) Design Process and product data modelling toward the propagation of engineering changes

Background

To remain competitive, the industrial companies have to act on their performance parameters (Cost, quality and delay). Consequently, it is important to identify the Five Ws in order to master their know-how and then to innovate.
Currently, we focus on the product design phase as more than 80% of product lifecycle costs emanate from the collaborative developments engaged during this phase. In this context, the product design is a highly complex and iterative process as it includes various pieces of information and knowledge associated with the evolution of the product throughout its lifecycle.
This thesis is, fully, in “what-if design” approach [Lutters et al. 2004] that supports designers, with methods and tools, in order to converge into a suitable design solution, within a heterogeneous context (models, information, tools…). The major performance lever is then to link product information to process ones. This requires integrating different processes and product models resulting from the collaborative design.
The main issue of this thesis is then to master the collaborative process modeling and eases engineering change management in product design context.

Objective

This involves developing a method to take into account the integrated product/process information to identify, first, the 5 Ws of the design process and, second, to simulate the impact of any technical modification (CAD model, tool, material…) on this design process. This method aims to capitalise all the effective transformation occurred between the different processes/product models and to capitalise the process execution trace (report on the results of process executing) in order to ease the identification of the “zone of the process” where is suitable to make change to drive a new solution for example.
The thesis intent is to develop a computer- demonstrator in order to support this method.

The first scientific objective is to model the various data and links between design processes models, and product data in order to eases the 5 Ws identification. It will be essential to consider the link between:

• The product data that are conveyed through heterogeneous supports and models. This information is then the value of the design process as it links the different data during the product lifecycle [Skander et al. 2008].
• The process models that capitalise all the knowledge related to the design processes and the choices made during this phase. Those choices have a critical impact on the obtained design solution and on the design process itself [Wang et al.2008].
An important issue concerns the study of the different process models by considering different point of view: information coverage, comprehensiveness, tools, simulation etc... The second issue concerns the identification of the effective transformation between process models. In this context, we could consider MDA (Model Driven Architecture) approach [Iraqi-Houssaini et al.2011].

The second objective is related to the engineering change management [Weidlich et al. 2012] and to the capability to trace the modifications (its propagation) through the design process and to evaluate the impact of its modifications, for example, on the context of an innovative design process.
Indeed, it is primordial to allow processes simulation, in order to capitalise the transformation required when acting a modification. A related issue, concerns the capitalisation of the process execution trace.
The developed demonstrator should take on consideration all these requirements.

With respect to the candidate profile, those objectives will be treated totally or partially.

Method

First year
- Bibliography (design processes models, integration product / process, engineering change management)
- Study of protocols for data/model exchange within the global information system
- Definition of the work program and digital tools that will be used (Choice of environmental technology and computer interfaces between applications).
- Specification of scenarios and case studies that will highlight the value added of the thesis

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Second year
- Implementation of the product/process models
- Development of computer software tool.

Third year
- Implementation of the validation scenarios
- Application to complex parts
- Writing a doctoral thesis.

Progress reports of the thesis will be written once a year. Publications to present the intermediate results will be written and presented in national and international conferences during the first two years. The entire process will be finalized in the form of international conferences and articles in international scientific journals with peer review. A point detailed progress will be made every six months with the presence of different partners.

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Keywords: product design process, system engineering, change management
Candidate profile: engineering design, process modelling (ex: UML/BPMN), computer programming,

Candidature: send CV + motivation letter to the above mentioned contacts.

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Application:
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5) Thermo-mechanical performance of multilayer coatings on machining FRP composites: multiscale analysis

Superior properties of polymeric composites explain the technological and commercial interest on these materials especially in the aerospace sectors. The gain in energy consumption and performance in improving system because of the high specific characteristics of these materials makes them good candidates face to metallic alloys. However, fiber reinforced polymer (FRP) composites exhibit particular machining response if compared to metals. Generally, the abrasive nature of fibers results in poor surface finish, delamination and tool wear. Thus, the processing of neat-shape parts still remains the common challenge since it closely depends on the surface finish quality. While FRP properties depend on the nature, orientation and volume fraction of fibers, the final quality of parts still remains very sensitive to the cutting conditions. In many cases, the mechanical and physical properties of FRP present an obstacle to controlling properly the applications and still raise various issues during machining. In particular, the interfacial behavior was outlined to be of main role in governing the mechanisms acting before final stage of chip separation.
In open literature, many attempts were conducted in order to set out the prominent parameters when cutting FRP. Most panels of the researches have interested to wear mechanisms on uncoated carbide inserts or single layer coated inserts typically composed of titanium carbide (TiC), titanium nitride (TiN), aluminum oxide (Al2O3), etc. In spite of the economic advantage of the tungsten carbide (WC) at low cutting speeds [1, 2], they exhibit real vulnerability at high cutting speeds since they undergo a severe wear. This affects the surface quality and increases the cutting forces [1, 3]. Nevertheless, only few studies have been conducted on the performance of multilayer coatings on cutting these materials. More than a decade after their apparition, multilayer coatings take increasingly their rightful position in machining FRP. Recently, multi-hard coating layers such diamonds and ceramics demonstrated their efficiency to improve wear resistance and to promote higher surface finish with minimum production costs [4, 5]. However, the elevated thermal gradient between the fiber and the matrix phases, and the relatively poor thermal conductivity of composites makes it rather difficult to industrialize any of the unconventional coating techniques for machining polymeric composites [6]. Hence, the physics of the induced cutting process and associated tribological mechanisms (i.e. heat generation, interface consumption, friction, etc.) [7] become necessary to evaluate the performance of the cutting tools to achieve the required quality of composite components.

The new coating generations obtained by CVD and PVD techniques combine multiple layers such as TiCN, TiN, Al2O3 and AlCrO [8, 9]. Titanium based constituents improve wear resistance to abrasion while oxide constituents are known to offer better chemical stability. Besides, thermal effects that might be of critical role in understanding the tool behavior when long duration cutting were often overlooked! Since the chip is powdery, it potentially able to dissipate only insignificant portion of localized heat. Hence, a high thermal conductivity was outlined as an additional primordial factor in selecting the adequate tool capable of successful FRP cutting [10].

Preliminary tests [11] showed that CVD mullti-layer coated tools are of better ability to dissipate the thermo-mechanical cutting energy due to the good coating-to-substrate adhesion. This acts to prevent catastrophic failure to the detriment of progressive wear compared to monolayer coating. Thermal analysis of fiber and matrix within the surface finish indicated also that the thermal conductivity of each of phases is proportional to wear. AFM micro-scratch tests using sliding contact probe revealed that friction at surface finish sensitively depends on the wear land aspect. The multiplicity of rough asperities seems to favor the thermal conduction on wear track.

This work covers a study on the performance of multilayer coatings when dry cutting Fiber Reinforced Polymers (FRP). A design of experiments including cutting tests on both unidirectional carbon/epoxy and glass/epoxy with various fiber orientations should be built. Multilayer coatings with neatly different constituents, grain size and substrate-to-coating adherence will be utilized for generating composite surfaces. Scanning Electronic Microscope (SEM) will be employed for characterizing the flank wear modes and highlighting the stages of the material removal process. The adhesive frictional signature of new and worn inserts will be examined by Atomic Force Microscope (AFM) using series of micro-scratch tests. Close inspections on the worn face are also required for correlating observations with physical mechanisms generated. FE simulation should be developed as an alternative to understanding the involved mechanisms. Thus, deep analyses on thermal effects will be necessary for determining heat partition coefficients required for calibrating the FE model. A particular focus must be put on mastering the thermo-mechanical behavior within the interface. The well-established model which is restricted to mechanical behavior will be hence extended for taking into account the thermal effects have been induced par cutting. The numerical analysis will be conducted on ABAQUS code using the options associated with dynamic issues.

