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, 2003**

1. Reporting Period	**1.1.2003 – 31.7.2003**
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	

2. Funding Situation	
Amount of money received specifically for COST	kEuros
Other resources partially used for the project	1,5 kEuros

3. International Collaboration (mention group and type of work done in collaboration during the reporting period)
Participation in the Working Group Meeting in Budapest + project progress report NO
LASQUO ISTIA Angers University (Dr Ridha Hambli) **Type of work : Numerical Design of Experiments. Tests of numerical optimization algorithms with ABAQUS software.** **Artificial Neural Networks** **Response Surface Methodology**

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

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

6. Progress within the reporting period
(Not exceeding 3 pages, including tables and Figures)

During the preceding period, some optimization techniques were investigated in conjunction with the identification of the process parameters happening in the optimization of the bending stage. The work during the last 6 months was devoted to the implementation and feasibility of particulars algorithms developed in Abaqus F.E. code. We formerly study the behavior of flat security parts subjected to tensile forces. This is an approximate evaluation of the exact response of the part suddenly subjected to a shock. Next, we submit three parts with different shapes to wiping die bending simulation in order to identify the residual stress field and the state of damage of the material.
The main functions to be optimized are the sheet metal residual stresses field and the material damage induced by the bending.

1- Algorithmic procedure to optimizing

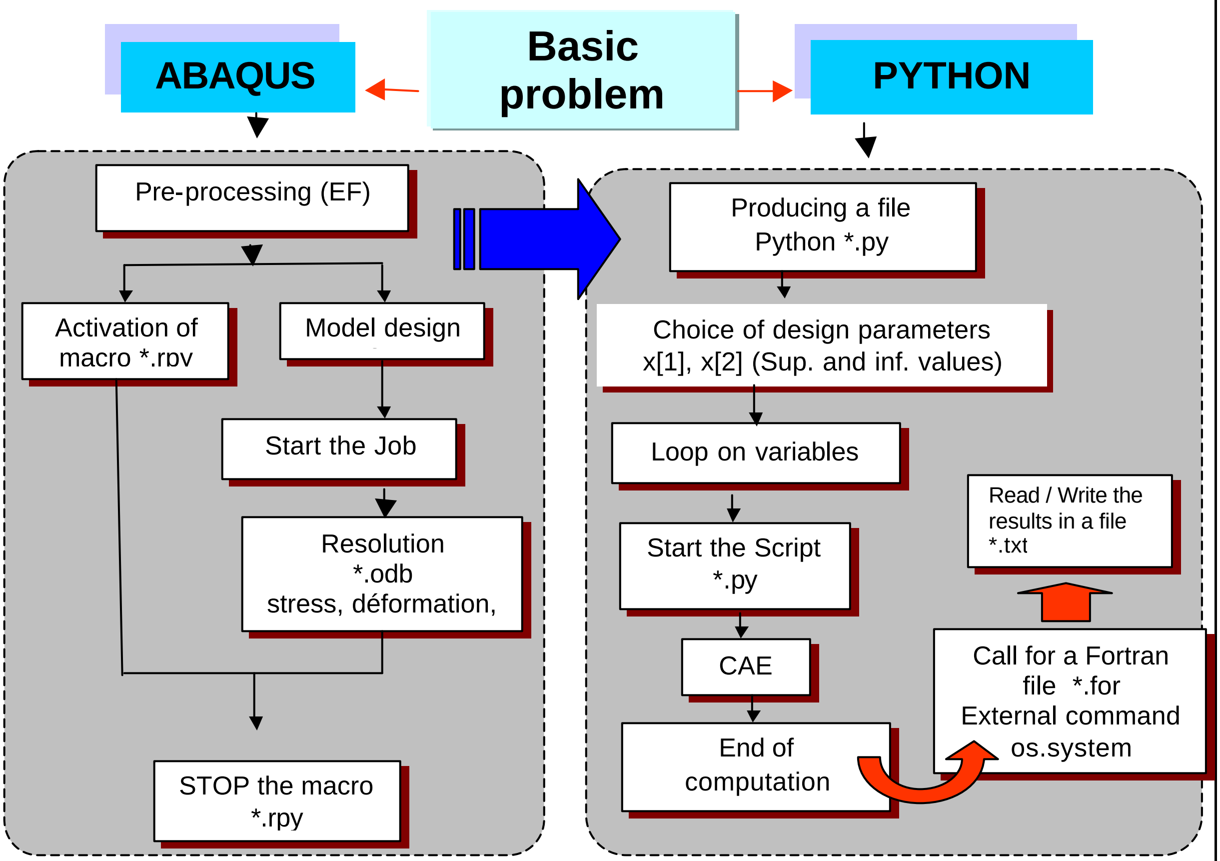

Figure 1- Algorithmic procedure

2- *Optimization of flat parts*

The objective function is relied to the shape of the part. The geometrical parameters consist in 3 radius which are the design variables. The goal is to minimize the von Mises stress and the material damage in the part.   the optimization problem reads :

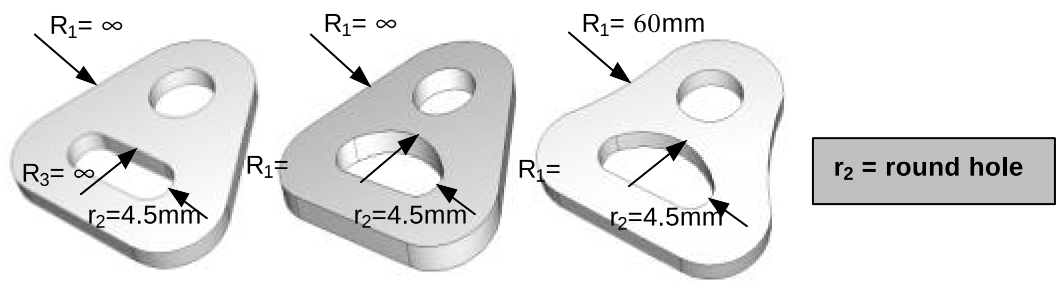

Figure 2- The three different shapes of the part

Minimize $\sigma_{vM}(R_1, r_2, R_3)$
Minimize damage $D(R_1, r_2, R_3)$
subjected to the following constraints :
$R_{1mini} < R_1 < R_{1Maxi}$ - $r_{2mini} < r_2 < r_{2Maxi}$ - $R_{3mini} < R_3 < R_{3Maxi}$
$D(\varepsilon^{pl}) \leq D_{crit}$ (in order to avoid material failure)

The results given by the simulation according to the above algorithm are summarized in the Figure below :

