



COST 526

“Automatic Process Optimization in Materials Technology”  
(APOMAT)

### Half-Yearly Report

To be sent to [V.Tesch@access.rwth-aachen.de](mailto:V.Tesch@access.rwth-aachen.de) until

<b>1. Reporting Period</b>	<b>1.1.2004 – 1.8.2004</b>
Project title Optimization of Sheet Metal Blanking and Bending Processes: Application to the Forming of High Strength Steel Security Parts  Project leader : Pr Alain Potiron Organization Ecole Nationale Supérieure d'Arts et Métiers 2 boulevard du Ronceray BP 3525 49035 Angers France Main collaborators involved	

<b>2. Funding Situation</b>	
Amount of money received specifically for COST	kEuros
Other resources partially used for the project	4,5 kEuros

<b>3. International Collaboration</b> (mention group and type of work done in collaboration during the reporting period)
Participation in the Working Group Meeting in Krakow + project progress report Yes
<b>LASQUO ISTIA Angers University (Dr Ridha Hambli)</b> Type of work : Numerical Design of Experiments. Tests of numerical optimization algorithms with ABAQUS software. Artificial Neural Networks Response Surface Methodology

<b>4. Industry participation</b> (mention name of companies and work done in collaboration during the whole project)
<b>Société DEVILLE S.A.</b> Type of work : Test specimens supply for experiments. Straightening process identification of the sheet-metal.

<b>5. Meetings, visits, exchange of scientists, short-term scientific missions</b>	<b>Location, date</b> OPTIMAT French Ministry program in Paris
<b>Dr Uma P. Singh</b> University of Belfast at Jordanstown Newtonabbey County Antrim Northern Ireland	<b>April 1<sup>st</sup> – July 15<sup>th</sup> 2003</b>



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## 6. Progress within the reporting period

(Not exceeding 3 pages, including tables and Figures)

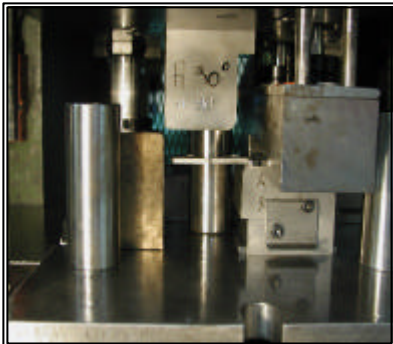
During the preceding period, the optimization techniques which were investigated concerning the process parameters influence on the part bending, had been developed. The algorithms developed in Abaqus F.E. code have been coupled with the solid C.A.D. modeler Solidworks.

**The study is concerned with process optimization in view of springback minimization.**

The main function to be optimized is the springback induced by the bending. In the following, an experimental study concerning the springback evolution is carried out.

Specimens with a central enlarged hole were blanked out from a sheet, after what they were bent in a mechanical press.

### 1- Experimental device for bending the specimens



A lot of specimens were bent (140) and all corresponding punch forces were analysed.

Figure 1- Press, specimen and machine tools

### 2- Experimental device for springback measure



The springback angle is measured on a profile projection device.

Figure 2- Bent specimen profile projection

### 3- Numerical modeling of the bending operation for specimen

The objective function is the springback angle  $\theta$ . The process parameters are the design variables  $\bar{J}$  and  $\bar{R}$ , the relative clearance between the blank and the tools

and the relative die radius. The goal is to minimize the the springback value. The optimization problem reads :

$$\text{Minimize } \theta(\bar{J}, \bar{R}) \quad \text{with} \quad \bar{J} = \frac{c}{t}; \bar{R} = \frac{r_d}{t}$$

subjected to the following constraints :

$$r_{\text{mini}} < r_d < r_{\text{Maxi}} ; J_{\text{mini}} < c < J_{\text{Maxi}}$$

$c$  is the clearance and  $r_d$  is the die radius.

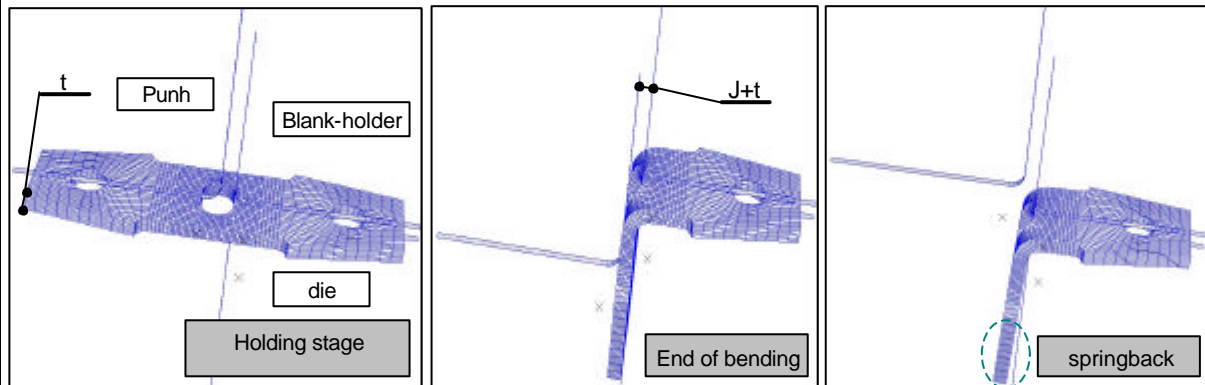


Figure 3- Part and process modeling by F.E.

