COST 526

"Automatic Process Optimization in Materials Technology"

(APOMAT)

Half-Yearly Report

To be sent to **V.Tesch@access.rwth-aachen.de** until **February 28, 2005**

1. Reporting Period	**1.7.2004 – 31.12.2004**
Project title	Optimization of Process Parameters in Sheet Metal Forming
Project leader Organization	**Dr. Catherine Knopf-Lenoir** Université de Technologie de Compiègne Laboratoire Roberval, UMR UTC-CNRS BP 20529 – 60205 Compiègne Cedex
Main collaborators involved	**Prof. Jean-Louis Batoz,** **Dr Arnaud Delamézière** InSIC, 27, Rue d'Hellieule 88100 Saint-Dié-des-Vosges **Dr Hakim Naceur, UTC**

2. Funding Situation

Amount of money received specifically for COST 0 kEuros
Other resources partially used for the project
Funding from the french Ministery of Research (OPTIMAT project): 60 kEuros per year

3. International Collaboration
(mention group and type of work done in collaboration during the reporting period)

Participation in the Working Group Meeting in Brno (November 18-19, 2004) + project progress report
YES

4. Industry participation
(mention name of companies and work done in collaboration during the whole project)

Quantech, Spain: improvement of the One Step code for stamping

5. Meetings, visits, exchange of scientists, short-term scientific missions	**Location, date**

6. Progress within the reporting period

(Not exceeding 3 pages, including tables and figures)

WP4: <u>Optimization with Incremental approach:</u> industrial application

The simulation + optimization approaches developed in the previous period (1-1-04 to 30-06-04) are applied to an industrial problem : the front door panel of Numisheet 1999.
The goal is to control the movement of the blank under the blankholder. Thanks to a deformable flexible blankholder, it is possible to create some independent zones. In each zone, a blankholder force can be applied on the sheet, so that a strong force can hold the blank in a zone, and a smaller one can let it move in another zone.

The front door panel benchmark of Numisheet'99 [1] is considered (FIGURE 1). The numerical simulations are performed using ABAQUS Explicit. The parameters of the finite element model (mesh density, speed of punch) are set to achieve a good prediction with a minimum simulation time.
The numerical simulation is carried out in three stages (gravity, holding and forming). The blanks are meshed by shell elements with reduced integration (68738 quadrangles and 12 triangles for the blank). The tools are modeled with 4-node and 3-node, three-dimensional discrete rigid surface elements (type R3D4 and R3D3). The speed of the punch is set to 1.35m/s for the simulation. Those parameters (mesh, punch speed) allow a quick simulation (average of 13h for the forming step on a Xeon 3 Ghz with 3Go RAM, Windows XP). They have been selected after several runs to evaluate their influence on total CPU time and precision in results.

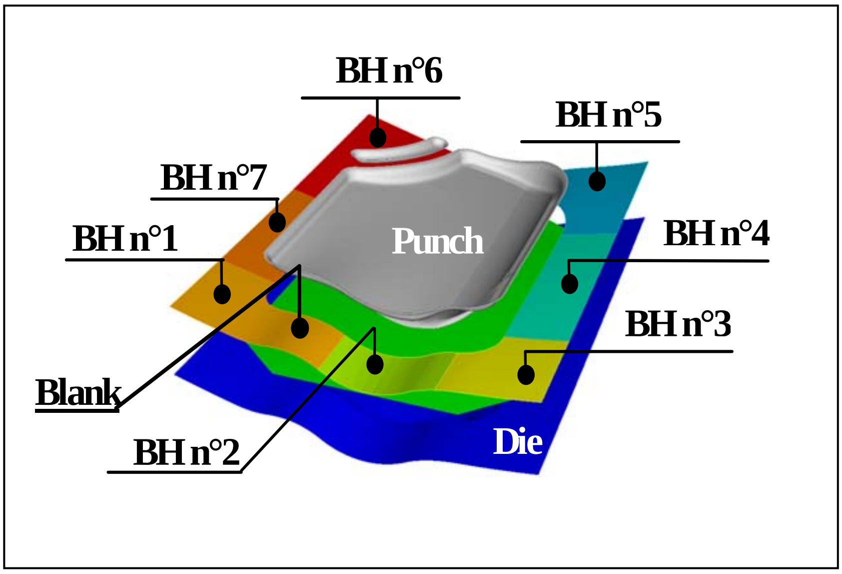

FIGURE 1. Blankholder zones.

Comparison with experimental results

Experimental results are available for benchmark tests carried out on three materials: Mild steel DDQ, Bake hardening steel BH220 and Aluminuim 6016T4. In this work, the simulation corresponding to the mild steel specimen was carried out.

FIGURE 2 shows the distribution of the thickness along the section defined by the equation X=-15 mm. Our result is in agreement with the experiment result. The shift between our result and experimental result around x ≈ -380 mm and x ≈ 380 mm is caused by drawbeads which are not modeled. FIGURE 3 shows the major strain distribution along the same section. Results are also in agreement with the experimental ones, unless in the blankholder regions where drawbeads affect the material flow. Our numerical results are also in agreement with the available results obtained by other researchers and published in the proceeding of Numisheet'99.

