Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics,

Subfield: Mechanical Engineering, Numerical Methods, Applied Mathematics

Title: Topology Optimization of Additive Manufactured Parts including fatigue behavior

ParisTech School: Arts et Métiers ParisTech (collaboration with NIIAM)

France Advisors (PIMM laboratory):
Pr. Véronique FAVIER(veronique.favier@ensam.eu)
Dr. Imade KOUTIRI (imade.koutiri@ensam.eu)
Dr. Eric MONTEIRO (eric.monteiro@ensam.eu)

Short description of possible research topics for a PhD:

In additive manufacturing processes, parts are manufactured layer by layer. Such technics allow the creation of complex structural designs that other classical processes cannot produce. Efficient numerical tools to generate automatically optimal structure satisfying some requirements are provided by topological optimization methods. However, standard topological optimization formulations for light weighting produce designs with stress concentrations and singularities that cause a reduction in fatigue life. The proposed work deals with the development of a new numerical tool to design lightweight but also fatigue-constrained topologically optimized structures for additive manufacturing with the SLM process. The prediction of this new tool will be compared to some experimental results generated during the thesis. This Phd thesis is a collaboration with the NIIAM (national institute and innovation of additive manufacturing). It will take plane in the laboratory PIMM (in Arts et Métiers Paristech school) in Paris.

Required background of the student:
The candidate should have a strong background in Mechanical Engineering, Materials Science and Engineering or Numerical Methods. Although prior knowledge of the French language is not mandatory, spoken and written English proficiency is needed.

A list of 5(max.) representative publications of the group: (Related to the research topic)

- N. Torabian, V. Favier, J. Dirrenberger, F. Adamski, S. Ziaei-Rad, S., N. Ranc, Correlation of the high and very high cycle fatigue response of ferrite based steels with strain rate-temperature conditions, Acta Materialia, 134, 40-52, 2017.
- Koutiri, E. Pessard, P. Peyre, O. Amlou, T. DeTerris, Influence of SLM process parameters on the surface finish, porosity rate and fatigue behavior of as-built Inconel 625 parts, Journal of Materials Processing Technology 255, 536-546, 2018.
- E. Monteiro, H.-B. Ly, G. Regnier, M. Dal, On the factors affecting porosity dissolution in Selective Laser Sintering Process, AIP Conference Proceedings 1960, 120014, 2018.

Research Topic for the ParisTech/CSC PhD Program

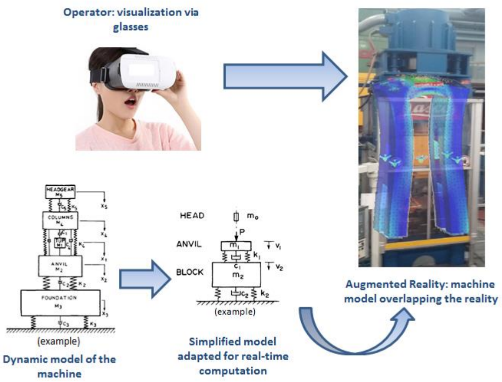
Field: Design, Industrialization

Subfield: Mechanical Engineering, Structural dynamic
Title: Toward Augmented Reality in forging processes

ParisTech School: Arts et Métiers ParisTech (Metz Campus)

Advisor(s) Name: Pr. BIGOT Régis, DURAND Camille, BAUDOUIN Cyrille
Advisor(s) Email: regis.bigot@ensam.eu; camille.durand@ensam.eu; cyrille.baudouin@ensam.eu
Research group/Lab: LCFC Design, Manufacturing Engineering and Control Laboratory
(Lab/Advisor website): LCFC, http://lcfc.ensam.eu/

Short description of possible research topics for a PhD: (10-15 lines in English + optional figure)
In the forging industry, there is a great contrast between the reality of the production with forging operations mostly performed by humans with the help of machines that are not instrumented and the stringent requirements of production tracking, quality control and flexible production. To fill that gap, the forging machine behavior has to be studied and modeled. The objective of the thesis could be to develop a dynamic and predictive model of energy restricted forging machines and to identify the model parameters through experiments. Once the dynamic model developed and validated, a simplified model should be deduced with parameters describing one forging context. This simplified machine model will be then coupled with a material and process model, to be able to simulate any forging operations. The response of the coupled models should be then visualized in Augmented Reality. This thesis aims at pushing the machine modelling forward to reach real-time prediction of machine reactions.



Required background of the student:
The candidate should have a good background in mechanical engineering and in mathematics, especially in solid mechanics. Experimental skills or experience of Finite Element Method in mechanics would be appreciated. Knowledge of metal forming processes would be useful.

A list of 5(max.) representative publications of the group: (Related to the research topic)

R. Ly, C. Giraud-Audine, G. Abba, R. Bigot, Experimentally validated approach for the simulation of the forging process using mechanical vibration, *Int. J. of Material Forming,* p.133-136, (2009)

C. Giraud-Audine, T.H. NGuyen, B Lemaire-Semail, G Abba, R Bigot, Modelling of forging processes assisted by piezoelectric actuators : principles and experimental validation, *IEEE Transactions on Industry Applications*, Vol. 50, n°1, p.244-252, (2014)

C. Durand, R. Bigot, C. Baudouin, Contribution to the characterization of metal forming machines: application to screw presses, *17th Int. Conf. on Metal Forming,* Toyohashi, Japan, 2018.

JF. Mull, C. Durand, C. Baudouin, R. Bigot, M. Borsenberger, Validation of a purely elastic model and a Finite Element model of a screw press, *22nd Int. Conf. on Material Forming ESAFORM* (2019)

Fields:
Economics, Management and Social Sciences
Energy, Processes
Design, Industrialization

Subfield: (Applied Physics, Chemistry, Mathematics, Mech. Eng. etc…)

Title: Energy Efficient Reconfigurable Manufacturing Systems (EE-RMS)

ParisTech School: Arts et Metiers

Advisor(s) Name:
Ali SIADAT
Lyes BENYOUCEF
Advisor(s) Email:
Ali.siadat@ensam.eu
lyes.benyoucef@lis-lab.fr

Research group/Lab:
LCFC - http://lcfc.ensam.eu
LSIS - https://www.lis-lab.fr

Short description of possible research topics for a PhD: (10-15 lines in English + optional figure)
To be relevant in nowadays' highly competitive market, the manufacturing system of a company has to be, simultaneously, cost and time efficient and environmentally harmless. According to a visionary report of Manufacturing Challenges 2020 conducted in USA, this trend will continue, and one of the six grand challenges of this visionary report is "*the ability to reconfigure manufacturing systems rapidly in response to changing needs and opportunities*" (National Research Council, 1998). Moreover, due to the escalation in fuel prices, higher tariff for electrical use and environmental legislations, the reduction in energy consumption and carbon footprint has become the need of the hour in the manufacturing sector.
Reconfigurable manufacturing system (RMS) is one of the latest manufacturing paradigms (Koren, 2010). In this paradigm, machine components, machines software's or material handling units can be added, removed, modified or interchanged as needed and when imposed by the necessity to react and respond rapidly and cost-effectively to changing requirements. RMS is regarded as a convenient manufacturing paradigm for variety productions as well as a flexible enabler for this variety. Hence, it is a logical evolution of the two manufacturing systems already used in the industries respectively dedicated manufacturing lines (DML) and flexible manufacturing systems (FMS). Nowadays, RMS is a very active research field where multiple state of the arts have been dedicated covering many areas, such as design, layout optimization, reconfigurable control, process planning and production scheduling (Benyoucef, 2020). The main goal of this PhD. project is to achieve a sustainable reconfigurable manufacturing system (S-RMS) through energy optimization.