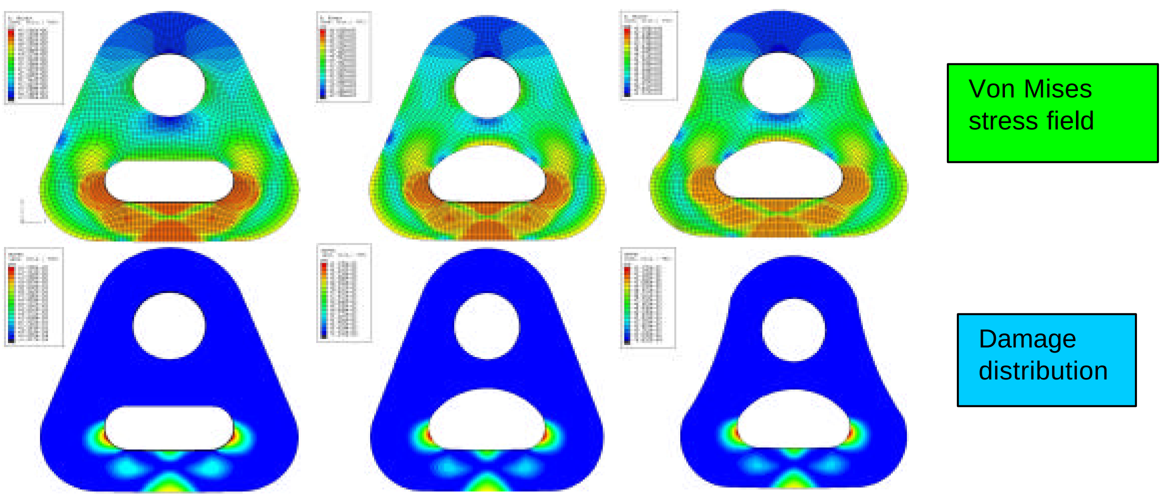

Figure 3– Reduced von Mises stress field $\tilde{s}_{vM} = \frac{s_{vM}}{s_{yield}}$**. Damage distribution**

When changing the shape, it appears that the von Mises stress field and the material damage are quite similar for the three parts.

The surface response method is then used in order to optimise more precisely the part shape. The approximation is chosen in the polynomial form :

$$\tilde{\sigma}_{vM_{max}} = \alpha_0 + \sum_{i=1}^{n}\alpha_i\rho_i + \sum_{i=1}^{n}\alpha_{ii}\rho_i^2 + \sum_{i<j}^{n}\alpha_{ij}\rho_i\rho_j + \sum_{i=1}^{n}\beta_{ii}\rho_i^3 + \sum_{i=1, j=1, i\neq j}^{n}\beta_{ij}\,\rho_i^2\rho_j + \prod_{i=1}^{n}\gamma\rho_i \quad (1)$$

For example Figure 4, in the case when the radius R_1 takes its minimum and maximum values, the main geometrical parameter leading to the maximum σ_{vM} stress, is the round hole r_2.

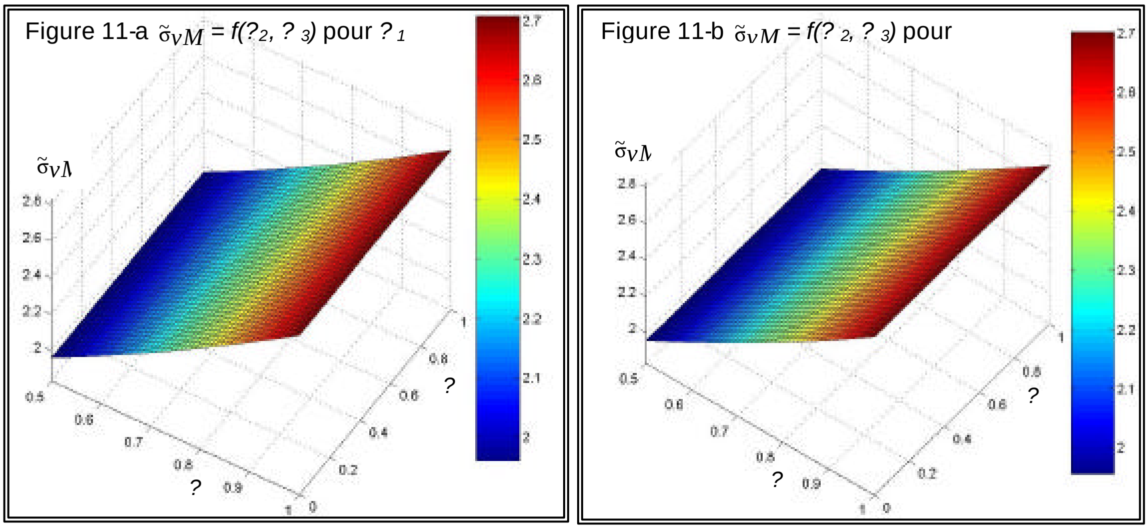

Figure 4- Surface response of von Mises stress when R_1 is fixed

Referring to formula (1), it will be possible now to minimize the stress in mathematical form.

3. *Wiping die bending*

The three parts were modeled in order to be bent by wiping die bending operation.