Application:
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Keywords: FRP, dry cutting, multilayer coatings, fiber scale, Interface consumption, wear

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6) Microstructure evolution and material flow characterization during the complete thixoforging process of a steel part

Thixoforging is a manufacturing process of metal alloys at semi-solid state. Semi-solid state is obtained by heating the material from the solid state, up to a temperature within the solidus-liquidus temperature range. The rheological behavior of the material at this temperature is highly dependent on the structure formed by the liquid and solid phases. For thixoforging, the liquid fraction is quite low, less than 20%. The liquid-solid structure characteristics are function of the alloy (chemical composition, as-received metallurgical structure…) and the heating. During forming, the liquid-solid structure undergoes quick modifications which correspond to rheological properties changings of the thixoformed material. These last ones are source of material flow heterogeneities and heterogeneities of the metallurgical structure within the thixoforged part. The solid fraction mainly depends on and is very sensitive to the temperature. For steel, a temperature variation of few Celsius degrees can lead to an increase or decrease of the liquid solid fraction corresponding to not negligibly different behavior. During thixoforging operation, thermal exchange between material and dies, the plastically dissipated energy are source of heterogeneity of the temperature field and of the associated behavior. The heterogeneity of the plastic strain and plastic strain rate fields may lead to important heterogeneity of the thixoforged microstructure.

The proposed subject is dedicated to the characterization of the evolution of the microstructure and the associated rheological behavior of the material during the thixoforging process. More precisely, from thixoforging testing on simple shape parts, with the help of simulation and using the experimental characterisation techniques, the projects consists in identifying the phenomena leading to the heterogeneization. The thixoforging testings could be performed with different alloys according to the future characterization. The main objectives of the research is to identify and characterize these phenomena in order to propose guidelines for thixoforged part and thixoforging process design.

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7) Multi scale global forgeability study of the multi material

Context

To meet complex requirements and / or to achieve a compromise between performance and manufacturing cost, it is possible to manufacture a multi-material part. Generally, multi-material parts are obtained by joining processes such as fusion welding, friction welding or brazing, etc. The manufacturing process consists of the manufacturing of the different parts of the work-piece which will then be joined. Another common solution is to clad the work-piece surface with a material with improved surface properties. In all cases, the part design is strongly constrained by the geometric constraints of the joining process.

To partially solve this problem the idea is to reverse the conventional fabrication layout. The multi-material is joined first and then formed. Joining would be performed on simple geometry. The complex geometry of the multi-material part is reached thanks to the following forming process.

Objectives

The main idea of the proposed thesis is to study the global forgeability of multi-material. As the forgeability is an intrinsic charracteristic of any material therefore due to the difference in rheological properties at different positions of the workpiece, three levels of forgeability are considered:

- Micro scale, corresponding to the intrinsic forgeability of the different materials constituting the multi-material considered separately.

Meso scale, corresponding to the deformation behaviour of the structure consisting of the two materials and their interface. The interface geometry local geometry is important to be considered due to its possible wavy shape (fusion welding cladding, explosion cladding…)

- Macro scale, corresponding to the ability of a multi-material under forming to obtain a desired defect free material distribution and structure.

Methods

The proposed work is based on the study of a set of characterization tests:

-The upsetting test;

-The hot bending test

-The two-punch compression test

The methodology for the forgeability characterization consists in:

-Parametric forming experimental study

-Numerical simulation of the forming process

-Macrographic and micrographic metallurgical characterization of the obtained multi-material parts.

The results of the method are the identification of the phenomena limiting the forgeability domain of multi-material (limit of ductility, debonding of the interface ...). By comparing simulation and experiment (using inverse methods of optimization), the idea is also to obtain a constitutive behavior law of the coating. The simulation study of the entire process of forming including in particular the cooling stage should allow, by comparison with the results of the metallurgical characterization, to estimate the residual stresses obtained at the workpiece surface.

Expected results: Expected results of the study are, first, the identification of the key parameters of the forging of multi-material. In a second step, a methodology for characterizing the forgeability must be proposed and validated in the case of two applications (part shape, couple of materials and joining processes)

Laboratory: Design, Manufacturing Engineering and Control Lab. (LCFC - EA 4495)
PhD Supervisors: Prof. Régis Bigot, Dr. Laurent Langlois
Email: régis.bigot@ensam.eu, Laurent.langlois@ensam.eu

Application:
Please send your CV and motivation letter by email to the PhD supervisor with copy to your University International Office and to Yvon VELOT (yvon.velot@ensam.eu).
If selected, you should then apply for scholarship to the Chinese Scholarship Council (CSC) through your University International Office.

8) PhD in Fluid Mechanics: DNS and LES simulations of cavitating flows

Supervisors: O. Coutier-Delgosha (olivier.coutier@ensam.eu), M. Marquillie (Laboratoire de Mécanique de Lille), M. Dular (Laboratory for Water and Turbine Machines, University of Ljubljana)

Location of work: main part at ENSAM Lille / partially at Laboratory for Water and Turbine Machines, University of Ljubljana

Title of the project: DNS and LES simulations of cavitating flows

Summary: Cavitation is the partial vaporization of a liquid in low pressure areas due to hydrodynamic effects such as local flow acceleration. In pumps, it leads to performance decrease and/or to perturbations due to the development of instabilities. Other problematic effects may occur, such as blade erosion after a long operating time, because of pressure waves initiated by the collapse of vapor bubbles. Instabilities also induce some large pressure fluctuations that may compromise the rotor equilibrium, or interact with the blade structure. In rocket engine turbopump inducers for example, unstable cavitation patterns are associated to significant vibrations, which have been found as plausible explanation for the failure of the Japanese launcher H-II in 1999.

Figure 1. Rocket engine inducer operating in cavitating conditions (LML laboratory, 2005)

Figure 2. Hydrogen inducer of Japanese launcher H-II (after the flight failure)

The PhD is devoted to the theoretical analysis and modelling of cavitating flows. Nowadays, the understanding of the physics of such flows, which involve simultaneously large density and compressibility variations, turbulence effects, and instabilities at various scales, is still beyond the current state of art. Indeed, numerical simulations of cavitation have only slightly evolved in the last 20 years, and the existing approaches do not presently provide the detailed information regarding the physical mechanisms that control the flow properties. The main reasons for this are i) the strong interaction between the biphasic and turbulence effects, which does not enable to improve separately the turbulence and cavitation models, ii) the lack of detailed experimental data to validate the simulations and discuss the efficiency of the models.

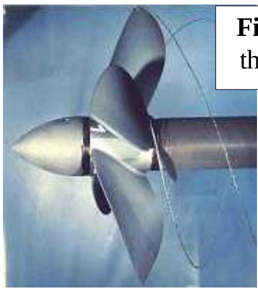

Figure 3. Vortex cavitation on the blades of a naval propeller

Figure 4. Developed cavitation in naval propeller

In the present project, a ground breaking scientific strategy is proposed to address this issue: it is based on i) innovative simulations with DNS and high resolution LES turbulence modelling associated with several cavitation models, ii) the recent development of original experimental techniques such as X-ray imaging, which have generated new appropriate data for validation of the numerical simulations. The basic idea is to separate the spurious effects of inappropriate turbulence models from the errors due to cavitation modelling, in order to assess the capability of different promising cavitation models to reproduce the structure and the dynamics of various cavitating flows.