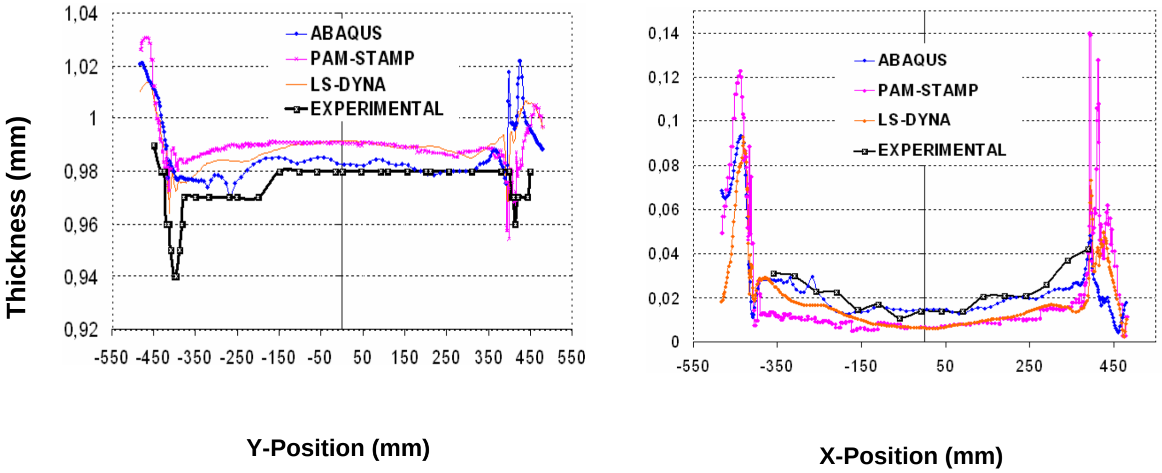

Figure 2

Optimization and control of the blankholder force

The formulation of the problem was presented in the previous report; the design variables are the blank holding forces (BHFi). Seven zones of holding are defined (Figure 1) and for each zone the force is considered as constant during the forming stage. The objective function is linked to the energy consumed by the forming process, and constraints are defined to avoid necking and wrinkling.

Moving least squares response surfaces are used to approximate objective and constraint functions, and a SQP algorithm finds the solution of this approximate problem. The domain is then adapted to focus on the last solution obtained and to improve the accuracy. This strategy allows to limit the number of process simulations.

A central composite design experiment was applied. Indeed, for n independent variables, the central composite design requires $2^n + 2n + 1$ function evaluations: 2^n factorial designs augmented by $2n$ axial points and one centre point. Thus, for seven blank holder forces 143 numerical simulations are necessary for each design of experiments. To reduce the number of evaluations we chose to solve the optimization problem in two stages (Figure 3.).

In the first stage, four blankholder forces will be optimized (bh_n°1, bh_n°2, bh_n°3 and bh_n°4). The blankholder (5, 6 and 7) will be replaced by one blankholder with a force to 100 kN. In the second stage, we continue the optimization only of the three blankholder forces (5, 6 and 7) by using the optimum forces obtained in the first stage.

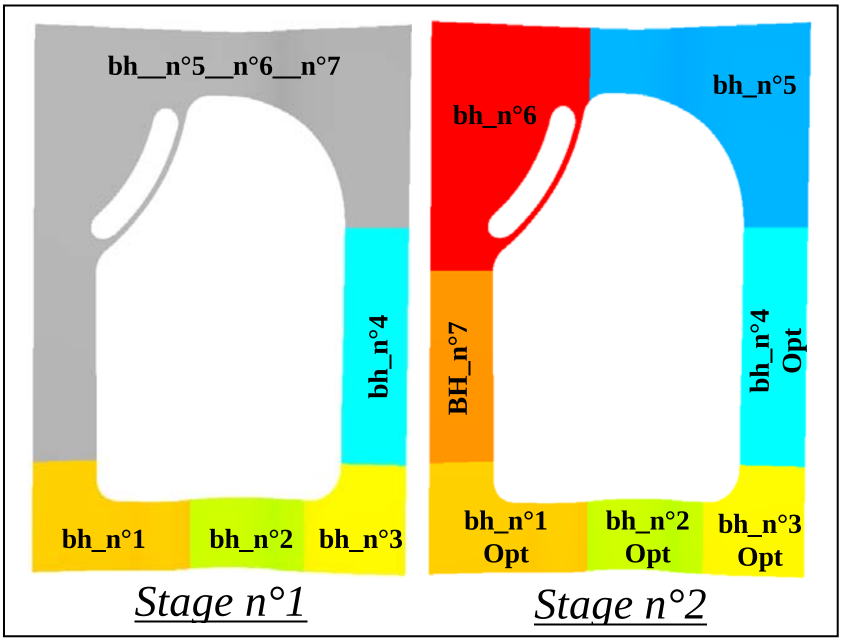

Figure 3. Blankholder forces optimized for each stage

Results:

This application presents significant wrinkles, specially in the zone under the blank holder. Before optimization, the maximum angle of inclination is found equal to five degree. For each stage, three response surfaces have been necessary to achieve convergence. For each optimization stage the optimum solution is carried out after three actualization of the research domain. In Figure 4 we present the optimum forces obtained for each blankholder. After optimization we succeed to reduce the maximum inclination angle from five to one degree.