Required background of the student: (Which should be the main field of study of the applicant before applying)
Mechanical Engineering, Industrial Engineering, Management Science

A list of 5(max.) representative publications of the group: (Related to the research topic)

Benyoucef L. (2020). Reconfigurable manufacturing systems: from design to implementation. Springer Series in Advanced Manufacturing, ISBN: 978-3-030-28782-5.
Koren Y. (2010). The global manufacturing revolution: product-process-business integration and reconfigurable systems. Volume 80. John Wiley and Sons.
National Research Council (1998) Visionary manufacturing challenges for 2020. Committee on visionary manufacturing challenges, board on manufacturing and engineering design, com- mission on engineering and technical systems. National academy press.
Qing XIA, Alain ETIENNE, Jean-Yves DANTAN, Ali SIADAT, « Reconfigurable machining process planning for part variety in new manufacturing paradigms: Definitions, models and framework", Computers and Industrial Engineering, Volume 115, pp. 206-219, 2018

Research Topic for the ParisTech/CSC PhD Program

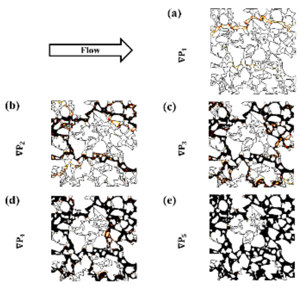
Fields: Environment Science and Technology, Sustainable Development, Geosciences; Chemistry, Physical Chemistry and Chemical Engineering; Energy, Processes; Materials Science, Mechanics, Fluids.
Subfield: Experimental Fluid Mechanics in Porous Media.

Title: An environmentally-friendly porosimetry method for core characterization in Geosciences based on the injection of yield stress fluids

ParisTech School: Ecole Nationale Supérieure d'Arts et Métiers.

Advisor(s) Name:
Pr. Azita AHMADI-SÉNICHAULT
Dr. Antonio RODRÍGUEZ DE CASTRO
Pr. Abdelaziz OMARI
Advisor(s) Email:
azita.ahmadi-senichault@u-bordeaux.fr
antonio.rodriguezdecastro@ensam.eu
abdelaziz.Omari@enscbp.fr
Lab, website:
Institut de Mécanique et d'Ingénierie de Bordeaux (I2M)
https://www.i2m.u-bordeaux.fr/Recherche/TREFLE-Transfert-Fluide-Energetique

Short description of possible research topics for a PhD: (10-15 lines in English + optional figure)
The Yield Stress fluids porosimetry Method (YSM) to characterize Pore Size Distribution (PSD) of porous media was recently presented as a clean alternative to toxic Mercury Intrusion Porosimetry (MIP). It consists in measuring the flow rate Q at several pressure gradients ∇P during flow experiments of yield stress fluids through porous media. PSD is essential in many industrial processes such as Enhanced Oil Recovery (EOR) or soil remediation. The objective of this PhD thesis is to improve YSM method in order to meet the industrial standards of robustness, accuracy and reliability. To do so, laboratory flow experiments will be conducted on a set of porous media with increasing complexity: 1) microfluidic chips with cylindrical patterns, 2) model granular media formed by packs of spherical glass beads with monomodal or bimodal particle sizes, 3) packs of glass beads with markedly different particle sizes and 4) real or reconstructed heterogeneous 3D porous media. The obtained PSDs will then be compared to those provided by well-established porosimetry techniques, such as X-ray micro tomography and MIP. In parallel to laboratory experiments, the method used to extract PSD from the (Q, ∇P) measurements will be improved on the basis of pore-network modelling approaches by considering variable cross-section and connectivity of the pores.



Shear viscosity maps showing the patterns produced by a yield stress fluid flowing through a sand pack under different pressure gradients ($\nabla P_1 < \nabla P_2 < \nabla P_3 < \nabla P_4 < \nabla P_5$). Dark areas represent the regions in which the fluid flows.

Required background of the student: A solid theoretical and experimental understanding of the fundamentals of fluid mechanics is required. The principles of mathematical programming and numerical methods must be known. Performing experiments requires dexterity, autonomy and meticulousness.

A list of 5(max.) representative publications of the group: (Related to the research topic)

- Rodríguez de Castro, A., Agnaou, M., Ahmadi-Sénichault, A., Omari, A., Application of non-toxic Yield Stress fluids porosimetry Method and Pore-Network Modelling to characterize the Pore Size Distribution of packs of spherical beads. Transport in Porous Media 130(3), 799 – 818 (2019). https://doi.org/10.1007/s11242-019-01339-2
- Rodríguez de Castro, A., Ahmadi-Sénichault, A., Omari, A., Using Xanthan Gum Solutions to Characterize Porous Media with the Yield Stress Fluid Porosimetry Method: Robustness of the Method and Effects of Polymer Concentration, Transport in Porous Media 122(2), 357 – 374 (2018). http://doi.org/10.1007/s11242-018-1011-8
- Rodríguez de Castro, A., Ahmadi-Sénichault, A., Omari, A., Savin, S., Madariaga, L.-F., Characterizing porous media with the Yield Stress Fluids porosimetry Method, Transport in Porous Media 114, 213-233 (2016). http://dx.doi.org/10.1007/s11242-016-0734-7
- Rodríguez de Castro, A., Omari, A., Ahmadi-Sénichault, A., Bruneau, D., Toward a New method of Porosimetry: Principles and Experiments, Transport in Porous Media, 101, 349-364 (2014). http://dx.doi.org/10.1007/s11242-013-0248-5

Research Topic for the ParisTech/CSC PhD Program

Field : Design, Industrialization

Subfield (Applied Physics, Chemistry, Mathematics, Mech. Eng. etc…) : robotic manufacturing, grinding, finishing process, forged workpieces.

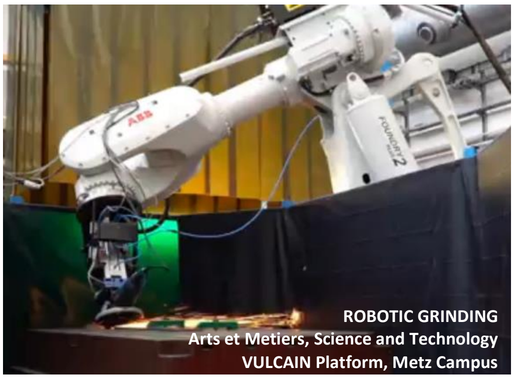
Title : Automation of a flexible and agile finishing process of forged workpieces with industrial robots.

