COST 526 APOMAT **September 1st, 2005**

FINAL REPORT FOR WG1 : Thin walled product processing

Working group leader: Dr. Jean-Philippe PONTHOT, Belgium
Deputy leader: Prof. Jean-Louis BATOZ, France

Participating projects:

- **Optimization of sheet-metal blanking and bending processes, Prof. A. POTIRON, France (F4)**
- **Tube and Blank Hydroforming Processes Optimization, Dr. J.M. FAURE, France (F1)**
- **Optimization of Properties and Dimensional Stability of Composites by Controlled Fibre Placement, N. JANSSON, P.O. HAGSTRAND and JA MANSON, Switzerland (CH1)**
- **Optimization of Process Parameters in Sheet Metal Forming, Dr. C. KNOPF-LENOIR, Prof. J.L. BATOZ, Dr. H. NACEUR, Dr. A. DELAMEZIERE, France (F3)**
- **Distributed Simulation –based Optimization in Sheet Metal Forming, Prof. M. GRAUER, Dr. T. BARTH, Germany (G1)**
- **Optimization of sheet and tube metal forming processes, Dr. L. STAINIER, Belgium (B1)**

Summary of working activities

Though all projects are concerned with thin walled products, the basic process in the different project can be different as deep-drawing (G1,B1,F3), hydroforming (F1,B1), blanking and bending (F4).

The materials dealt with were mainly metals (all but CH1), but composite materials were also involved (CH1).

As far as the direct simulations were concerned, many different codes were used. Nevertheless, they were all based on the finite element methods. The codes used were either commercial codes, ABAQUS (CH1,F3,F4), RADIOSS (F1), INDEED (G1) or homemade codes (F3,B1).

So, one can say that for the direct problem simulation quite different approaches were proposed. Therefore, there was a danger that some of the participants, through their discussion, did not meet a common agreement on how to improve their optimization procedures. Actually, the main topics of discussion were the definition of sound optimization variables, objective or cost functions, model parametrization and, of course optimization algorithms. In spit of this diversity the many discussions we had were fruitful and we all agreed on a way to better apprehend the optimization procedures and how to actually implement it. As an example of the results, we will hereafter briefly present and comment a typical example based on the work of project F3.

This problem is concerned with the optimization of the deep drawing of the dashpot cup of a European car (see figure 1)°. The design variables are the initial dimensions of the blank. (Figure 1).

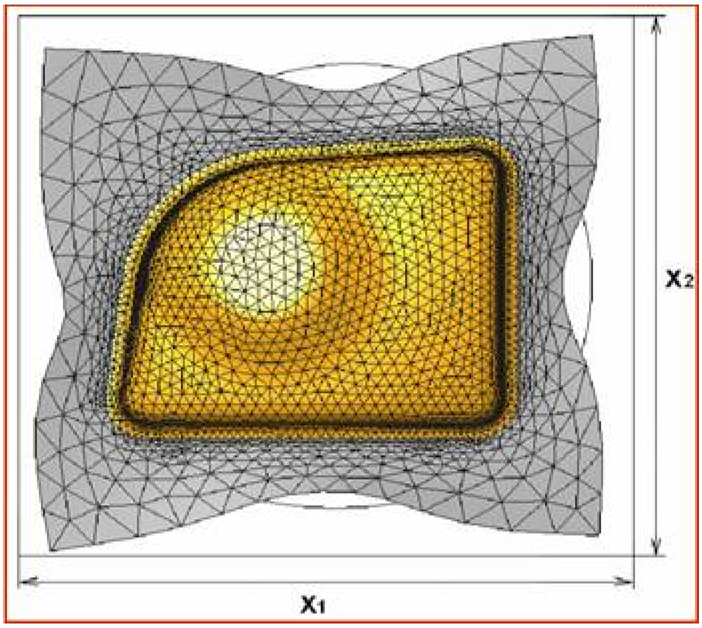

Figure 1: Twingo dashpot cup: optimization variables and final configuration

The process is also constrained in the sense that the strains induced by the deep drawing operations have to be located under the FLC curve (forming limit curve) and above the wrinkling tendency curve (see figure 2).

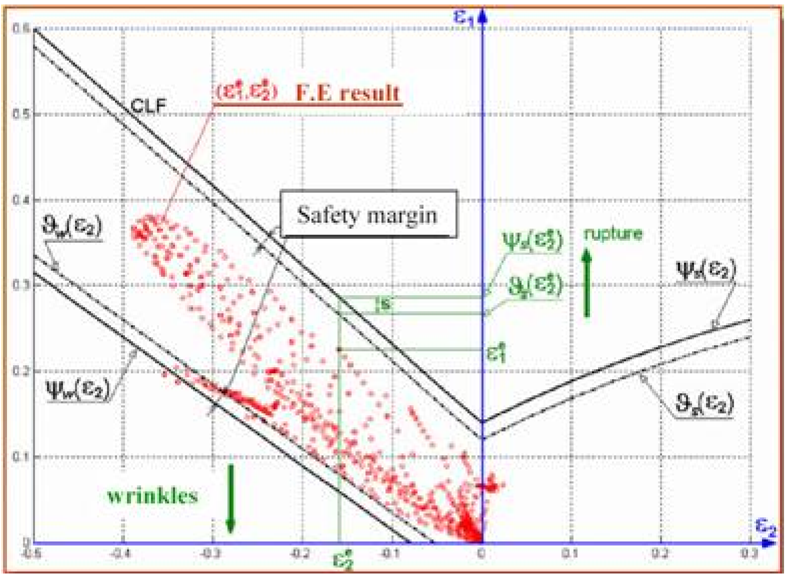

Figure 2. Forming Limit and Wrinkles Curves

The optimization algorithm used is based on **the response surface method,** an algorithm that is now widespread amongst the participants of this working group.