In Figure 4 we present the major and minor strain distribution before and after optimization. We notice that all the points are below the CLF with a security margin (S=0.015).

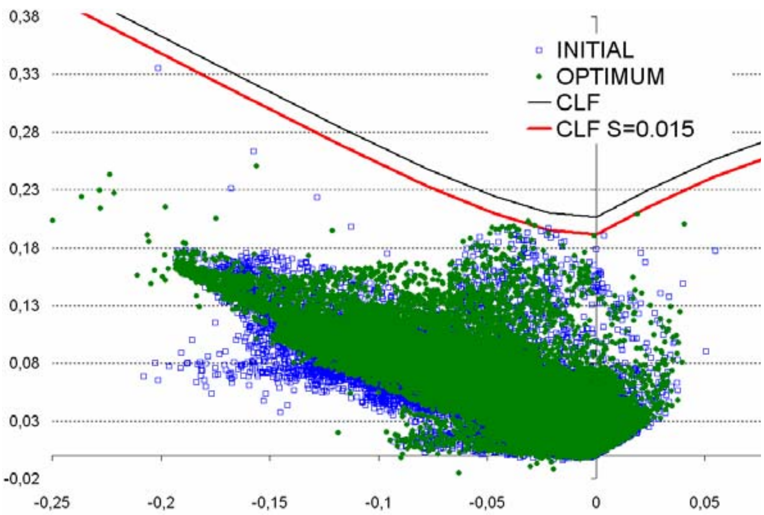

Figure 4. Major and minor strain distribution before and after optimization

These results shows that a satisfactory solution has been found: wrinkles and necking risk are reduced. Obviously, the quality of the optimum depends on the choice of the zones where the forces are applied and optimized, and also on the optimization strategy (as the seven variables are not taken into account simultaneously). This application demonstrates that a constrained optimization problem involving incremental simulations and seven design variables can be successfully performed with a reasonable number of simulations.

[1] Proceedings of NUMISHEET'99, The 4th International Conference and Workshop on Numerical Simulation of 3D Shee Forming Processes, Volume 2, Edited by J. C. Gelin and P. Picart, Besançon, FRANCE, 13-17 September (1999).

7. List of publications

a) Published

NACEUR H., DELAMÉZIÈRE A., BATOZ J.L. , KNOPF-LENOIR C., Somme improvements on the optimum process design in deep drawing using the Inverse Approcach, J. Mater. Process. Technol. V146 (2) pp 250-262 (2004).

NACEUR, H., GUO, Y.Q., BATOZ, J.L. "Blank optimization in sheet metal forming using an evolutionary algorithm", Journal of Materials Processing Technology, Volume 151, pp. 183–191, 2004.

H. NACEUR, S. BEN-ELECHI, C. KNOPF-LENOIR, J.L. BATOZ, Response Surface Methodology for the Design of Sheet Metal Forming Parameters to control Springback Effects using the Inverse Approach, NUMIFORM 2004, 13-17 Juin 2004, Columbus, Ohio, US.

BEN AYED L., DELAMÉZIÈRE A., BATOZ J.L. *, KNOPF-LENOIR C., "Optimization of the blankholder force with application to the Numisheet'02 deep drawing benchmark test B1", 8th International Conference on Numerical Methods in Industrial Forming Processes, NUMIFORM 2004, 13-17 Juin 2004, Columbus, Ohio, US, 6 pages.

BEN AYED L., DELAMÉZIÈRE A., BATOZ J.L. *, KNOPF-LENOIR C., "Optimization and control of the blankholder force in sheet metal stamping with application to deep drawing" European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS 2004, 24-27 Juillet 2004, Jyväskylä, Finlande. 14 pages on CD-ROM.

b) Submitted for publications

[5] BREITKOPF P. NACEUR H., RASSINEUX A., VILLON P., Moving least squares response surface approximation: formulation and metal forming applications, submitted to Computers and Structures

c) In preparation

Colloque Calcul des Structures (GIENS, France, May 2005)
COST 526 Conference APOMAT (Morschach, Swiss, May 2005)
Premier Congrès International de Conception et Modélisation des Systèmes Mécaniques (Hamamet - Tunisie, 23 – 25 mars 2005)
NUMISHEET'05 (Detroit, Michigan, USA, August 2005)