Figure 5 : Example of unsteady simulation of sheet cavity with a homogeneous model based on a barotropic law of state (the colours indicate the density, white for pure liquid and from red to blue when the void ratio increases)

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International Office and to Yvon VELOT (yvon.velot@ensam.eu).
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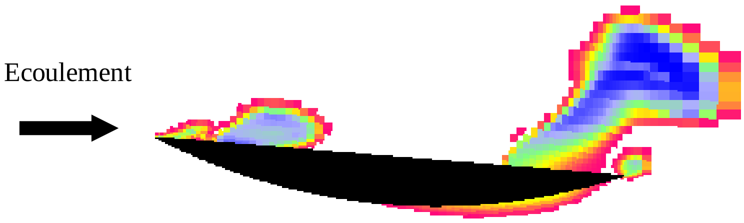


Therefore, DNS simulations will be conducted in a configuration of small-scale flow that has been already used in the last years for the development of experimental techniques such as fast X-ray imaging or time-resolved LIF PIV. At such millimetric scale, moderate Reynolds numbers are obtained, which enables to perform challenging DNS simulations that will enable to get rid of errors related to the use of inappropriate RANS models. For this purpose, an existing code developed in the LML laboratory, providing highly resolved three-dimensional flow states, will be used. This numerical tool, which is based on multi-domain decomposition, high-order compact finite-differences in all three space-coordinates, and massively parallel implementation, will enable to perform as well DNS and LES simulations. Cavitation models will be i) homogenous approaches used presently, which require the knowledge of mixture properties, ii) bubble cloud models based on interaction laws between bubbles.

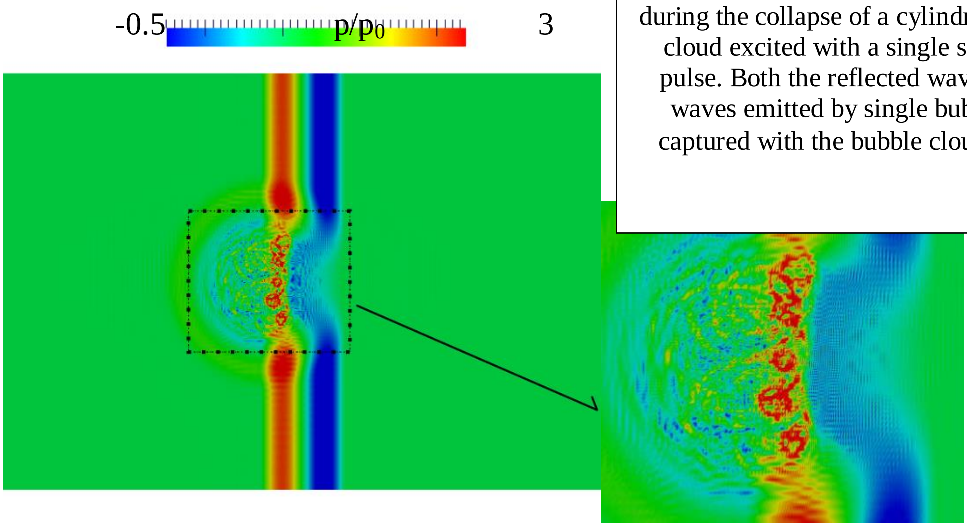
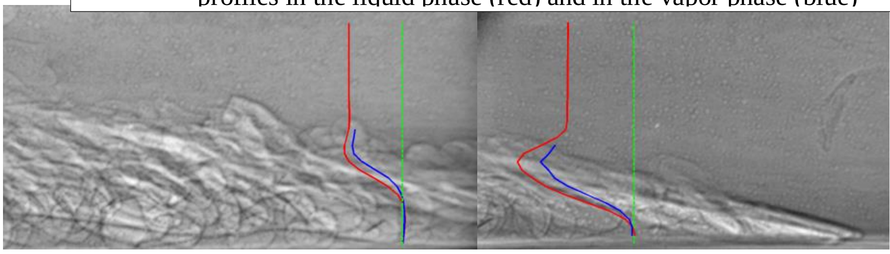


Figure 6 : Non-dimensional pressure field during the collapse of a cylindrical bubble cloud excited with a single sinusoidal pulse. Both the reflected wave and the waves emitted by single bubbles are captured with the bubble cloud model.

The validation of the results, in both cases, will be based on the comparison with the recent experimental data obtained in the same flow configuration, especially the time-resolved velocity fields in both phases, the time resolved local volume fraction of vapor, and the fast visualization of the flow structure. The objective is the characterization of the mechanisms that control the processes of vaporization and condensation, the momentum exchanges between the two phases, and the turbulent properties. In addition, comparisons between DNS and LES results should enable to develop an appropriate strategy for turbulence modelling in configurations of cavitating flows.

Figure 7. X-ray imaging of a cavitating flow in a Venturi type Section, and velocity profiles in the liquid phase (red) and in the vapor phase (blue)



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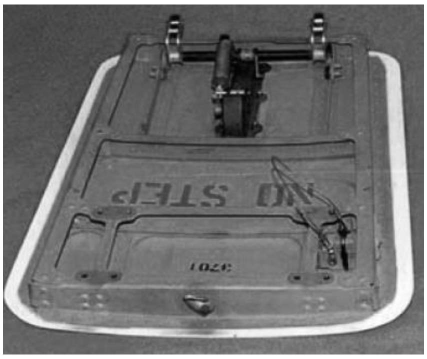
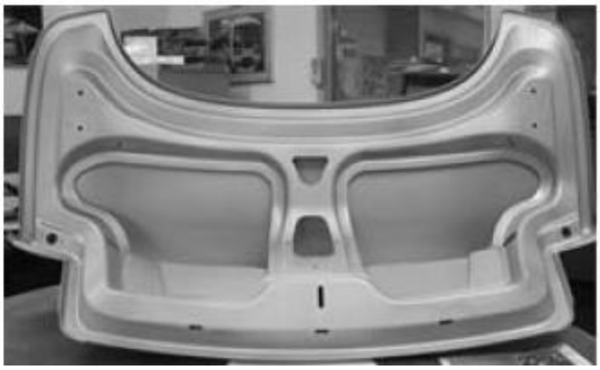
9) Development of Rheological Laws for Superplastic Forming of Metallic Materials

Superplastic forming of metallic materials, despites its complexity and cost, remains a privileged forming process in aeronautic and automotive industries. The main cause lies in the high deformation which can be reached by the material before failure. Complex shape parts can thus be formed from a simple flange by applying a time-dependent pressure (figure 1). This peculiar ability is mainly due to the activation of some high-temperature deformation mechanisms during the forming operation such as grain-boundary sliding [1]. Indeed, superplastic parts are generally obtained by using temperatures above $0,5.T_M$ (where T_M is the melting temperature of the material) [1]. Additional conditions to obtain superplastic deformation are also necessary i.e. low strain rates ($< 1.10^{-3}$ /s) and fine equiaxed structures [1].

Body panels of the Ford GT supercar [2]



737 Blowout door [3]



Prototype auto parts [2]

Figure 1. Few examples of complex shape parts obtained by superplastic forming

Numerical simulations are commonly used to predict the good manufacturing conditions of a given part. These simulations allow determining the appropriate pressure law to apply in order to: (i) avoid damage, (ii) reach a minimum thickness and (iii) obtain a minimum thickness variation in the part. The protocol to identify this pressure law has already been studied in the LAMPA laboratory: a proportional algorithm has been developed [4] and leads to a good process control. However, the good knowledge of some input data, such as material model, is primordial.

Material model must include rheological behavior as well as damage response of the material under superplastic conditions (i.e. high temperature and low strain rate). Norton-Hoff law [5] is mostly employed to describe the rheological behavior of a superplastic material. Some strain correctors [6] can be used to reproduce the possible decrease in stress at very high strain; which underlines the occurrence of some damage. Some factors [7] can also be added to the rheological law to take microstructural changes in account. The prediction of the material failure is then obtained by introducing a thickness limit into the numerical simulations. The main disadvantage of this approach lies in the use of empirical laws which not really describe the physics phenomena occurring during the forming process notably in terms of damage evolution.