ParisTech School: Arts et Métiers ParisTech

Advisor(s) Name: Pr. BIGOT Régis, BAUDOUIN Cyrille, DURAND Camille
Advisor(s) Email: regis.bigot@ensam.eu ; cyrille.baudouin@ensam.eu ; camille.durand@ensam.eu
(Lab, website): LCFC, http://lcfc.ensam.eu/

Short description of possible research topics for a PhD: (10-15 lines in English + optional figure)

Grinding is necessary to remove overage parts from forged workpieces (flash, surface imperfections, oxide encrustation, etc.). Finishing processes of forged workpieces are still done manually in most cases. Automation of the finishing process is expected to eliminate the manual operations of high hardness that can lead to musculoskeletal disorders and productivity decrease. Greater accuracy and repeatability of operations is hoped. However, at the end of a forging operation, each piece is unique, and is the image of the accumulation of all process variabilities. The artificial intelligence would be able to control the robot to perform grinding according to observations made on the workpiece. In the meantime, this PhD consists in **creating and deploying a methodology that would allow an effective collaboration between the observation of a workpiece and the interpretation made by an operator and the realization of the expected operations by a robot** in a context of industrial productivity. The robot must be able to understand human-like instructions (by gesture, graphics or digital interface). The robotic grinding must also be able to provide a desired geometry or surface roughness despite variations originating from the upstream phases of the process. Robotic grinding has to be able to master the interactions between grinding tool and material, vibrations, robot paths, and forces applied during grinding.



Required background of the student :

- Knowledge in robotics, manufacturing (grinding) if possible
- Computing
- Applied mechanics

A list of 5(max.) representative publications of the group: (Related to the research topic)

Mohamed DIDI CHAOUI, François LEONARD, Gabriel ABBA – Improving Surface Roughness in Robotic Grinding Process. In: Arakelian V., Wenger P. (eds) ROMANSY 22 – Robot Design, Dynamics and Control. CISM International Centre for Mechanical Sciences (Courses and Lectures), vol 584. 2019. Springer, Cham. Doi:10.1007/978-3-319-78963-7_46

Laurent LANGLOIS, Sandra ZIMMER-CHEVRET, Amarilys BEN ATTAR, Nejah JEMAL, Jonathan HATSCH, Gabriel ABBA, Régis BIGOT - Robotized FSW – Evolution of forces and torque with nonlinear welds - In: 10th International Friction Stir Welding Symposium, China, 2014-05-19 - Proceedings of the 10th IFSWS' 2014 - 2014

Sandra ZIMMER-CHEVRET, Nejah JEMAL, Laurent LANGLOIS, Amarilys BEN ATTAR, Jonathan HATSCH, Gabriel ABBA, Régis BIGOT - FSW process tolerance according to the position and orientation of the tool: requirement for the means of production design – Materials Science Forum - Vol. 783-786, p.1820-1825 – 2014

Jinna QIN, François LEONARD, Gabriel ABBA - Nonlinear Discrete Observer for Flexibility Compensation of Industrial Robots - In: IFAC World Congress 2014, South Africa, 2014-08-24 - Proceedings of IFAC World Congress 2014 – 2014

Sandra ZIMMER-CHEVRET, Laurent LANGLOIS, Julien LAYE, Jean-Claude GOUSSAIN, Patrick MARTIN, Régis BIGOT - Qualification of a robotized Friction Stir Welding System - In: INTERNATIONAL CONFERENCE ON SCIENTIFIC AND TECHNICAL ADVANCES ON FRICTION STIR WELDING AND PROCESSING, France, 2010-01-27 - Proceedings of the FSWP'2010 – 2010

Research Topic for the ParisTech/CSC PhD Program

Field: Materials Science, Mechanics, Fluids
Subfield: Mechanical Engineering
Title: Improvement of the prediction of the ductility limit of polycrystalline materials by using relevant multiscale schemes.
ParisTech School: Arts et Métiers (ENSAM, Metz Campus)
Advisor(s):
- Farid ABED-MERAIM (Full Professor, LEM3): farid.abed-meraim@ensam.eu
- Mohamed BEN BETTAIEB (Associate Professor, LEM3): mohamed.benbettaieb@ensam.eu

Short description of possible research topics for a PhD:
The proposed PhD project aims to improve the capability of the developed numerical methods and tools in the prediction of the ductility limit of polycrystalline metallic sheets by using some relevant multiscale approaches. To reach this goal, the most advanced developments in the field of the modeling of the mechanical behavior at the microscopic scale and of multiscale schemes will be carefully analyzed and explored. At the microscopic scale, the existing models will be improved and extended to take into account the effect on the ductility predictions of some microstructural phenomena not sufficiently analyzed in the previous contributions (such as twinning for hcp materials, the non-Schmid effects, intragranular and intergranular damage). An extensive study will be carried out also to further understand the effect of other microstructural parameters on the ductility (such as morphologic and crystallographic texture and the evolution of crystallographic dislocation density). At the macroscopic level, the effect of the multiscale schemes on the prediction of the ductility limit of polycrystalline aggregates will be particularly analyzed. In this aim, the numerical predictions obtained by using the self-consistent multiscale scheme (developed by our team) will be compared with the predictions determined by the periodic homogenization technique and the FFT method. The numerical tools developed in this thesis will be validated by comparing the numerical predictions to several experimental results achieved by partnership research teams. Once validated, these numerical tools will be used, in academic and industrial contexts, to provide guidelines and assistance in the design of new generation of metallic alloys with improved ductility.

Required background of the student:
Computational mechanics, Material behavior, Sheet metal forming processes

A list of 5(max.) representative publications of the group:
[1] Franz, G., Abed-Meraim, F., Lorrain, J. P., Zineb, T. B., Lemoine, X., & Berveiller, M. (2009). Ellipticity loss analysis for tangent moduli deduced from a large strain elastic–plastic self-consistent model. *Int. J. Plast.*, *25*(2), 205–238.

[2] Franz, G., Abed-Meraim, F., & Berveiller, M. (2013). Strain localization analysis for single crystals and polycrystals: Towards microstructure-ductility linkage. *Int. J. Plast.*, *48*, 1–33.

[3] Akpama, H.K., Ben Bettaieb, M., & Abed-Meraim, F. (2016). Numerical integration of rate-independent BCC single crystal plasticity models: comparative study of two classes of numerical algorithms. *Int. J. Num. Meth. Engng.*, *108*, 363–422.

[4] Akpama H.K., Ben Bettaieb M. & Abed-Meraim F. (2017). Prediction of plastic instability in sheet metals during forming processes using the loss of ellipticity approach. *Latin American Journal of Solids and Structures*, *17*, 1816–1836.