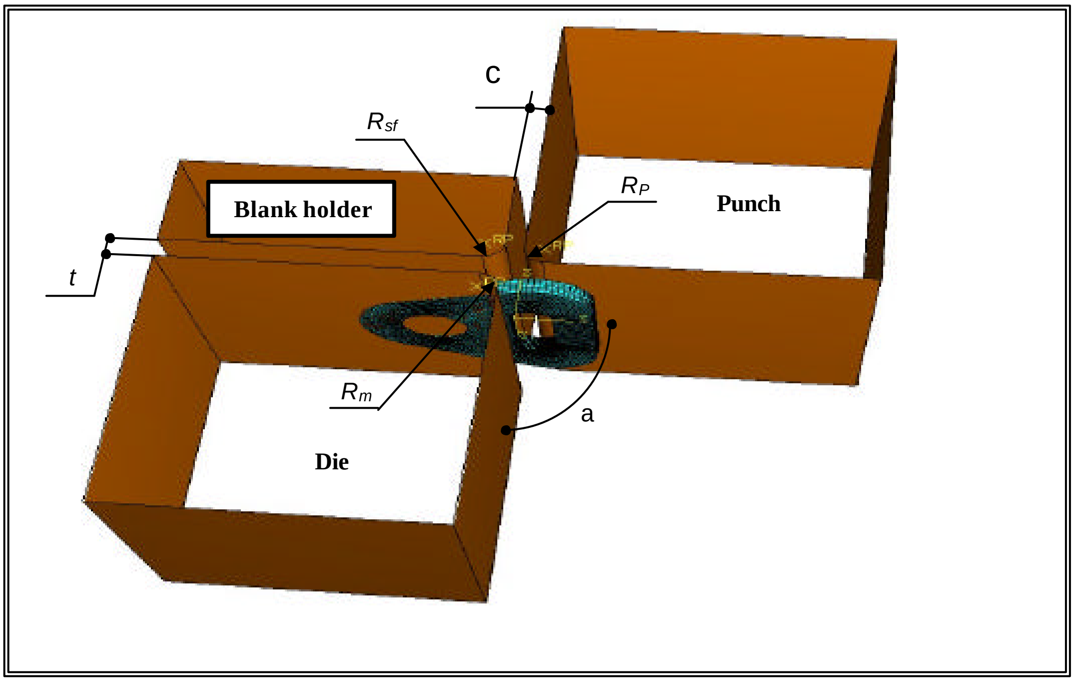

Figure 5- Wiping die bending operation

The design parameters are the punch and die radius R_{p1} and R_{m1} and the clearance C_1 between the punch and the die.
In the study, the optimisation procedure for the process optimisation is not yet implemented. The first step is to define the residual stress field and material damage.

4. *Study of residual stress and material damage after L-bending*

The security parts are very sensitive to the bending process as it can be viewed in Figure 6. The stresses field show that it remains some residual stresses and damage which can influence the further behaviour of the parts.