The main objective of the thesis will therefore consist in developing material models for two different metallic materials: an aluminum alloy sensitive to cavitation and a bi-phased alloy (such as titanium alloy or duplex stainless steel) sensitive to microstructural evolution. The works will be divided into three main steps:

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1. Characterization and Modeling of the rheological behavior (including damage) of the materials under thermo-mechanical conditions similar to those encountered during superplastic forming.
2. Development of a numerical simulation (ABAQUS…) coupling thermal, metallurgical and mechanical approaches.
3. Validation by elaborating complex shape parts by superplastic forming

Scientific fields: materials, mechanics, forming processes
Key words: metallic materials, superplasticity, forming process, damage, numerical simulation

Supervisor: Prof. Philippe Dal Santo
Co-supervisor: Dr. Eliane Giraud
Email: eliane.giraud@ensam.eu ; philippe.dalsanto@ensam.eu

University: Arts & Métiers ParisTech
Location: Laboratory LAMPA (Angers – France)

Applicant profile: The applicant will have to possess good aptitudes in mechanics of material and numerical simulation. It will be appreciated if he, or she, has got some background in experimentation and metallurgy.

References

[1] T.G. Nieh, J. Wadsworth and O.D. Sherby, *Superplasticity in metals and ceramincs,* Cambridge: Cambridge University Press, 1997
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[4] C. Robert, *Optimisation du procédé de mise en forme par formage incrémental profond de tôles minces. Prédiction du comportement à l'usage des pièces formées*, Thèse de doctorat, Arts & Métiers ParisTech, 2009
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10) Energetic Macroscopic Representation and Nonlinear Modal Control of Multi-actuated Systems

Arts et Métiers ParisTech – Campus of Lille
L2EP – Laboratory of Electrical Engineering of Lille – http://l2ep.univ-lille1.fr/index2.php
LSIS – Laboratory of Information and System Science – http://www.lsis.org/

Supervisor of the Master Thesis: **Xavier KESTELYN**	E-mail: **Xavier.Kestelyn@ensam.eu**	Phone number: +33 (0)3 20 62 22 38
Associate supervisor: **Olivier THOMAS**	E-mail: **Olivier.Thomas@ensam.eu**	Phone number:

Keywords:

Dynamic Performances	Nonlinear Vibrations	Nonlinear Normal Modes

Expected student profile:

Master in Electrical or Mechanical Engineering with skills in Automatic control

Context:

The increase of system performances (dynamic as energetic) imposes a drastic reduction of the inertias. Consequently, the reduction of the total mass of the system leads to an increase of the flexibility of its mechanical parts. In the linear case, Independent Modal Space Control (IMSC) [1], in conjunction with the Energetic Macroscopic Representation developed by the Control team of the Laboratory of Electrical Engineering of Lille (L2EP), has shown some important advantages over advanced automatic control methods to address the control of multi-degree of freedom flexible systems [2]-[3].

Dynamic performances of systems are also increased by moving mechanical parts with high-power actuators. The level of stresses in the parts of the system is then so high that the assumption of linear vibrations is no longer acceptable. Consequently, IMSC cannot be used anymore and new methods have to be developed.

In order to keep advantage of the strong physical insight that IMSC offers and due to the nonlinear vibratory behavior of high-performance systems, we propose in this work to develop methodologies based on the concept of Nonlinear Normal Modes (NNM) [4]-[6] which is a strong expertise of the INSM team of the Laboratory of Information and System Science (LSIS).

The extension of this concept leads to the development of an innovative Nonlinear Modal Space Control of multi-actuated machines.

Objectives and expected results:

The global objective of the project is to use Nonlinear Normal Mode in order to extend the concept of Independent Modal Space Control to nonlinear cases.

The intermediary steps are:

- Discovering of high-performance production machines and their inherited problems
- Literature review on IMSC and NNM and application to case-type examples
- Development of the Nonlinear Modal Space Control Method
- Simulation and practical validations of the concept to multi-actuated systems present at Arts et Métiers ParisTech (see Fig.1)
- Participation to international conferences and redaction of scientific papers

References:

[1] L. Meirovitch. "*Dynamics and Control of Structures*", John Wiley & Sons Inc, 1990.
[2] X. Kestelyn, J. Gomand, A. Bouscayrol, and P.J. Barre. "*Control of a symmetrical dual-drive gantry system using energetic macroscopic representation*", Solid State Phenomena (SSP), Volume 144, Pages. 181-185, 2009.

Application:

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[3] I. M. GarciaHerreros, X. Kestelyn, J. Gomand, R. Coleman, P.J Barre. *"Model-based decoupling control method for dual-drive gantry stages: A case study with experimental validations",* Control Engineering Practice, Vol. 21, N°. 3, pages. pp. 298-307, 2013.
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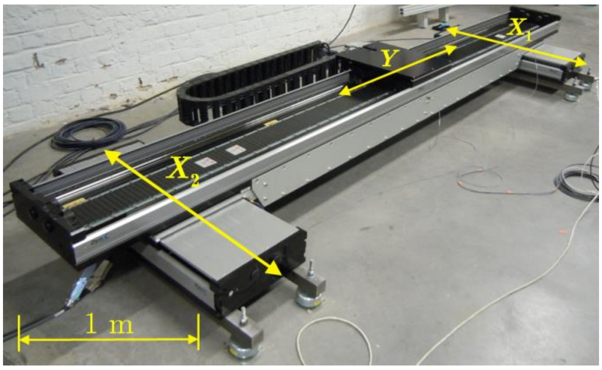
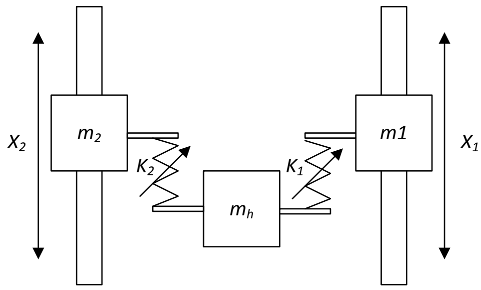
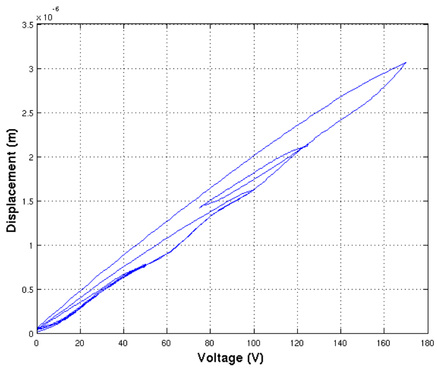
[6] C. Touzé, O.Thomas, and A.Chaigne. *"Hardening/softening behaviour in non-linear oscillations of structural systems using non-linear normal modes"*. Journal of sound and vibrations, Volume 273, Issues 1–2, Pages 77–101 273, 2003.

Figure 1: Some of the multi-actuated systems present at Arts et Métiers ParisTech





Gantry system with multiple linear motors from ETEL Company and its nonlinear model taking into account nonlinear vibrations



Prototype of a piezoelectric vibration assisted forging tool, with its nonlinear displacement versus voltage

Application:
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11) Modeling and simulation of sintering(coalescence and densification) of the particles and bubble migration in rotational molding of the blend

Director: Prof. Abbas TCHARKHTCHI

Background

This project is interested by the impact of the processing conditions and the nature of the materials on the performance of technical parts made by rotational molding. The choice of rotational molding as the technique for obtaining these parts requires a deep study on the condition of processing and effect of this condition on the properties of the finished part.

One of the characteristics of rotational molding is the lack of pressure during and at the end of the process. Indeed, the polymer is only in contact with air inside the mold without any external pressure. In this case, air between the grains will be entrapped in the molten polymer and forms the bubbles in it. It is, then necessary to eliminate the bubbles before the end of process; because the presence of them is very unfavorable for the performance of the parts, in particular the technical parts. A micro air bubble present in the part can initiate cracks under mechanical stress.
The migration of air bubbles during the rotational molding is based on the phenomenon of coalescence and densification of grains, a particularly well studied phenomenon in the field of metallic materials. However, this phenomenon has been less investigated in the field of polymers and blends.