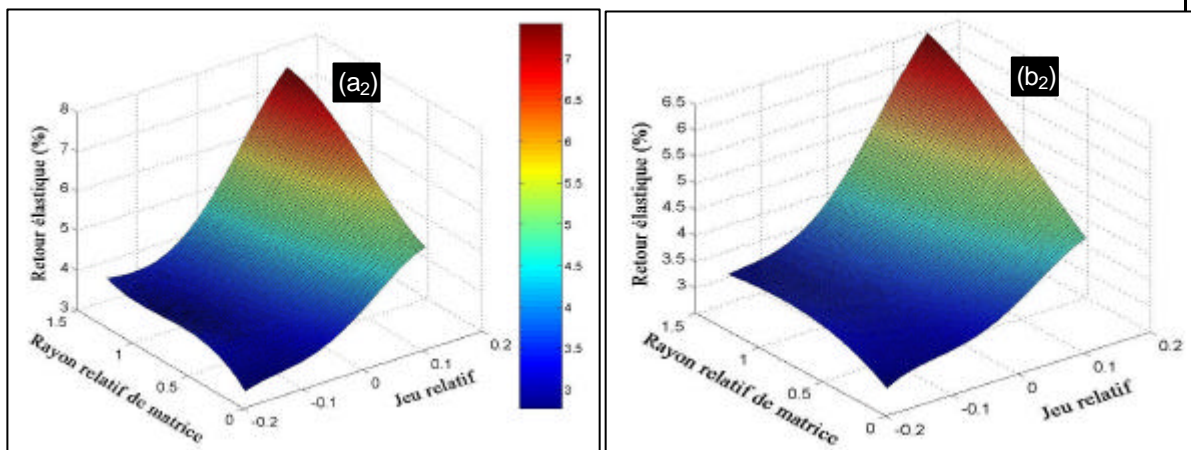
#### 4- Response surface methodology

The surface response method is used in order to optimise the springback angle. The approximation is chosen in the fourth order polynomial form:

$$\tilde{Y}_i = a_0 + \sum_{i=1}^n \hat{a} a_i x_i + \sum_{i=1}^n \hat{a} a_{ii} x_i^2 + \sum_{i < j} \hat{a} a_{ij} x_i x_j + \sum_{i=1}^n \hat{a} b_{ii} x_i^3 + \sum_{i=1, i' < j} \hat{a} b_{ij} x_i^2 x_j + \sum_{i=1}^n \hat{a} g_{ii} x_i^4 + \sum_{i=1, i' < j} \hat{a} g_{ij} x_i^3 x_j + \tilde{O}_{i=1}^n x x_i^2$$

The  $x_j$  are the process parameters. They are determined by means of a Design of Experiments matrix build with:

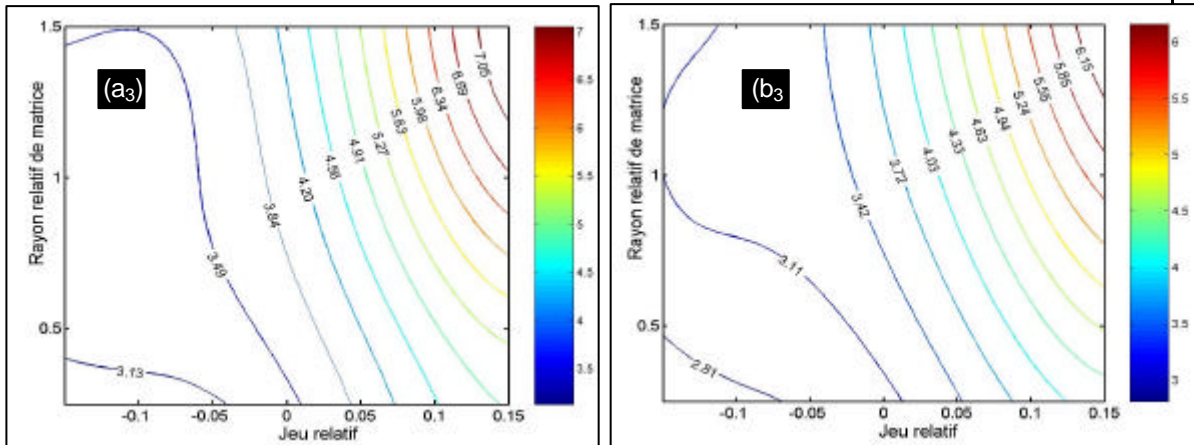
- the experimental results in a first stage
- the numerical results in a second stage



Experimental

Response surfaces

Numerical



Contours plots

Figures 4- Experimental ( $a_2, a_3$ ) and numerical ( $b_2, b_3$ ) results

In the figures the surface responses are quite similar but the results are underestimated by the numerical calculations. In view of the overestimated numerical value of the punching force, not presented here, the material seems to be too much hard. This is perhaps due to an underestimation of the material damage which is accounted for in the simulation.