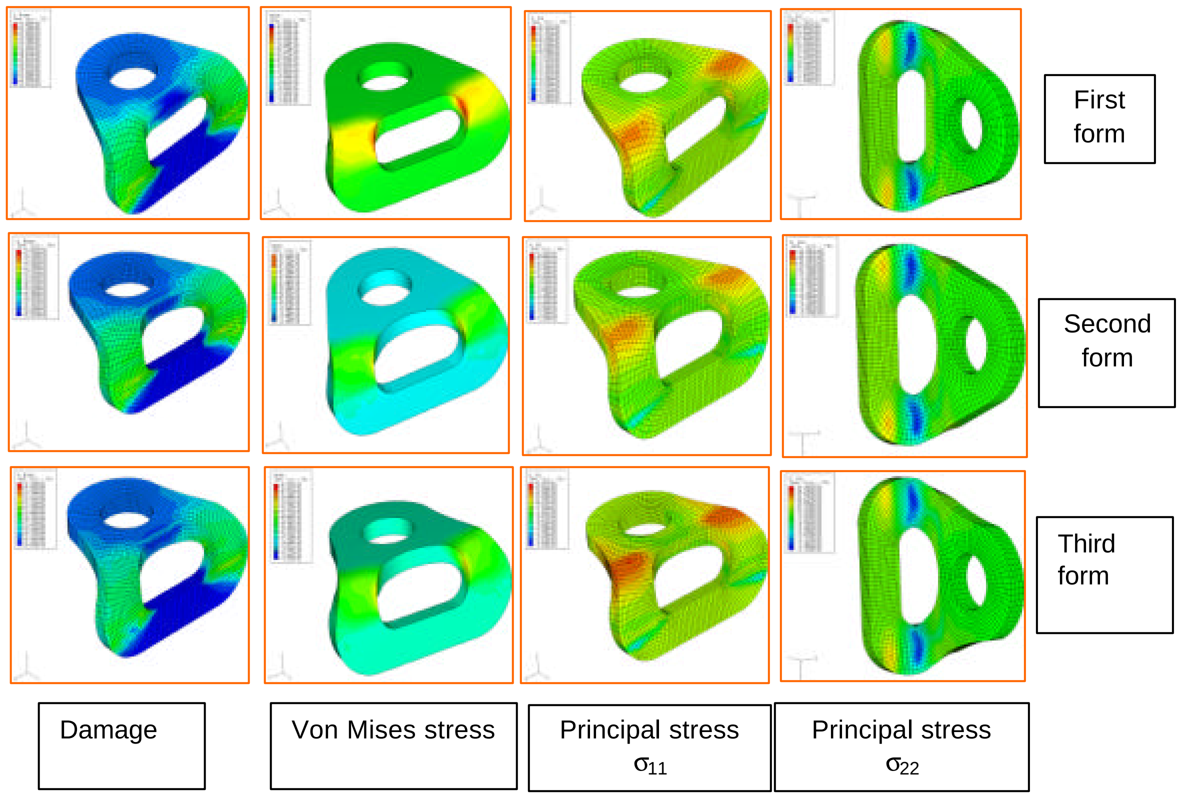

Figure 6- Stresse $\tilde{s}_{vM} = \frac{s_{vM}}{s_{yield}}$ and damage residual fields after L-bending

The optimisation would involve such observation but the study remains to be done.

In a first stage, an investigation on response surfaces can be carried out to characterize the influence of the tool parameters.

5. *Response surfaces*

Partial study are shown in the following Figure 7. It concerns the influence of the geometrical parameters (design parameters) on the reduced stress $\tilde{s}_{vM} = \frac{s_{vM}}{s_{yield}}$ and the material damage field.