The aims of this subject may be explained as follows:

- In a previous study, coalescence and densification of identical grains have been studied by Bellehumeur model. However, this model does not take into account the effect of neighboring grains on the evolution of the interface between two grains during the coalescence. In this study, we will study this effect and we will propose a rectifying model for sintering of polymers and blends.
- The formation of bubbles, their migration and diffusion of the gas in molten polymer will be studied and be simulated during densification.
- The study of polymer blends by the coalescence method is a new approach . This approach will be used during this project.

Program

Literature review
Experimental Study of the coalescence
Study of the diffusion of air into the molten polymer during the second stage of densification
2D and 3D Modeling coalescence and densification
Comparison of experimental and theoretical results
Modeling and simulation of definition in the context of rotational molding

Equipments

• Characterization :

Optical microscope with heating stage ,

Rheometer, DMTA, DSC,...

machine for measuring surface tension, tensile test machine ,

Software for modeling and simulation

Materials

The materials used for this study are the following

- Homopolymer (PLA)
- Blend (PMMA / PVDF)

Application:
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12) Investigation of damage–localization interactions for a better prediction of thin sheet metal formability

School: Arts et Métiers ParisTech
Laboratory: LEM3 (Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux), UMR CNRS 7239.
Web site: http://www.lem3.fr
Team: Computational Mechanics.
Head of the team: Michel POTIER-FERRY.
Supervisors: Farid ABED-MERAIM and Xavier LEMOINE (Professors), Hocine CHALAL (Assistant Professor).
Emails: farid.abed-meraim@ensam.eu ; xavier.lemoine@ensam.eu ; hocine.chalal@ensam.eu
Scientific collaboration with other partners during the PhD:
In France: H. CHALAL (LEM3, ENSAM), ArcelorMittal (R&D Automotive Products), CEMEF (Mines ParisTech).

Title: Investigation of damage–localization interactions for a better prediction of thin sheet metal formability.
Scientific field: Mechanics of Materials, Damage Mechanics, Sheet Metal Forming, Elasto-Plasticity.
Key words: Sheet metal forming, Material instabilities, Localized necking, Ductile damage, Thin sheet metals, Plasticity, Strain localization, Limits to ductility.

Scientific context

Due to increased requirements in terms of societal and environmental issues, the industrial world needs to process and develop new materials with improved mechanical properties. The processing stage of these new materials seems to be well controlled by metallurgists. However, these new materials are still too rarely used by manufacturers, who do not control well forming conditions involving large multiaxial plastic strains.

Pushed by these industrial needs, the control and prediction of sheet metal formability for complex loading paths has been the focus of numerous scientific studies during the last 50 years. It is indeed a major and challenging research field, due to the intimate interaction of multiple mechanisms leading to final ductile fracture. A reliable prediction of formability for complex loading paths would indeed require the combined development and use of:
- Plastic and viscoplastic behavior laws for large plastic strain as well as multiaxial and non proportional loadings;
- Physical representation and numerical modeling of ductile damage and/or strain localization;
- Anisotropy in terms of mechanical behavior and damage;
- Observation of micro and macro mechanisms leading simultaneously to necking and damage in order to evaluate the influence of one mechanism on the other;
- Identification strategy for material parameters in such complex loading paths.

The aim of the thesis is to clarify, model and finally predict the phenomena limiting sheet formability for advanced metallic materials. The latter include new grades of steel characterized by their high strength and improved mechanical performances.

Main stages of the project

The working program can be divided into two main areas:

Application:
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From a theoretical point of view, localization criteria dedicated to elastic-viscoplastic materials and accounting for materials anisotropy - in terms of texture or/and hardening - and damage will be defined. These models should account for the individual contributions of ductile damage and strain localization on formability for various loading conditions, and describe their interaction.

From a numerical point of view, these models will be implemented in the commercial finite element software Abaqus, thus facilitating their future transfer to industry. Special attention will be paid to robustness, modularity and efficiency. The identification of material parameters will be achieved through inverse analysis, based on global or/and local (digital image correlation) measured quantities.

Finally, these developments will be validated through the comparison of numerical results with existing experimental data or other industrial experiments to be performed by ArcelorMittal.

Application:

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If selected, you should then apply for scholarship to the Chinese Scholarship Council (CSC) through your University International Office.

13) Taylor meshless methods and sheet metal forming

School: Arts et Métiers ParisTech
Laboratory: LEM3 (Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux), UMR CNRS 7239.
Web site: http://www.lem3.fr
Team: Computational Mechanics. **Head of the team:** Michel POTIER-FERRY.
Advisors: Farid ABED-MERAIM and Michel POTIER-FERRY (Professors)
Emails: farid.abed-meraim@ensam.eu ; michel.potier-ferry@univ-lorraine.fr
Scientific collaboration with other partners during the PhD:
Wuhan University, Wuhan (China); Université Nangui Abrogoua, Abidjan (Ivory Coast).

Title: Taylor meshless methods and sheet metal forming.
Scientific field: Solid Mechanics, Computational Mechanics, Meshless Methods, Fabrication Processes.
Key words: Meshless Methods, unilateral contact, thin shell models, sheet forming processes, rolling tests, shell buckling, coupled nonlinearities.

Scientific context

Fabrication processes such as deep drawing [1] or rolling are very important in many industrial branches and nowadays their control is based on numerical simulations that have to be precise and fast in view of real-time applications. These simulations are generally done by the Finite Element Method, the spatial discretization being done by creating a mesh. The quality of a FEM-simulation may be diminished by a mesh distortion and this necessitates re-meshing, a time and human labor consuming task. Many efforts have been done since twenty years to develop meshless discretization methods because it seemed easier to add control points than to manage a full re-meshing [2, 3]. Nevertheless there are few practical applications of meshless methods, except some rare exceptions (SPH method…), and important questions like numerical integration or matrix conditioning have no definitive answer [4].

That is why a new class of meshless methods has been introduced that relies on an explicit solution of the Partial Differential Equations inside the domain with the help of Taylor series expansions. Because the PDE is solved analytically in the domain, one is reduced to a discrete boundary problem whose size is rather small. Recent works [5, 6] have established the robustness of the method and its ability to solve large scale problems.

The aim of the thesis is to apply the method to unilateral contact problems and to thin shell models in view of applications to sheet metal forming.

Main stages of the project

1. Taylor Meshless Method and unilateral contact: definition of the algorithm, numerical evaluation, application to rolling tests.
2. Analytic representation of surfaces. Algorithm to solve shell problems by Taylor series. Application to benchmarks for shell buckling.
3. Treatment of coupled nonlinearities: contact, friction, plastic behavior.

References

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[3] Belytschko, T., Krongauz, Y., Organ, D., Fleming, M., Krysl, P. (1996). Meshless methods: an overview and recent developments. *Computer methods in applied mechanics and engineering*, 139(1), 3-47.

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Application:
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PhD Proposals 2014 for China

14) Multi-scale instabilities and failure of materials

School: Arts et Métiers ParisTech
Laboratory: LEM3 (Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux), UMR CNRS 7239.
Web site: http://www.lem3.fr
Team: Computational Mechanics. **Head of the team:** Michel POTIER-FERRY.
Advisors: Farid ABED-MERAIM and Michel POTIER-FERRY (Professors)
Emails: farid.abed-meraim@ensam.eu ; michel.potier-ferry@univ-lorraine.fr
Scientific collaboration with other partners during the PhD:
Wuhan University, Wuhan (China); Université Hassan II-Mohammedia, Casablanca (Morocco); Université de Montpellier (France).