[5] Akpama H.K., Ben Bettaieb M. & Abed-Meraim F. (2017). Localized necking predictions based on rate-independent self-consistent polycrystal plasticity: Bifurcation analysis versus imperfection approach. . *Int. J. Plast.*, *91*, 205–237.

Research Topic for the ParisTech/CSC PhD Program

Field: *Mechanics, Materials Science, Fluids*
Subfield: Mechanical engineering, Computational mechanics, Mechanics of Materials.
Title: **Energy approaches to predict the thermomechanical fatigue life of polymer composites for automotive applications.**
ParisTech School: Arts et Metiers Institute of Technology
Advisor(s) Name: Pr. Fodil Meraghni, Dr. Adil Benaarbia, Dr. George Chatzigeorgiou
Advisor(s) Email: fodil.meraghni@ensam.eu, adil.benaarbia@ensam.eu, georges.chatzigeorgiou@ensam.eu
Research group/Lab: **SMART** research group **/ LEM3 UMR CNRS 7239** National Key Lab (Metz)
Project in the framework of scientific collaboration with University of Freiburg (Germany)

Short description of possible research topics for a PhD:

In the transportation industry, the demand for weight reduction is driven by the demand for better fuel efficiency and reduced emissions. Polymer composites offer lightweight benefits in comparison to other structural metallic materials. However, the complex behavior under multiaxial loading and the lack of a full cradle-to-grave life cycle assessment methodology continue to be the major limiting factors for a rational engineering use of such materials. Considering the recent growing interest for polymer composites in the automotive industry, it seems essential to characterize and model the energy behaviour of such materials under cyclic loading conditions. The analysis of the mechanical, thermal and energy properties of these engineering materials is complicated because of the many parameters involved, for example, the matrix composition, type of reinforcement and the fiber architecture. To achieve successful modelling of the thermomechanical behaviour of such heterogeneous materials, complete energy balances must be determined to enable a primary understanding of the dissipative phenomena (**figure 2**).

This PhD project aims at developing a mixed experimental-modelling investigation geared towards rational design of polymer composites and improved structures, with regards to thermomechanical performance, extended lifetime and sustainability. The main objective consists in the formulation of energy based fatigue criteria accounting for the release of stored energy related to the nonlinear behaviour coupled to damage. This PhD research project will involve powerful set of non-destructive photomechanics (viz. infrared thermography and digital image correlation, **figure 1**) and damage mechanisms characterization (e.g. microtomography) techniques. A good combination of such techniques with advanced finite element simulation tools will yield important scientific research and industrial benefits, for example, optimal design of automotive components subjected to multiaxial fatigue.

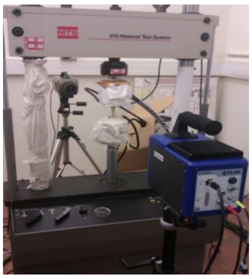


Figure 1: Experimental setup including hydraulic testing machine, infrared camera and visible camera.

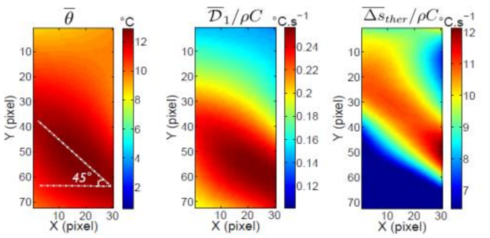


Figure 2: Thermal, dissipation and thermomechanical coupling sources for a fiber reinforced composite oriented at 45°.

Required background of the student:

Applicants should have, or expect to achieve at least a Master's degree (or an equivalent overseas degree) in Mechanical Engineering, Materials Science, Applied Mathematics and/or a related subject. Candidates with suitable experience and strong capacity in numerical modeling, experimental testing and/or measurement skills are particularly welcome to apply.

A list of 5(max.) representative publications of the group: (Related to the research topic)

1- Arif MF., Saintier N., Meraghni F., Fitoussi J., Chemisky Y., Robert G (2014). Multiscale fatigue damage characterization in short glass fiber reinforced polyamide-66. Composites Part B: Engineering 61, 55-65.
2- Arif MF., Meraghni F., Chemisky Y., Despringre N., Robert G (2014). In situ damage mechanisms investigation of PA66/GF30 composite: Effect of relative humidity. Composites Part B: Engineering 58, 487-495.
3- Benaarbia A., Chatzigeorgiou G., Kiefer B., Meraghni F. (2019). A fully coupled thermo-viscoelastic-viscoplastic-damage framework to study the cyclic variability of the Taylor-Quinney coefficient for semi-crystalline polymers. International Journal of Mechanical Sciences 163: 105128.
4- Benaarbia A., Chrysochoos A., Robert G (2015). Thermomechanical behavior of PA6. 6 composites subjected to low cycle fatigue. Composites Part B: Engineering 76, 52-64.
5- Chatzigeorgiou G., Charalambakis N., Chemisky Y., Meraghni F (2018). Thermomechanical Behavior of Dissipative Composite Materials. Elsevier.

Research Topic for the ParisTech/CSC PhD Program

Fields: Design & Industrialization, Computer science, Information and Communication Sciences and Technologies, Mathematics and their applications.

ParisTech School : Arts et Métiers – Laboratory LISPEN Campus of Aix-en-Provence

Title : **Deep learning and multimodal declarative modeling for fast sketching of draft CAD models in the creative design phases**

Advisor(s):
Prof. Dr. Jean-Philippe PERNOT / jean-philippe.pernot@ensam.eu / http://lispen.ensam.eu/
Dr. Arnaud POLETTE / arnaud.polette@ensam.eu / http://lispen.ensam.eu/

Short description of possible research topics for a PhD :
This PhD program addresses the way draft CAD models can be efficiently sketched from a combination of multimodal inputs. Such an approach is particularly interesting in the creative design phases when the shapes are not yet fully defined and when the designer may be interested in describing his/her shapes using multiple modalities. The main idea relies on the development of a new declarative modeling framework which will drive an existing CAD modeler, and/or research prototype software, from a user-specified description combining the use of a dedicated vocabulary/grammar as well as the possible use of low-cost interaction devices. Several modules are foreseen. In a first step, the designer will describe his/her shape using a vocabulary and grammar and possibly using interaction devices such as a Leap Motion or a Kinect. Here, a Convolutional Neural Networks (CNN) will be trained to be able to generate coarse 3D representations from 2D sketches. This will be made possible by means of an ad-hoc combination of shape descriptors. Then, this description will be processed and transformed in a generic shape description, i.e. a set of generic geometric operations that can be used to obtain the shape whatever the CAD modeler or research prototype software are. At this stage, the system will have to manage issues related to the possible incompleteness and/or inconsistency of the user-specified description. Finally, this generic shape description will be transformed in a set of geometric operations specific to a CAD modeler and/or research prototype software. The output of this modeling process will be a draft CAD model to be used and further refined in the later stages of the design process. The proposed framework will be implemented and validated on academic as well as industrial examples.