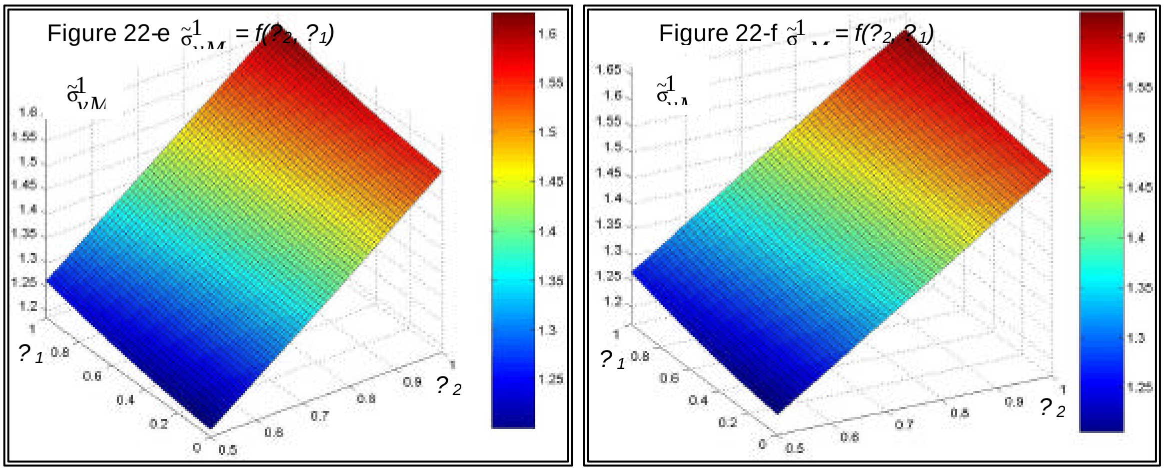

Figure 7- Response Surfaces $\tilde{\sigma}^{1}_{vM}$ when ρ_3 is fixed

The Figure 7 shows that the round hole is obviously the main parameter governing the stress behaviour of the part. Same noting appear with the material damage field.

6. Future optimisation strategy

The development of further optimisation strategy is based on the schematic algorithm in Figure 8.

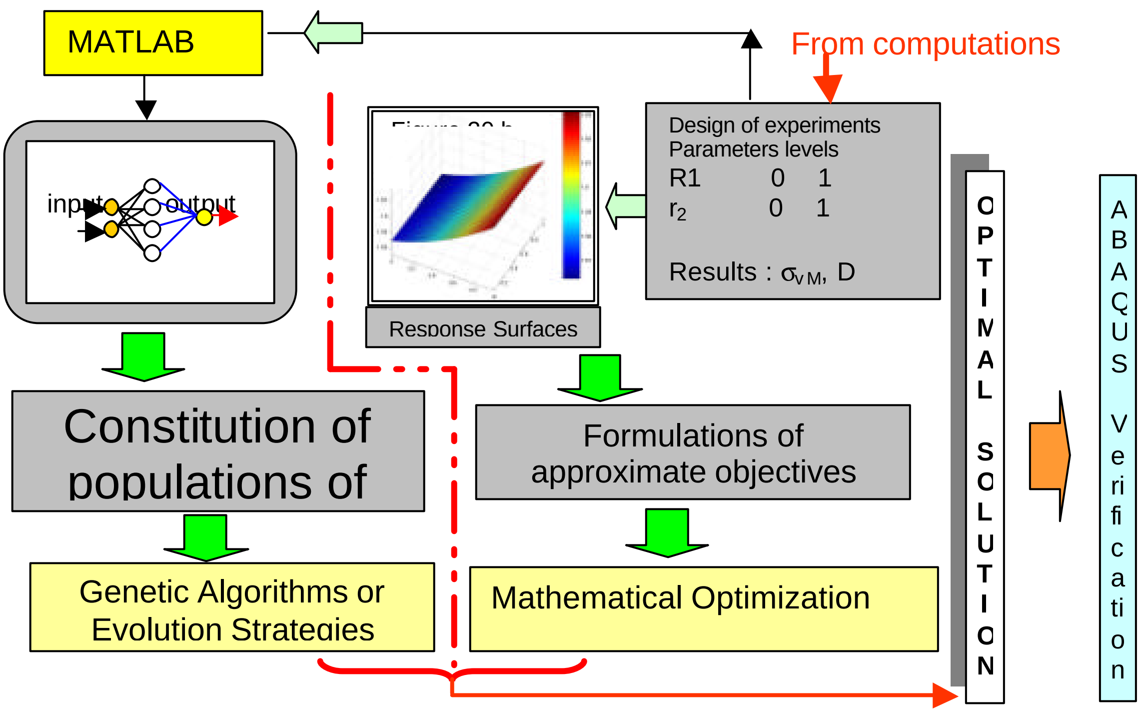

Figure 8- Optimisation strategy

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 Intemational 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)

b) Submitted for publications

A. Mkaddem, R. Hambli, A. Potiron "Comparison between Gurson and Lemaître damage models in wiping die bending process". Jour, (accepted with revisions)

c) In preparation