Title: Multi-scale instabilities and failure of materials.
Scientific field: Solid Mechanics, Computational Mechanics, Homogenization, Failure Mechanics.
Key words: Instabilities, buckling, wrinkling, necking, double-scale methodologies, reduced-order models, failure mechanics, post-bifurcation, computational homogenization, internal length, metal forming.

Scientific context

Nonlinear behavior and failure of materials often follow from instabilities occurring at a local level. Conversely a local softening may induce macroscopic instabilities such as buckling, wrinkling, necking and shear bands … A typical example is the wrinkling of membranes, and its modeling must include at least two scales: the scale of the wrinkles and more macroscopic length scales [1]. Generally instability at local level induces a nonlinear macroscopic behavior that can lead to a global instability and a failure of the structure [2]. It is known that a local buckling is strongly connected with a macroscopic failure and a loss of ellipticity of the macroscopic model and therefore an ill-posed macroscopic problem [3]. Such double scale instability phenomena are encountered in various circumstances: failure of long fiber composites generated by a fiber micro-buckling [2], membrane wrinkling [1] and surface wrinkling [4], for instance skin wrinkling; forming limit of metal sheets, where the micro-structure has an intricate and random behavior [5]. The recent literature proposes several tools that are more or less able to account for these double scale behaviors: first order computational homogenization [6, 2], self-consistent model [5], second order homogenization [7], Fourier series with slowly variable coefficients [8] … Note that these models involve generally two nested meshes and they can be very heavy for this reason: hence the definition of reduced-order models is important.

The aims of this thesis are: 1) to discuss double scale methodologies that are able to describe the behavior just before failure, which requires a macroscopic model with internal length; 2) to define reduced-order models permitting fast failure computations; 3) to apply these methodologies to computational failure mechanics of structures and to simulations of fabrication processes.

Main stages of the project

1. Coupling of post-bifurcation projection techniques and computational homogenization. Application to wrinkling of membranes and surfaces.
2. Reduced-order models in the case of long fiber composite materials.
3. Computational homogenization with internal length for polycrystalline metals and application to metal forming.

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Application:
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15) Optimization of an industrial PVD system - Study of hard layers for mechanical applications

Laboratoire Bourguignon des Matériaux et Procédés (LaBoMaP-EA 3633) - Laboratory Arts et Métiers ParisTech

Location: the research will be carried out on the LaBoMaP laboratory at Cluny (collaboration of the Metal machining, Wood and Materials teams of this lab) and also in collaboration with R&D partners (ICB of University of Burgundy-Dijon, MSMP of Arts et Métiers Paris of Lille and Aix-en-Provence, FEMTO-ST of Besançon) and industrial partners (Forézienne-MFLS (wood tool maker) and FPInnovations-Québec (Forest Research Centre)).

Subject: Optimization of the deposition conditions and determination of the limits of an industrial PVD system. Study of hard layers on different (materials and geometry) wood and metal cutting tools obtained in the optimized design of the PVD system.

Context: On the horizon 2020, wood will make important contributions in reaching the objectives of the European Union, in particular in terms of environmental sustainability in housing (ie. better insulation, building homes with positive energy). In France, Grenelle Environnement highlighted the interests in using more wood in the building industry. For these various reasons, developing wood employment in construction is carried by a political will of the European Union, States and Regions with a measure of autonomy. Besides, “Wood Industry” is now one of the 34 strategic sectors identified by François Hollande, the French Republic President, after his speech in September 2013. Over the next 10 years, wood manufacturing will need to develop and adapt to the demands from the construction industry. This will require the adaptation and the improvement of the current tools used in the primary and secondary processing of wood. One solution for this improvement in wood cutting tools is surface treatment, a field of research almost nonexistent in industry.

Even if the hard coatings are used since the 70s in manufacturing metal, the industrial demand in this sector makes more and more pressing in particular because of the use of new more successful materials (in aeronautical, aerospace, automobile…) and thus requiring permanently to improve the durability of cutting devices used for their shaping.

Surface treatments such as PVD hard layers are one of the solutions to improve the durability of these cutting tools for metal and wood industry. This study will come in support of a study planned within the framework of a program ANR 2014-2018.

Objectives of the study: this study aims to optimize the parameters of an industrial (4 plan and rectangular magnetron cathodes) PVD system. The first objective of this study will consist in the determination of the limits of the machine in terms of deposition conditions such as targets bias voltage (RF, DC and pulsed DC polarization); time deposition; heating during deposition; gas mixture (constant or pulsed injection of the reactive gas); working pressure; position of the substrates on the substrate-holder (homogeneity of the coating); substrate-holder in rotation or not (variation of the velocity), in static position or oscillating in front of the target; position of substrates and substrate-holder to obtain multilayers or supperlattices with this system…The second objective of the study is to define the limits of this system in terms of substrates capacities: to optimize the position of the substrates on the substrate-holder according to their type (Si, steel or carbides samples, cutting tools…) and their geometry, to optimize the number of substrates that can be coated per process according to their geometry and to the part that has to be protected. These experiences will be made with well-known hard layers such as CrN or CrMeN (with Me=metalloid). The cutting devices will be provided by our industrial partners for metal and wood machining. The candidate will have to design new substrate-holders if necessary. Finally, after all the limits of the system known, the candidate will apply optimized hard coatings on cutting tools to be tested in metal and wood industry by our industrial partners.

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Profile of the candidate: the candidate should have a master degree in experimental materials and engineering and especially in surface treatments. A previous experience in the area of PVD (or CVD) coatings will be highly appreciated. Experimental mechanics and software knowledge such as Catia, SolidWorks… would be also necessary for this study. The candidate must be motivated and curious in his work, he will have to know how to take initiatives and decisions, propose alternatives or ideas in front of unforeseen, become integrated quickly into the laboratory, work in team, and naturally be quickly autonomous.

Keywords: industrial PVD system, deposition parameters, capacities of use, substrates capacities, hard layers, cutting tools, metal and wood industry.

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16) Analysis of abrasion-induced damage during brittle material finishing: A multigrain approach to model the micromechanical contact

Duration: 36 months
Support: China Scholarship Council (CSC)
University: Arts et Métiers Paris Tech
Location: Châlons-en-Champagne, France.
Starting date: October 2014

Keywords: Abrasion, damage, multigrain contact, brittle materials, surface integrity.

The process of removing material influences the life and quality of the surfaces of brittle materials such as glass. Generally, grinding process is considered as one of the most efficient and cost-effective technique to manufacture optical components. However, due to the hard and brittle nature of optical glass, ground specimen often contains brittle damages. The subsurface damages (SSD), i.e., subsurface micro-cracks, strongly affect the mechanical strength and the optical quality of optical glasses [1, 2]. The mechanism of removing material is not really understood. In fact, grinding process involves numerous parameters that can be classified in three categories:

- Tool parameters: abrasive nature, size and shape of wheel, bond material…
- Machining parameters: depth of cut, feed rate, wheel speed, grinding direction
- Contact parameters: lubricant type, temperature, flows…

All of these parameters make difficult the understanding of the mechanisms of grinding process. However, in order to understand the fundamental fracture characteristics of optical glasses during grinding, an experimental works is conducted in the laboratory to study the influence of process parameters (cut of depth, feed rate) [3] and wheel parameters [4] on surface finishing quality. Three different damage regimes have been observed:

- Regime I: partial ductile with cutting action accompanied by chip formation.
- Regime II: crushing or fragmentation regime.
- Regime III: partial ductile by ploughing action with the displaced material