Required background of the student: Computer science, geometric modeling, computer-aided design

A list of 5 (max.) representative publications of the group:
Cheutet V., Catalano C.E., Pernot J-P., Falcidieno B., Giannini F., Léon J-C., 3D Sketching for aesthetic design using Fully Free Form Deformation Features, Computers & Graphics, vol. 29(6), pp. 916-930, 2005.
Pernot J-P., Falcidieno B., Giannini F., Léon J-C., Incorporating free-form features in aesthetic and engineering product design: State-of-the-art report, Computers in Industry, vol. 59(6), pp. 626-637, 2008.
Gouaty G., Fang L., Michelucci D., Daniel M., Pernot J-P., Raffin R., Lanquetin S., Neveu M., Variational geometric modeling with black box constraints and DAGs, Computer-Aided Design, vol. 75-76, pp. 1-12, 2016.
Décriteau D., Pernot J-P., Daniel M., Towards a declarative modelling approach built on top of a CAD modeller, Computer-Aided Design and Applications, vol. 13(6), pp. 737-746, 2016.
Sadeghi S., Dargon T., Rivest L., Pernot J-P., Capturing and analysing how designers use CAD software, Tools and Methods for Competitive Engineering (TMCE'16), Aix-en-Provence, France, vol. 1, pp. 447-458, 2016.

Research Topic for the ParisTech/CSC PhD Program

Fields: Design & Industrialization, Computer science, Information and Communication Sciences and Technologies, Mathematics and their applications.

ParisTech School : Arts et Métiers – Laboratory LISPEN Campus of Aix-en-Provence

Title : **3D shape analysis from 2D images using deep neural networks trained on synthetic photorealistic images generated from CAD models**

Advisor(s):
Prof. Dr. Jean-Philippe PERNOT / jean-philippe.pernot@ensam.eu / http://lispen.ensam.eu/
Dr. Arnaud POLETTE / arnaud.polette@ensam.eu / http://lispen.ensam.eu/

Short description of possible research topics for a PhD :

This PhD program aims to implement methods for extracting 3D information from 2D captured images of mechanical products using machine learning. Different applications will be tackled: analysis of complex parts from simple pictures, alignment of geometric elements for augmented reality (e.g. for aided mechanical maintenance), generation of preliminary basic shapes for reverse engineering. However, this kind of deep learning methodology requires a lot of input data, which is not always available depending on the application and domain. In our context, these data do not exist in sufficient quantity due to the difficulty of labelling these large volumes of data. The main idea is to generate artificial databases that allow learning on a sufficient amount of data. Targeted 3D features can be of different types and levels, such as edges or planes at low levels, and CAD features or parts at higher levels. The first step will be to develop and validate an image generation method that is realistic enough to train neural networks to work on real captured data, the generation method can be based on different rendering algorithms (such as raytracing). Since the generation is based on digital CAD models, it becomes possible to automatically link CAD features and geometric elements to the areas of the generated images. Then, the deep neural networks will be designed and trained to be able to estimate 3D features from new real images. The proposed methodologies will be implemented and validated on academic as well as industrial examples through interfaces adapted to different applications.

Required background of the student: Computer science, geometric modeling, computer-aided design

A list of 5 (max.) representative publications of the group:

- Danglade F., Pernot J-P., Véron P., Fine L., “A priori evaluation of simulation models preparation processes using artificial intelligence techniques”, Computers in Industry (2017), vol. 91, pp. 45-61.
- Hu H., Kleiner M., Pernot J-P., “Over-constraints detection and resolution in geometric equation systems”, Computer-Aided Design (2017), vol. 90, pp. 84-94.
- Lupinetti K., Giannini F., Monti M., Pernot J-P., “Content-based multi-criteria similarity assessment of CAD as-sembly models”, Computers in Industry (2019), vol. 112, pp. 1-20.
- Montlahuc J., Shah G. A., Polette A., Pernot J-P., “As-scanned point clouds generation for virtual Reverse Engineering of CAD assembly models”, Computer-Aided Design and Applications (2019), vol. 16(6), pp. 1171-1182.
- Polette A., Meunier J., Mari J-L., "Shape-Curvature-Graph": Towards a New Model of Representation for the Description of 3D Meshes. 4th International Conference on Augmented Reality, Virtual Reality and Computer Graphics (AVR 2017), Ugento, Italy, pp.369-384.

Research Topic for the ParisTech/CSC PhD Program

Fields: Computer science, mathematics and their applications, human computer interaction and interface, design & industrialization.

ParisTech School : Arts et Métiers – LISPEN Aix-en-Provence / Chalon-sur-Saône

Title : **Deep learning for 3D scanning strategies quality estimation and exploitation in virtual and augmented reality**

Advisor(s):
Prof. Dr. Jean-Philippe PERNOT / jean-philippe.pernot@ensam.eu / http://lispen.ensam.eu/
Dr. Ruding LOU / ruding.lou@ensam.eu / http://lispen.ensam.eu/

Short description of possible research topics for a PhD:

Acquiring good quality 3D representations of existing physical objects has become mainstream in the scope of the Industry 4.0, and notably to maintain the coherence between a real object and its digital twin. The quality of the acquired data (e.g. points clouds) depends on many parameters related to the adopted sensor and scanning configuration: scanning strategy (e.g. trajectory, speed and sensor settings), object properties (e.g. shapes and material) and environmental conditions (e.g. lighting). It is thus very difficult to identify the optimal set of parameters for a given scanning configuration.
This PhD program addresses the way the quality of 3D scanning configurations can be estimated using a deep learning approach and exploited within ad-hoc Virtual Reality (VR) and Augmented Reality (AR) environments. The idea is to train a Convolutional Neural Networks (CNN) using automatically generated data. Two data generation strategies will be studied and implemented. The first will consist of using as-scanned points clouds obtained while virtually generating points clouds on virtual objects. The second will consist in generating real points clouds while following many scanning strategies automatically executed using a motorized acquisition system. Once trained, the quality estimator will then be used within an optimization loop to automatically identify the optimal set of scanning parameters for a given object. The results will then be exploited within a new Augmented Reality framework used to support decision-making when scanning real objects. They will also be used within a new Virtual Reality framework used to train the end-user on how to scan object. In both cases, the idea is to develop new visualization and interaction metaphors specifically designed to support scanning scenarios. The proposed approach will be implemented and validated on academic as well as on industrial examples.

Required background: Computer science, computer vision, geometric modeling, CAD.