This type of approximation is based on the value of the « exact » functions (provided by a finite element model) in a few points of the design domain, and must be explicit or easy to compute.
Classical methods use mainly least-squares fitting, and some recent improvements of this technique (moving least squares or diffuse approximation) seem very promising for minimization. The choice of the points where the exact functions are to be evaluated (design of experiments) is a difficult problem because it must be a compromise between cost and precision. Therefore, it is more efficient to build local approximations; the initial optimization problem is then replaced with a sequence of local, approximate sub-problems which can be solved at low cost with a descent method using the analytical expression of the response surface.
As can be seen in figure 3, the algorithm is very robust since different starting points, sometimes very far from one another all lead to the same final optimum. As can be seen in that figure, fast and stable convergence is achieved.

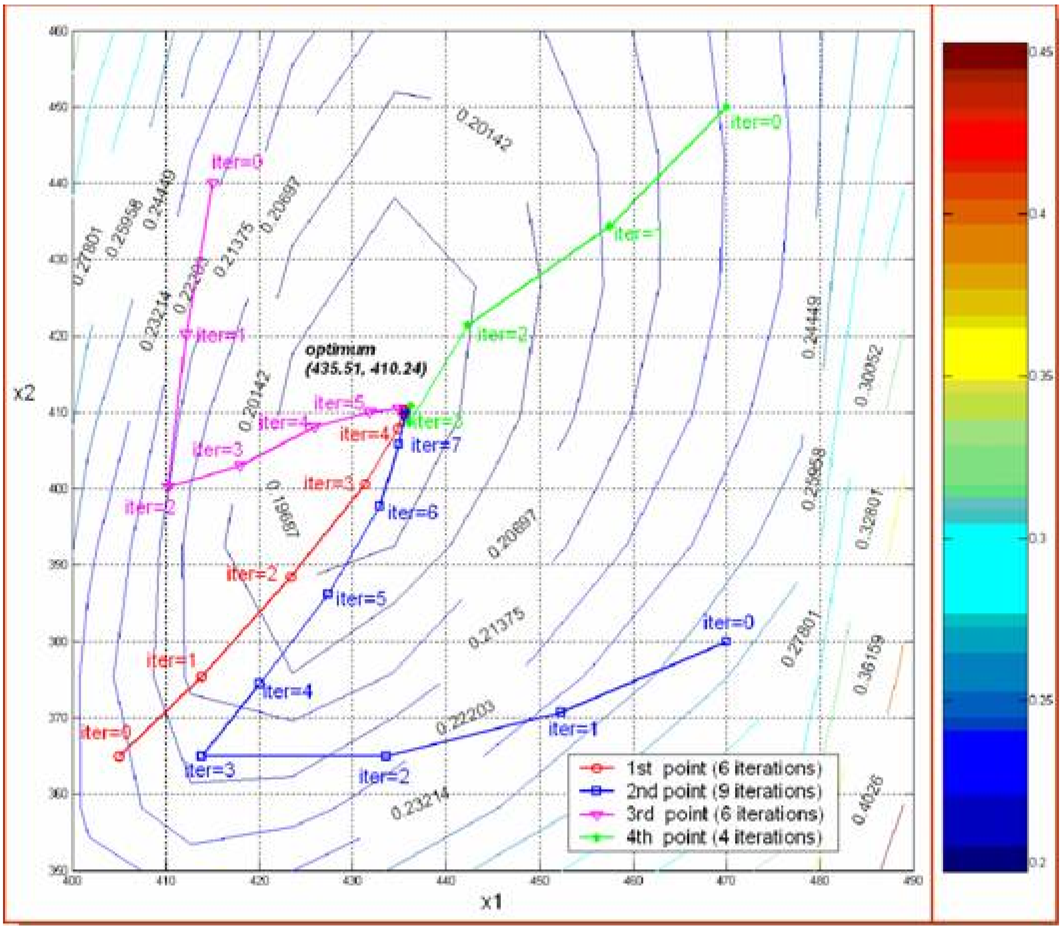

Figure 3: Iso-level curves and convergence path in the optimization variables plane

Another important point to mention is the **excellent and active cooperation** that existed in the group, especially between projects F4 (Prof. Potiron), F1 (JM Faure), project F3 (Dr. Knopf-Lenoir), project G1 (Prof. Grauer) and B1 (Dr. Stainier) regarding the optimization definition (objective/quality function, parametrization of design variables) and methodologies based on the response surface method.

As a follow-up of this action, a three-month stay of a researcher from the group of the WG leader (Université de Liège) will start next November. This researcher will be hosted in the group of Prof. Batoz in Saint-Dié des Vosges (GIP-InSIC), France.

Dissemination has been important in the COST526 Action. The projects of WG1 have been fully or partly presented in International Conferences (ECCOMAS 2004 in Finland, COMPLAS 2003 and 2005 in Barcelona, Spain, NUMIFORM 2004 in Columbus, Ohio, USA, ESAFORM 2004, Italy) Around 20 Communications and 10 papers in International Journals partly resulted from the Action.