This regime generated surface with different characteristics. Many other researchers identified equivalent regimes: brittle mode, semi-brittle mode, semi ductile mode and ductile mode [5-10].
Another approach is to consider indentation and scratch processes to understand behavior of grinding process [11-14]. These processes involve the interaction between the abrasive gains and the specimen. The indentation and scratch processes in brittle mode usually involve two principal crack systems: (i) lateral cracking responsible for material removal and surface formation, (ii) radial/median cracking for strength degradation. However, processes cannot capture the cumulative nature of grinding during which interactions lay occur between neighboring grits. This fact influences therefore the process of material removal.
These mechanisms greatly influence the depth of sub surface damage (SSD). In some application, the removal or minimization of SSD depth is required for improving material strength. Some works studied the depth of SSD as a function of grinding parameters [15, 16]. This leads to a relationship between roughness and SSD depth [15]. However, various physical mechanisms are not well understood.
In this context, a better understanding of material removal mechanisms is related to a decomposition of tool on a finite numbers of grits (minimum 3). This decomposition eliminates the large number and random nature of grains in the grinding wheel. In comparison to the case of single grits, interaction between neighboring grits could be studied in terms of force analysis, surface topography, surface damage and mechanical surface parameters. Various number of grit and arrangement of grits will be test. In parallel, numerical simulations will be undertaken to have additional information (stress, strain, SSD depth prediction…) to complete the comparison. The ultimate goal is to extrapolate the results to the case of process with wheel (a large number of grits).

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17) Optimal control of an Atomic Force Microscope (AFM) for nano-machining applications

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Associate supervisor (IMME, Cardiff School of Engineering, Cardiff University)
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Keywords: AFM Probe based nano machining, optimal control, tip path trajectories, real-time control, CAD/CAM, automation.

Based on its on-going collaboration with Cardiff University, the Laboratory of Information Sciences and Systems (LSIS - UMR CNRS n° 7296) proposes a research program for a PhD study concerning the improvement and optimization of the AFM probe-based nano machining control. In particular, the main aim is to develop a novel approach to obtain an efficient machining at nano-scale by a freely range of motion and with a high level of automation. Control also needs to be optimized, to obtain accurate machining with a predictable height profile.
Fig 1 shows the AFM probe based machining principle and Fig 2 shows Cardiff University's AFM (XE-100 model from Park Systems).

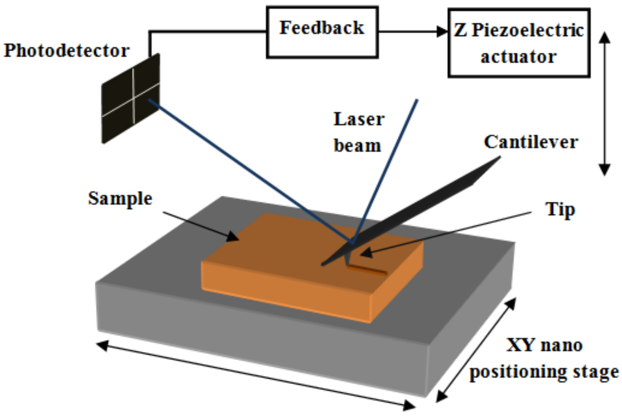

Fig 1: AFM probe-based machining principle

Fig 2: XE-100 AFM from Park Systems

The subject of this proposal is motivated by the further development of this machining technique which can produce features with nanometer dimensions as it represents a cost-effective alternative to vacuum-based manufacturing processes. For instance, recent collaboration between ParisTech of Lille and Cardiff showed the applicability of the technique for the fabrication of nano structured moulds. These masters were then used for the production of complex nanostructure components by micro injection moulding [2,3] (Fig 3).

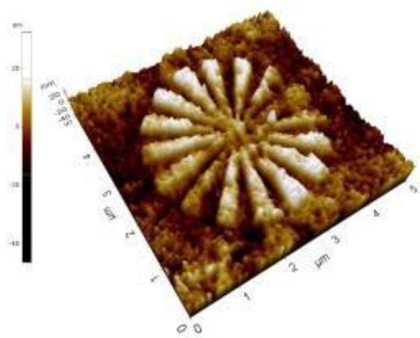

Fig 3: A micro injected polymer replica from a mould fabricated with AFM probe-based machining

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The Atomic Force Microscope (AFM) was originally developed for the purpose of imaging [7], and thus, by default, the typical path followed by the tip of an AFM probe implements a raster scan strategy. Fig 4 shows a machining with a raster scan strategy.
Although some AFM manufacturers provide software modules to perform lithography operations, such solutions can be limited with respect to

- the range of tip motions that can be developed,
- the flexibility in realizing desired defined tip displacement strategies,
- their portability for easily transferring tip trajectories data between different AFM instruments.

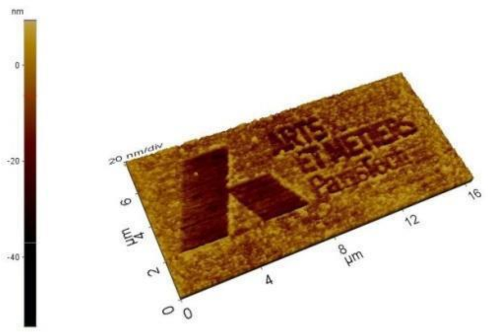

Fig 4: Arts et Métiers Paris Tech Logo machining with AFM
(size: 16µm by 8µm and depth around 20nm)

Efforts to unlock these limits have only been conducted by a few researchers in recent years (in particular [4]). In [1], the feasibility of integrated widespread CAD/CAM solutions with an AFM instrument, in order to conduct AFM probe-based nano machining operations with a high level of automation and a larger range of tip path motions, was shown and implemented on Cardiff University's AFM (see Fig 5).

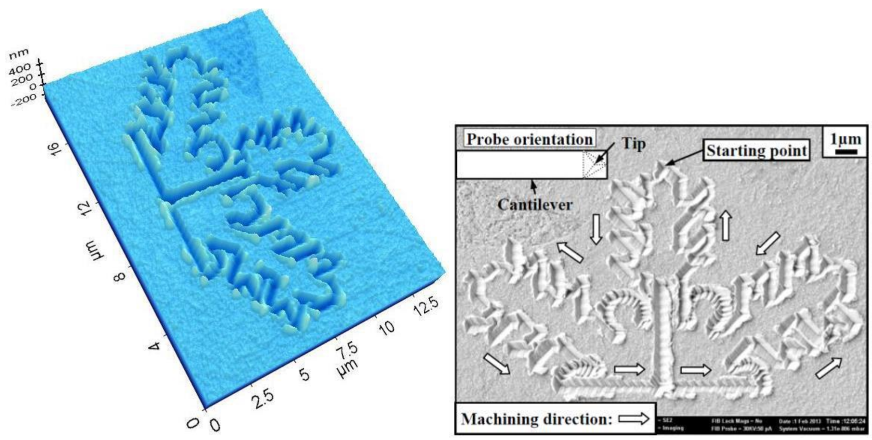

Fig 5: Machining of a half snow-flake pattern by the CAD/CAM approach developed between Cardiff and ParisTech of Lille

However, this study showed that relative important machining errors occur depending on the tip direction during the machining and the stiffness of the AFM's probe.
The approach developed in [1] and new equipment highlight issues to produce efficiently machining of complex nanostructures. In this context, the PhD candidate will conduct the following studies:

- Control the XY nano positioning table by CNC (Computer Numerical Command) approach, with a National Instrumental equipment, for a motion freedom.
  The first step is to define from the CAD model of the desired pattern, the tip path machining trajectories along polynomials splines curves [5,6]. The dynamic behavior of the system will have to be taken into account for defining the kinematic laws to be applied to the nano positioning table. The second step is to improve the development of the post-processor between the CAD software and the control algorithm.