A list of 5 (max.) representative publications of the group:

- Danglade F., Pernot J-P., Véron P., Fine L., “A priori evaluation of simulation models preparation processes using artificial intelligence techniques”, Computers in Industry (2017), vol. 91, pp. 45-61.
- Hu H., Kleiner M., Pernot J-P., “Over-constraints detection and resolution in geometric equation systems”, Computer-Aided Design (2017), vol. 90, pp. 84-94.
- B. Li, F. Segonds, C. Mateev, R. Lou, F. Mérienne, “Design in context of use: An experiment with a multi-view and multi-representation system for collaborative design”, Computers in Industry (2018), vol. 103, pp. 28-37.
- B. Faliu, A. Siarheyeva, R. Lou and F. Mérienne, “Design and Prototyping of an Interactive Virtual Environment to Foster Citizen Participation and Creativity in Urban Design”, Advances in Information Systems Development, Lecture Notes in Information Systems and Organization, Springer, Cham (2019), vol. 34, pp. 55-78.
- Montlahuc J., Shah G. A., Polette A., Pernot J-P., “As-scanned point clouds generation for virtual Reverse Engineering of CAD assembly models”, Computer-Aided Design and Applications (2019), vol. 16(6), pp. 1171-1182.

Research Topic for the ParisTech/CSC PhD Program

Fields: Energetics, Optimization, Life cycle, Multi-energy, Production / Storage / Network systems

ParisTech School : Arts et Métiers – Laboratory LISPEN Campus of Aix-en-Provence

Title : **Impact of the life cycle of multi-energy micro-grid systems on their energy efficiency**

Advisor(s):
Prof. Dr. Lionel ROUCOULES / lionel.roucoules@ensam.eu / http://lispen.ensam.eu/
Dr. Pierre GARAMBOIS / pierre.garambois@ensam.eu / http://lispen.ensam.eu/

Short description of possible research topics for a PhD :
This research project aims at developing a decision tool that proposes various multi-energy mix compromises (electric, photovoltaic, wind, thermic, hydraulic, nuclear…) for a given territory, in order to optimize both the cost and the global energy consumption. The tool will takes into account both the operational phase and the impact of the life cycle of each system.
Most energy optimization studies focus either on the modelling, dimensioning and managing of a specific energy system (or power grid), or on long term global prospective studies of single energy mix like MARKAL-TIMES models ignoring most of the physical parameters. The idea of this research project is to model the global energy mix as a multi-energy micro-grid, using aggregated energy models of each production, storage and grid technology, through parameters that represent the corresponding engineering field. Each model will be analysed over his own life cycle, including the production, transport, operational, maintenance and recycling phases, and will seek to represent both the scale of one operator and the scale of the whole quantity produced of this system (population scale). The numerical performance of the micro-grid is of substantial importance for the purpose of a use in multi-objective genetic optimization algorithms and stochastic methods.
The main goal is to propose a decision tool able to provide multiple optimum choices for a territory regarding the type of energy choice, the architecture of the system, the storage and the power network and strategy, with the objective of minimizing the costs, global energy consumption and the use of primary resources.

Required background of the student: Energetics, Engineering, Computer science

A list of 5 (max.) representative publications of the group:
T. Lambert, P. Gilman, and P. Lilienthal, « Micropower System Modeling with Homer, in Integration of Alternative Sources of Energy », F. A. Farret et M. G. Simões, Éd. Hoboken, NJ, USA: John Wiley & Sons, Inc., p. 379‑418, 2006.
N. Maïzi, E. Assoumou, M. Bordier, G. Guerassimoff, and V. Mazauric, « Key features of the electricity production sector through long-term planning: the french case », IEEE PES Power Systems Conference and Exposition, p. 1796-1801, 2006.
A. Chaouachi, R. M. Kamel, R. Andoulsi, and K. Nagasaka, « Multiobjective Intelligent Energy Management for a Microgrid », IEEE Transactions on Industrial Electronics, vol. 60, no 4, p. 1688‑1699, 2013.
E. Kuznetsova, Y.-F. Li, C. Ruiz, and E. Zio, « An integrated framework of agent-based modelling and robust optimization for micro-grid energy management », Applied Energy, vol. 129, p. 70‑88, 2014.
A. Alarcon-Rodriguez, G. Ault, and S. Galloway, « Multi-objective planning of distributed energy resources: A review of the state-of-the-art », Renewable and Sustainable Energy Reviews, vol. 14, no 5, p. 1353‑1366, 2010.

Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics, Fluids

Subfield: Mechanical Engineering, Manufacturing

Title: Optimization of the Friction Stir Welding tool design

ParisTech School: Arts et Métiers Institute of Technology (ENSAM)

Advisor(s) Name: Dr. Sandra CHEVRET, Dr. Tudor BALAN
Advisor(s) Email: sandra.chevret@ensam.eu, tudor.balan@ensam.eu

(Lab, website): LCFC, Laboratory of design, manufacturing and control, http://lcfc.ensam.eu/

Short description of possible research topics for a PhD: Friction Stir Welding (FSW) is an innovative solid-state welding process. To perform FSW, a non-consumable rotating tool, made up of a shoulder and a probe, is inserted into the interface of two workpieces and is moved along the joint-line. During welding, the tool stirs the softened material to create the joint. In consequence, as welding, high forces (travel and transverse) are applied on the tool. The pin geometry and features (flats, threads, etc.) are very important for the weld creation. Therefore, it is important to understand the relationship between the tool design and the weld obtained. In this research project, the tool design will be investigated experimentally through a design of experiment. The two main output studied will be the weld quality and the forces generated as welding. The weld geometry will be obtained by macrographic inspection and the forces will be recorded thanks integrated sensor as welding. The recorded travel and transverse forces are full of information. Based on the evaluation of sensor data and the weld quality, a database will be created and afterwards analyzed thanks mathematical statistical model to draw the guideline of an ideal industrial tool design. In a second time, the data base will be used to monitor the process to detect weld with quality problems. Therefore, an automatic weld quality evaluation, based on of force sensor data, will be developed and implemented on a FSW system in order to reduce control after welding. The PhD student will rely on the strong LCFC knowledge and experimental equipment, like a FSW industrial robot with a six-axis load sensor, a laser tracker, load cells, etc. to get the most complete experimental procedure and succeed in its PhD work.

Required background of the student: The candidate should have a good background in mechanical engineering, especially in manufacturing. Computer programming skills would be appreciated, and/or experimental skills in mechanics or material science.

