PhD Grants from the China Scholarship Council:
Research project proposal:
Multi objective optimization for forming processes based on proper orthogonal decomposition method

Overview of the context:
The numerical simulation of manufacturing processes plays a key role in the process of product development. These simulations facilitate the simultaneous development of the product and its appropriate manufacturing process. Many research works are conducted in this area. These research activities are motivated by growing industrial needs in simulation tools capable to predict physical phenomena involved in this manufacturing processes. Theses simulations help engineer in choosing the appropriate parameters of the manufacturing process. The best tools allow the optimization of the manufacturing process in order to lower cost or wear of tools.

For example, recent advances in forging process control and high-quality requirements to the forged part, make it very difficult to develop the proper procedure of forging. This process require now several preform operations. So in order to obtain the final forged part in good quality (correct shape, no defects) with lower cost (material volume, energy), the use of multi-objective optimization technology becomes necessary to the design of multi-stage forging process.

In this area the mechanical system and concurrent engineering team of “Institut Charles Delaunay” of University of Technology of Troyes have leaded an important research work and have proposed:

- Some advanced simulation tools, based on finite elements (implemented in Abaqus™), using advanced thermo-visco-plastic behavior model fully coupled with ductile damage in large deformation.
- More recently, an optimization methodology for multi-step forging process based on surrogate meta-models in order to reduce defects and the volume of material.
This optimization methodology uses advanced simulation tools to calculate the “responses” (i.e., strain, stress, and the level of ductile damage in the forged part) for a given geometry of the tools (the initial billet, the die, and punch). This simulation required about 2 hours of calculation. The complete optimization of the tool’s geometry requires a lot of simulation. In order to decrease the number of simulation, we have used a polynomial approximation for the “response”. This approximation, called meta-model, is built with a limited number of simulations and replaces the high fidelity “response” from the simulation, during the optimization process. The optimal solution highly depends on the type of approximation and the number of simulation used to build the meta model. This work has been done in a previous “China Scholarships Council” PhD [Meng 2010, Meng 2012].

Finally, one of the key issues for efficient optimization methodology is to be able to develop optimization technic combining the best compromise between high accuracy of advanced simulation tools and the best optimization efficiency (i.e., total number of calculation to reach an optimal solution).

**The proposed subject:**
This proposal is focused on this issue. The main idea of the proposal is to investigate new meta-modeling technic based on “reduced model” of the simulation. This “reduced model” can be evaluated more quickly and more easily than the complete model based on advanced simulation by finite elements.

To build this “reduce model”, recent numerical technics use “proper orthogonal decomposition”. This technic has proven his efficiency in several applications like, for example, finite element analysis for transient thermal simulation [Bialecki 2005], acoustic propagation [Petit 2007], fluid dynamic [Forrester 2006] and solid mechanics [Chinesta 2008]. This are mainly two way to use proper orthogonal decomposition. The first one consists in a reformulation of the finite elements model, which is complex but guarantee the best physical restitution of response. The second one consists in a reformulation of the response by assuming a given mathematical model of the response. This way is simpler that the first one but doesn’t give the same quality of physical restitution of response.

This work will be plan on the following main steps:

1. Based on an extensive bibliography study, the specific “constrained proper orthogonal decomposition” technic will be analyzed and adapted to the specific case of response obtained by finite elements simulations. In this study, the constraint and the several objective function of the optimization problem have to be take into account to define the “reduce model”. This step required to develop a specific calculation code.
2. Development on an adaptive procedure (enrichment of the design space) to complete and refine locally the meta-model
3. The previous code have to be integrated in this optimization software “ModeFrontier™” in order to control the C.A.D. model of tools and initial billet.
4. This methodology will be apply on the metal forming of bulk component by forging process or sheet component by stamping process.
Some bibliographic references:


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