On the effect of uncertainties in advanced modelling of material for forming processes

Work environment for the PhD student:

The University of Technology of Troyes (UTT)

UTT is a French institution of higher education established in 1994. It is today one of the largest engineering schools in France. Over 2,500 students are registered at the University, enrolled on undergraduate, postgraduate and doctoral study programs. In the renowned yearly ranking of French magazines, UTT takes enviable positions. Information that is more detailed is available on http://www.utt.fr/en/about-utt.html.

The LASMIS research team

The ICD/LASMIS team has a significant experience in the field of residual stresses engineering (modelling, experimental analysis) and advanced modeling of the behavior of materials for forming processes numerical simulation and optimization (hot and cold stamping, forging, stamping, cutting ...).

Our team cooperates with industrial partners such as Renault, Peugeot SA, SNECMA or Turbomeca (Safran Group) and academic partners such as University Paris VI, University of Reims, ENSAM or INSA de Lyon, in the field of process modeling together with experimental characterization and understanding of physical phenomena.
For more details, see: http://www.utt.fr/en/education/phd-studies/mechanical-systems-and-materials.html (in English) and http://lasmis.utt.fr/fr/projets_de_recherche.html (in French).
Moreover, this research project is part of the global research policy on risk management of the joint research laboratory of CNRS (French National Research Council) and UTT established in January 2010.

Background of the project

At University of Technology of Troyes (UTT), the research axes in mechanics within the Charles Delaunay Institute (ICD) / Laboratory of Mechanical Systems (LASMIS) has acquired a recognized expertise for the modelling of materials behavior and simulation of metal forming processes. The LASMIS is indeed at the origin of several models that, applied to the simulation and optimization of manufacturing processes, enable to consider a complete virtualization of the line production/manufacturing. This work is based on a multi-physical approach including thermodynamics to describe any real complex motion of the matter. These models have proved their efficiency to simulate and to optimize various manufacturing processes such as forming, shot peening, machining.... Even today, the current practice in process simulation and optimization is to consider that the properties of the materials, the geometry of the shaped parts and those of the tools, as well as the process parameters, have exact values known with precision and invariable. However, in practice, these quantities are not known with precision and are likely to vary with time but also in the shaped parts. For example, in a sheet metal strip intended for deep drawing, the material will not have the same properties everywhere. In the same way the conditions of contact between the parts the tools will evolve during the successive operations of forming or stamping.

These "uncertainties" must be taken into account in process simulation and optimization, as they have significant effects on the simulation result. These "uncertainties" must be taken into account in process simulation and optimization, as they have significant effects on the simulation result. Moreover, it is extremely costly, if not impossible, to assess the consequences of these experimental uncertainties as this would require a large amount of experience to obtain statistically significant results. Of course there are measurement data, but this is obtained from observation of real processes and is not available when developing a new part and a new process.
In the LASMIS team, two PhD studies as already deal with effects off “uncertainties” ([1,2,3,4]) in optimization of forming processes. Specific optimization framework has been proposed to overcome issues of the cost of numerical simulation and optimisation forming processes under uncertainties. In these PhD we have developed global approach of the problem based on the propagation of uncertainties by considering model of simulation of processes as a black box. In this approach, the uncertainties on the material properties, for example, are modelled with a small number of random parameters, and theses parameters are the same for the entire volume of the part. Obviously, this is not the case in real situation, in which material properties can vary from one point to another.

Description of the PhD proposal:
The main objective of this PhD proposal is to study the effect of uncertainties on material properties considering advanced modelling of the material behaviors.
As a first step, uncertainties will be model by considering the classical framework of random variables associated with probability distribution. Here we will assume, for simplicity, that parameter of the behavior are random variables with the same expected value in all the material. So, under this assumption and based on existing behavior model, the main objective will be to quantity the effect of uncertainties on stress and strain fields in the material.
As a second step, we will assume a kind anisotropy of uncertainties exists in the material. In this case we will assumed that parameter of the behavior model could have a distribution of expected value across the volume of material.
However, the propagation and analysis of uncertainties in a high-fidelity model (HF) using a Monte Carlo method requires a large number of evaluations of this model. The idea is to replace this model with a meta-model or a reduced model to increase the computation time performance.
The key idea of this method is to search for a basis which contains all information about the behavior of model HF. The reduced model is then the projection of the initial model in this basis.
Let the displacement solution $\vec{u}$ of the FEM model be described by the following equation:

$$\vec{u}(\vec{x},\vec{p}) = \vec{U}_{moy} + \sum_{i=1}^{K} \alpha_i(\vec{p})\vec{\varphi}_i(\vec{x})$$

where $\vec{U}_{moy}$ is the average reparation of the nodal displacement vector, $\vec{x}$ are the coordinate vector of the node, $\vec{p}$ are the uncertainties variables, $\vec{\varphi}_i(\vec{x})$ are the orthonormal basis function and $\alpha_i(\vec{p})$ are the POD coefficient
In practice, we use the so-called “method of snapshots”. It first consists in computing an exact evaluation of the model HF. The objective is to extract as many information as needed from this set.
The advantages of a POD decomposition are that the uncertainty treatment affected only the POD coefficients and do not disturb the spatial operators of the mechanical fields

(displacement, stress, ...). Thus, the integration of a variability on the POD coefficients does not affect the equilibrium and consistency conditions.
The objective of this thesis is to develop a structure or virtual metal forming processes optimization methodology based on the use of meta-model type POD and incorporating uncertainty constraints.
Different applications will then be tested. for example, the study of the uncertainties on an aeronautical part's dimensions and the uncertainties of the material properties on the estimate of its life in service (behavior of this component during a flight of an airplane).

The PhD advisors:

Carl Labergere, 43 years, professor of University of Technology of Troyes. He is graduated from the ENSMM engineering school in Besançon in 1999 and defended his PhD in the Franche Comte mechanical science University on the subject "modelisation, simulation and optimization of hydroforming processes" in 2003. Responsible for the "Virtual Training" theme integrated into the ICD / LASMIS team (UMR CNRS 6281). Responsible for the engineering training of Mechanical Engineering at UTT. Scientific and educational activities in the fields of modeling, simulation and numerical optimization of metal forming processes. Co-author of 25 international journals, 58 national and international congress papers. Co-supervision of 8 theses at 50% (3 supported and 5 in progress), 5 post-doctoral frameworks at 50% and 1 to 100%, 15 frameworks of M2R (co) supervised

Pr. **Pascal Lafon,** 52, obtained a Master of Mechanical Engineering from Toulouse university in 1989, and defended his PhD in the Engineering School on applied science of Toulouse in 1994 on the subject "Optimal design of mechanical system: optimization in mixed variables". He was involved in the creation of University of Technolology of Troyes in 1994 and became full professor in 2009 in the Physics and Mechanics engineering department. He was the head of the LASMIS team from 2012 to 2016. His research activities are related to optimization of mechanical system and processes. He supervised 12 PhD students (8 defended) and published 93 papers among which 26 in international journals. He is actually responsible of the programme "Mechanics, Materials and Optics and Nanotechnology" of PhD doctoral school and also responsible of the Master in "Mechanics, Materials and Advanced Processes".

Available equipments

- Finite Element codes (ABAQUS, Z-Set for which source code is available).
- High level computing facilities.
- Every PhD student shares an office with other PhD students. A personal desk is offered to each PhD student along with a personal computer and full personal access to the internet and bibliographic databases.

References:

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