A list of 5(max.) representative publications of the group:

K. KOLEGAIN, F. LEONARD, S. CHEVRET-ZIMMER, A. BEN ATTAR, G. ABBA, Off-line path programming for three-dimensional Robotic Friction Stir Welding based on Bézier curves *Industrial Robot: An International Journal, https://doi.org/10.1108/IR-03-2018-0038 (2019)*

S. ZIMMER-CHEVRET, N. JEMAL, L. LANGLOIS, A. BEN ATTAR, J. HATSCH, G. ABBA, R. BIGOT, FSW process tolerance according to the position and orientation of the tool: Requirement for the means of production design. *Materials Science Forum 783–789:1820–1825 (2014)*

S. ZIMMER, L. LANGLOIS, J. LAYE, R. BIGOT, "Experimental investigation of the influence of the FSW plunge processing parameters on the maximum generated force and torque", *International Journal of Advanced Manufacturing Technology, Vol.47, Issue 1-4, pp.201-215 (2009)*

Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics, Fluids

Subfield: Life and Health Science and Technology

Title: Experimental modeling of stenotic carotid blood flows

ParisTech School: Arts et Métiers Paris Tech (campus de Lille)

Advisor(s) Name: Farid Bakir (Dynfluid, Arts et Métiers Paris Tech, campus de Paris)
Sylvie Fuzier (Laboratoire de Mécanique des Fluides de Lille, Arts et Métiers Paris Tech, campus de Lille)
Emmanuel Leriche (Département de mécanique, Université de Lille)
The PhD will be done at the LMFL in Lille with co-advisors at Dynfluid and Université de Lille.
Advisor(s) Email: Farid.BAKIR@ensam.eu , sylvie.fuzier@ensam.eu , emmanuel.leriche@univ-lille.fr

Short description of possible research topics for a PhD:
Lipids, carbohydrates and blood residues can progressively aggregate locally on the inner wall of carotid arteries (atheromous plaque) causing a local reduction of their diameter (carotid artery stenosis) and modification of the blood flow around this local protuberance. The stress caused by the blood flow in this reduced section can cause a detachment of this plaque that can then flow in the bloodstream and cause an obstruction of smaller blood vessels resulting in a myocardial infarction (heart attack) or brain stroke. The goal of this PhD is to experimentally measure the wall shear stress caused by the blood flow on the plaque in these complex geometries to better understand the cause of its breaking of.
The PhD student will participate in the fabrication of a transparent phantom of stenotic artery and measure the velocity field with the technique of Particle Image Velocimetry. The velocity will also be measured with an innovative technique using ultrasounds (based on acoustic phase conjugation principle) allowing this measurement across opaque surfaces. This allows more flexibility in the choice of material used for the phantom and therefore to increase its level of realism.

Required background of the student:
Fluid Mechanics. Experience with the use of experimental measurement techniques appreciated

A list of 5(max.) representative publications of the group: (Related to the research topic)
A new hemodynamic Ex Vivo Model for medical devices assessment. B. Maurel, C. Sarraf, F. Bakir et al. Annals of Vascular Surgery, vol 29, Issue 8, 1648-1655, 2015
Banc de test pour stent. Bakir F., Maurel B. and al. Brevet 2013
T. Belzacq, S. Avril, E. Leriche, A. Delache. « Modelling of fluid structure interactions in stenosed arteries : effect of plaque deformability », Computer Methods in Biomechanics and Biomedical Engineering, 13(S1), 25-26, 2010
Belzacq, T., Avril S., Leriche E. et Delache A. « A numerical parametric study of the mechanical action of pulsatile blood flow onto axisymmetric stenosed arteries », Medical Engineering and Physics, Vol. 34(10), 1483-1495, 2012
Belzacq, T., Avril S., Leriche E. et Delache A. « Mechanical action of the blood onto atheromatous plaques: influence of the stenosis shape and morphology », Computer Methods in Biomechanics and Biomedical Engineering, 2013, DOI 10.1080/10255842.2012.697898

Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics, Fluids

Subfield: Computational mechanics, Mechanics of Materials, Phase field fracture, Shape memory alloys

Title: **Phase field fracture modelling of shape memory alloy actuators for aerospace applications**

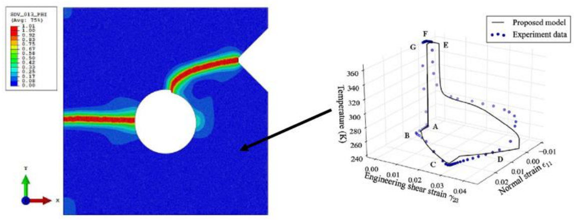
ParisTech School: Arts et Metiers Institute of Technology
Advisors Names, E-mails: **Pr. Fodil Meraghni**, fodil.meraghni@ensam.eu
Dr. Francis Praud, francis.praud@ensam.eu
Dr. Boris Piotrowski, boris.piotrowski@ensam.eu
Research group/Lab: **SMART** research group **/ LEM3 UMR CNRS 7239** National Key Lab (Metz)

Project in the framework of scientific collaboration with University of Houston (USA)

Within the last decades, Shape Memory Alloys (SMAs) have demonstrated a great potential in various engineering applications in aerospace. Indeed, SMAs are particularly attractive in a wide range of actuator, energy absorption, and vibration damping devices. This is achieved thanks to their unique thermo-mechanical behaviour, which results from a crystallographic phase transformation from austenite to martensite and vice-versa. In our research group several phenomenological and micromechanical models have been proposed to describe the thermomechanical response of SMAs [1–5] but none of them integrate their strain localization effects and the related crack initiation and propagation. Indeed, it becomes important to predict the response of SMA components upon crack initiation and propagation.

The present work aims at formulating an original model accounting for stress-induced phase transformation integrating the martensitic reorientation mechanism in conjunction with forward and reverse austenite-martensite transformation [3]. The damage induced by those deformation mechanisms is expected to act as crack driving force in SMA components subjected to complex thermomechanical loading (see Figure below).

To treat fracture problems, the recently developed phase field fracture method is proven to be particularly attractive. This method is based on the variational approach to fracture, which aims at seeking both the displacement field and the crack surfaces while minimizing the potential energy of the system. Thus, by approximating the discrete topology of cracks by means of a spatially regularized scalar damage-like variable (so-called crack phase field), the problem is reduced to a set two strongly coupled partial differential equations, which is far more efficient than classical discontinuous methods. Initially developed for elastic brittle materials, the phase field fracture method has a great potential to predict localization and will be extended to inelastic SMAs exhibiting phase transformations mechanisms.



works of F. Praud (on left), work of D. Chatziathanasiou [3] (on rigth)

Required background of the student:
Mechanical engineering, Mechanical behaviour of materials, Finite element method

A list of 5(max.) representative publications of the group: (Related to the research topic)

[1] G. Chatzigeorgiou, Y. Chemisky, and F. Meraghni, "Computational micro to macro transitions for shape memory alloy composites using periodic homogenization," *Smart Mater. Struct.*, vol. 24, 2015.

[2] F. Meraghni, Y. Chemisky, B. Piotrowski, R. Echchorfi, N. Bourgeois, and E. Patoor, "Parameter identification of a thermodynamic model for superelastic shape memory alloys using analytical calculation of the sensitivity matrix," *Eur. J. Mech. - A/Solids*, vol. 45, pp. 226–237, 2014.

[3] D. Chatziathanasiou, Y. Chemisky, G. Chatzigeorgiou, and F. Meraghni, "Modeling of coupled phase transformation and reorientation in shape memory alloys under non-proportional thermomechanical loading," *Int. J. Plast.*, vol. 82, pp. 192–224, 2016.

[4] Y. Chemisky, D.-J. Hartl, and F. Meraghni, "Three-dimensional constitutive model for structural and functional fatigue of shape memory alloy actuators," *Int. J. Fatigue*, vol. 112, pp. 263–278, 2018.