Plots ( $a_3, b_3$ ) are the contour lines of the response surfaces.

In that case, the functions are smooth and the minimum value of the springback angle is easily found by a direct differentiation.

A comparison between experimental results and numerical predictions is found in figure 5 below.

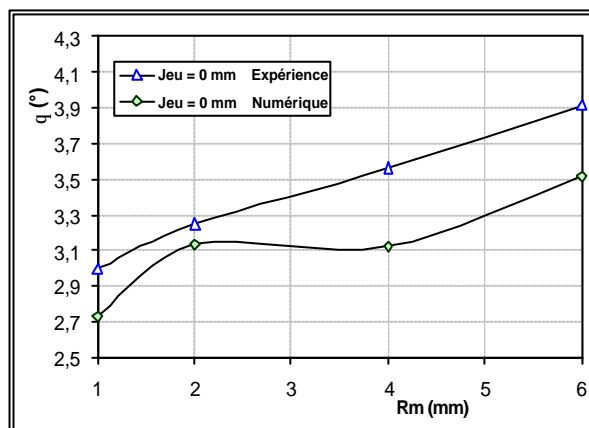


Figure 5- Comparison numerical/experimental results for a clearance of 0 mm.

## 7. List of publications

### a) Published

HAMBLI R. and POTIRON A., 'Evaluation of springback in L-bending processes including damage effects', TSS International Conference on Advances in Mechanical Engineering, March 18 - 20, 2002, Hammamet, Tunisia.

Mkaddem A., Potiron A., Boude S., "Straightened modification of 0.09% sheet metal carbon steel - micro hardness characterization in bending process", TSS International Conference on Advances in Mechanical Engineering, March 18-20, 2002, Hammamet Tunisia.

Mkaddem A., Hambli R., Badie-Levet D., "Experimental determination of damage laws for high strength low alloy E420 HSLA steel using inverse technique", TSS International Conference on Advances in Mechanical Engineering, March 18-20, 2002, Hammamet – Tunisia

Mkaddem A., Potiron A., Lebrun J-L. "Straightening and bending process characterization using Vickers micro hardness technique", International Conference of Advanced Technology of Plasticity, Oct.27-Nov. 31, 2002, Proc. Vol.1- p 631-636 Institute of Industrial science, The University of Tokyo Komaba – Japan

A. Mkaddem, A. Potiron, and S. Boude, "A comparison between experimental, numerical and theoretical springback angle in wiping die bending process" VII International Conference on Computational Plasticity COMPLAS 2003, E. Oñate and D. R. J. Owen (Eds) © CIMNE, Barcelona, 2003

Ridha Hambli, Alain Potiron, Abdessam Kobi "Application of design of experiment technique for metal blanking processes optimization", *Pages 175-180 Mécanique et Industrie* Volume 4, Issue 3, Pages 159-327 (May - June 2003)

Ridha Hambli, Alain Potiron "Modélisation et découpage des tôles" *Techniques de l'Ingénieur* (in french) Vol BM 7 505, pp 1-18

A. Mkaddem, R. Hambli, A. Potiron "Comparison between Gurson and Lemaître damage models in wiping die bending process". *Journal of Advanced Manufacturing Technology* 2004 Vol 23 issue 5-6 pp 451-461

Mkaddem A., Boude S., Da-Santo P., Potiron A.

Springback evaluations in wiping die-bending processes with experimental verification, International Conference on material forming ESAFORM 2004, Apr.28-30, Trondheim-Norway

Mkaddem A., Bahloul R., Potiron A., Reszka M..

H.S.L.A. steel sheet metal characterisation for metal forming processes by using experimental approaches, International Conference on material forming ESAFORM 2004, Apr.28-30, Trondheim-Norway.

### b) Submitted for publications

Mkaddem A., Bahloul R., Potiron A HSLA steel characterization in sheet forming processes by using Vickers microhardness technique. *Int. Journal of Mat. Processing Techn.*

Mkaddem A., Bahloul R., Potiron A Experimental approach and RSM procedure on examination of springback in wiping-die bending processes. *Int. Journal of Mat. Processing Techn.*

Mkaddem A., Bahloul R., Potiron A Experimental and numerical investigation in the optimization of sheet products geometry, using RSM. *Int. Journal of Mat. Processing Techn*

### c) In preparation

Mkaddem A., Bahloul R., Potiron A., Influence of interface frictional design on sheet-metal bending operation. Numerical prediction of material damage and maximum bending force.