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- Study the influence of strategies for tip trajectories on the efficiency and quality of the obtained patterns when machining at such small scale.
- Reduce machining errors and improve the quality/efficiency of machining, using both the development of a predictive model error, and real-time control methods algorithms based on algebraic approaches. By the predictive model error, corrections of the tip path trajectory could be done by anticipation, and the efficiency of the three axis control could be improved using the real-time control to improve both the precision and the quality of the height profile.

Research activities will take place at Arts et Métiers ParisTech of Lille on a nano XY positioning table (see Fig 6). The PhD student will realize nano machining experiments, both at Arts et Métiers ParisTech of Lille and on Cardiff University's AFM.

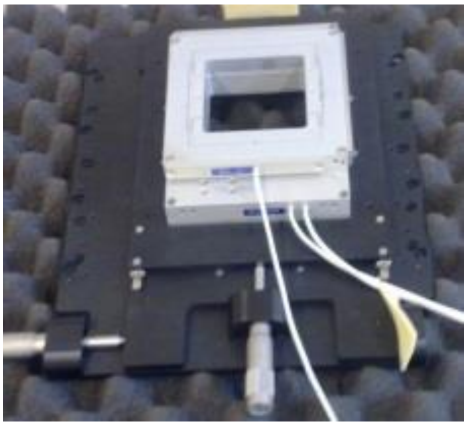

Fig 6: The nano XY positioning table (PDQ series – MadCityLabs) available at Arts et Métiers ParisTech of Lille

We expect candidates having strong mathematic skills and good control theory skills. Candidates having good skills in programming (C or C++) and a very good scientific ethic will be appreciated.

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18) On the thermal and environmental performance evaluation of Solar Decathlon Europe 2014 movable building prototypes, in their local context, by the use of measurements in Versailles context: Application to the definition, design and dimensioning of the prototype for the participation of Aquitaine Region to Solar Decathlon China

Key words: Sustainable buildings, Thermal and environmental performance, Thermal and environmental metrologies.
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Research Laboratories: I2M-Bordeaux (student location)

Solar Decathlon Europe is an international competition among universities which promotes research in the development of efficient houses. The objective of the participating teams is to design and build houses that consume as few natural resources as possible and produce minimum waste products during their life cycle. Particular emphasis is put on reducing energy consumption and on obtaining all the necessary energy from the sun.

Arts et Métiers ParisTech (www.ensam.eu), in collaboration particularly with the Civil Engineering Department at the Institut d'Enseignement Technologique de Bordeaux (http://www.iut.u-bordeaux1.fr/gc/www/index.php) and Nobatek (www.nobatek.com), took part in Solar Decathlon Europe 2010 and 2012 in Madrid (http://www.sdeurope.org/). In 2014, this competition will be hosted in France, at the château of Versailles in the gardens of the Sun king (http://www.solardecathlon2014.fr/fr), and Arts et Métiers ParisTech is the Engineer School active member of the steering commitee.

A consortium composed of Arts et Métiers ParisTech, Nobatek and the Civil Engineering Department at the Institut d'Enseignement Technologique de Bordeaux is responsible for setting up the monitoring and the thermal and environmental assessment of the houses in competition at Versailles in 2014. This assessment combines two issues: (1) defining and setting up appropriate measuring systems at the Solar Decathlon Europe 2014 competition site, (2) defining and setting up a digital tool to assess the performances of the houses, in a real life situation (in their home region), based on the measurements taken during the competition in 2014 at Versailles. After the Solar Decathlon Europe 2014 competition, this assessment will be used to exploit all the data and measurements from all 20 participating houses.

The aim of this PhD thesis is, first, to deal with the two issues described above, and then to use the data from the 20 houses in competition at Versailles in 2014 to define efficient, tried and tested strategies to design autonomous solar buildings. This definition will lead to an Aquitaine Region candidature and hopefully participation to Solar Decathlon in China 2015. The preparation of this participation will be done in two stages: (1) definition of the architecture of the planned building project, and (2) definition of the planned energy strategy (and associated or existing energy systems, and/or any that have yet to be designed and produced).

This PhD thesis will be prepared in Bordeaux. Registration will take place at the Combined Doctoral School of "Sciences et Métiers de l'Ingénieur" at "Arts et Métiers ParisTech" and "Mines ParisTech" (http://edsmi.ensam.eu/). There will be regular working meetings in Paris (at the Ministry of Ecology, Sustainable Development and Energy) and in Marne la Vallée (at CSTB - Scientific and Technical Centre for Building).

The successful candidate must have the appropriate competence in mechanics and thermal science. He/She must speak and write English with ease. He/She will join a team of researchers and software developers working in the field of Thermal techniques in Buildings and renewable energies.

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19) Digital mock-up management for the visualization of complex technical data in multiple dimensions

PhD subject description

The **digital mock-up (DMU)** is an exhaustive representation of a complex object, it contains not only its **geometric model** but also its properties and characteristics which are called **multiple-dimensional technical data** in the domain of industrial engineering. The DMU is created in order to study all the data it contains. Therefore, the geometry of the object and the technical data must be visualized. For example, in automotive industry the technical data could be relative to the resistance of the chosen material or the heat transfer characteristics of this material. In the domain of petroleum industry the geological strata with their mechanical constraints are considered as technical data in the DMU.

Thus the DMU is usually very heavy in terms of the information quantity it contains, complex shape of the geometry as well as the technical data attached to each position and each moment of the object. On the other hand **concurrent engineering** is developing since many years and replaces sequential engineering. For example the multiple-site collaboration is becoming a common practice between the design office and production/maintenance site. The device used by the second one on-site to visualize the DMU could be very poor in terms of computational performance such as tablet or smartphones. The huge amount of the necessary data generated by the DMU is loaded in the light device available on-site, this could make **real time** interaction with the DMU such as visualization, selection and editing the geometry and the technical data impossible due to the load of processing.

Many existing research have been focused on the **geometry simplification** in terms of resolution and topology. These proposed approaches allow controlling the degree of the shape fidelity with the initial geometry according to the rate of reduction of the geometric data. Some simplification methods are also taking into account the criteria of visual perception thus they are better adapted to the real time interaction with a user. However there is very few work proposing approaches allowing geometry simplification driven by the **pertinence of information** based on the technical data selected by the users. The papers [1 – 3] propose methods of geometry simplification based on the criteria relative to one dimension particular semantic data. However, the real industrial needs consist of working with the DMU that is attached with technical data of a very important number (more than 100) of dimensions and during the project review some dimensions would be selected by the users. For example the geological strata of terrain could be the technical data of various sciences such as the material composition, the resistance of material, the rate of heat flow, etc.

Within the context of the above raised issue, the identified **scientific research questions** for this PhD subject are the following:

- How to simplify the geometry under the constraints of taking into account the technical data of selected dimensions?
- How to adapt automatically and in real time the simplified geometry to different combinations of technical data selections?

A preliminary **idea suggested** for this PhD thesis consist of elaborating **new simplification paradigms** of the DMU specific to numerical engineering. The geometry **fragmentation** according to the type of the technical data would be investigated. Each fragment would be available in the **different resolutions** corresponding to different level of details (LOD) for the technical data. The **reassembling** of fragments could be carried out according to the **combination** of the technical data, to the **hierarchy** for the user of the technical data to visualize as well as to the other criteria for the visualization of multi-dimensional data.

Keywords

Digital Mock-Up (DMU), Interactive visualization, Mesh, Multi-dimensional technical data

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Application:
Please send your CV and motivation letter by email to the PhD supervisor with copy to your University International Office and to Yvon VELOT (yvon.velot@ensam.eu).
If selected, you should then apply for scholarship to the Chinese Scholarship Council (CSC) through your University International Office.

The profile of the PhD candidate would better include:

- Applied mathematics, numerical methods.
- Computer graphics, geometric modeling, Computer Aided Design.
- Algorithmic, C/C++ programming.

Candidature: send CV + motivation letter to the above mentioned contacts.

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