[5] D. Chatziathanasiou, Y. Chemisky, F. Meraghni, G. Chatzigeorgiou, and E. Patoor, "Phase Transformation of Anisotropic Shape Memory Alloys: Theory and Validation in Superelasticity," *Shape Mem. Superelasticity*, vol. 1, no. 3, pp. 359–374, 2015.

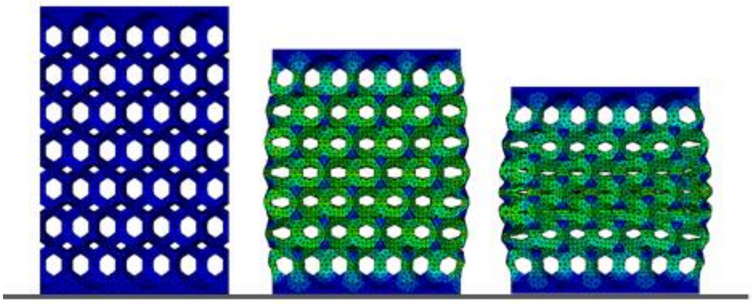
Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics, Fluids

Subfield: Materials Science, Mechanics of Materials

Title: **Topology optimization of cellular materials for energy absorption**
ParisTech School: Arts et Métiers – ParisTech
Advisors Names, E-mails: Pr. Halim HADDADI, halim.haddadi@ensam.eu
Dr. Eric MONTEIRO, eric.monteiro@ensam.eu
Dr. Imade KOUTIRI, imade.koutiri@ensam.eu
Research group/Lab: **CoMet** research group / **PIMM** Lab (Paris)
Lab/Advisor website: ***http://pimm.ensam.eu*** / ***http://aa1.free.fr***

The metal foams have interesting multi-physical properties (mechanical, thermal, acoustic, ...). The large void volume fraction allows the foam to reach significant macroscopic deformations with an applied force level that depends on the topology of its cells. The growing interest for metal foams for energy-absorbing applications is due to the fact that they allow a reduction of the mass, and thus a reduction of the fuel consumption of the vehicle, while increasing its safety. This PhD project has two main objectives: (i) the numerical one starts with finite element modeling of the collapse of the cells under the effect of a mechanical load in order to estimate the absorbed energy as well as the effort transmitted to the structure bonded to the metal foam. Then, the topology of the cells will be optimized to maximize the specific energy absorbed during severe deformation while limiting, to tolerable values, the force transmitted by the foam. (ii) The second goal of the project concerns the experimental part. The foams will be fabricated by additive manufacturing. Then, it will be necessary to develop a methodology for the measurement of kinematic full-fields until very large deformations. These measurements will permit to study and verify the reproducibility of the different scenarios of the collapses of cells one after the other during the mechanical loading of the metallic foam. Thus, the design protocol can be validated and/or enhanced.



alveotech.fr

Required background of the student:
- Mechanical engineering, Mechanical behavior of materials
- Finite element method and Matlab tools will be appreciated.

A list of 5(max.) representative publications of the group: (Related to the research topic)

- H. Haddadi, S. Belhabib, (2012), Improving the characterization of a hardening law using digital image correlation over an enhanced heterogeneous tensile test, International Journal of Mechanical Sciences, 62, 1, 47-56.
- H. Haddadi, S. Belhabib, (2008), Use of rigid-body motion for the investigation and estimation of the measurement errors related to digital image correlation technique, Optics and Lasers in Engineering, 46, 185-196.
- S. Belhabib, H. Haddadi, M. Gaspérini, P. Vacher, (2008), Heterogeneous tensile test on elastoplastic metallic sheets: Comparison between FEM simulations and full-field strain measurements, International Journal of Mechanical Sciences, 50, 14-21.

Research Topic for the ParisTech/CSC PhD Program

Field :

Environment Science and Technology, Sustainable Development, Geosciences
Materials Science, Mechanics, Fluids

Subfield: (Applied Physics, Chemistry, Mathematics, Mech. Eng. Etc…) Civil engineering

Title: Integrated design for the building envelops: convergence of concepts for comfort and sustainable design

ParisTech School: ENSAM
Advisor(s) Name: Nicolas PERRY / Bertrand LARATTE / Tingting VOGT WU
Advisor(s) Email: nicolas.perry@ensam.eu / bertrand.laratte@ensam.eu / tingting.vogt-wu@u-bordeaux.fr
Research group/Lab: I2M
(Lab/Advisor website): https://www.i2m.u-bordeaux.fr/

Short description of possible research topics for a PhD: (10-15 lines in English + optional figure)
With human development, consumptions of raw materials and natural resources have greatly increased. Today the environmental impacts of such a high consumptions are evident. In the composition of energy consumption, buildings consume the largest part (more than industry, transport and others). Moreover, buildings are also responsible for about 17% of total direct energy-related CO2 emissions from final energy consumers. Climate controlling (space heating and cooling) occupies more than half of the building's consumption. Building envelops with good thermal performances can reduce this consumption and improve the building energy efficiency. So the thermal parameters of building envelops are an essential information for building energy simulation, economic optimization and retrofitting energy efficiency of buildings. All around the world, several kinds of climates exist. Three main parameters to characterize the comfort in winter or in summer seasons are the air temperature and relative humidity and the direct solar radiation. Apart the thermal physics for the comfort estimation, there are different large cities in the world concerned by a very hot or extremely hot, dry or slightly humid, climates, or the regions where the climate is both, extremely hot and humid. In this kind of climates, the nocturnal temperature often doesn't decrease during a period of several days or several months. Outside of these extreme meteorological periods, a lot of existing solutions and their combinations deserve to be studied. All the design solutions combine the different energy consummations (construction materials, energy systems). That is, in the whole life cycle of products (materials and the building), we should systematically consider the impact of raw materials selection, design, production, sale, use, recycling and other links on resource and environment, in order to reduce the resources consumption, pollutant generation and emissions in the different compartments (air, water, soil). So the integrated design for the building envelops will be studied in this work. That means the convergence of concepts for comfort and sustainable design.

Required background of the student: (Which should be the main field of study of the applicant before applying)
Maltlab, comsol, thermal characterization bench, , Simapro, Umberto, Open LCA

A list of 5(max.) representative publications of the group: (Related to the research topic)

Y. Yang, T.V. Wu, A. Sempey, J. Dumoulin,, J.-C. Batsale, "Short time non-destructive evaluation of thermal performances of building walls by studying transient heat transfer", Energy and Buildings. 2019, 184, pp.141-151
Guilhem Grimaud, Nicolas Perry, Bertrand Laratte, "Aluminium cables recycling process: Environmental impacts identification and reduction", Resources, Conservation and Recycling, Volume 135, August 2018, Pages 150-162
J. W. Owens," Life-Cycle Assessment Constraints on Moving from Inventory to Impact Assessment", Journal of Industrial Ecology 1997;37-49.
International Standard ISO14040 Environmental management — Life cycle assessment — Principles and framework 2006;1-20.