COST 526

"Automatic Process Optimization in Materials Technology"

(APOMAT)

Half-Yearly Report

1. Reporting Period	**1.1.2002 – 30.6.2002**
"Optimization of Sheet Metal Blanking and Bending Processes: Application to the Forming of High Strength Steel Security Parts" Project leader: **Pr Alain Potiron** 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)
project progress report
LASQUO ISTIA Angers University (Dr Ridha Hambli) **Type of work : Numerical Design of Experiments. Tests of numerical optimization algorithms with ABAQUS software.**

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

6. Progress within the reporting period (Not exceeding 3 pages, including tables and figures)
During the first period, the identification of the material was investigated. The reporting period deals with the identification of the material characterization.

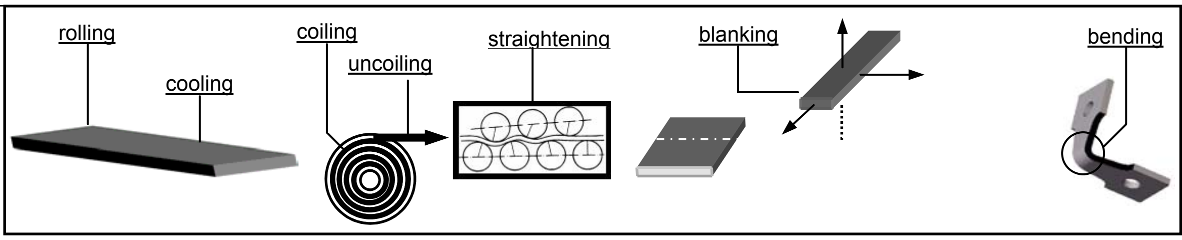


Figure 1- Sheet processing

The main operations inducing the initial modifications of the sheet are shown on Figure 1. We suppose that the material is in its "virgin" state after straightening and we start the material identification from that stage.

The main mechanical parameters to be identified are :
The material hardening law
The material damage evolution during loading

1. Material characterization

1.1- Hardening law

The hardening law identification is carried out by tensile tests with electrical gauges.

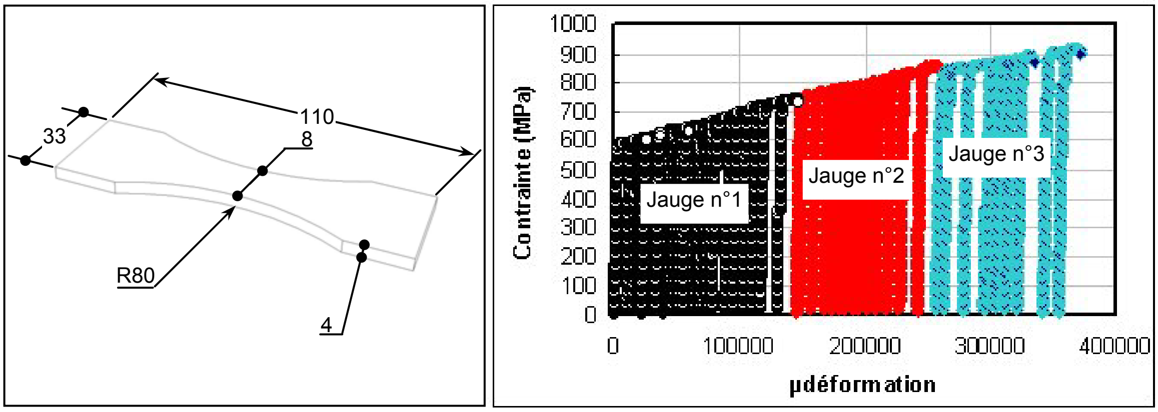


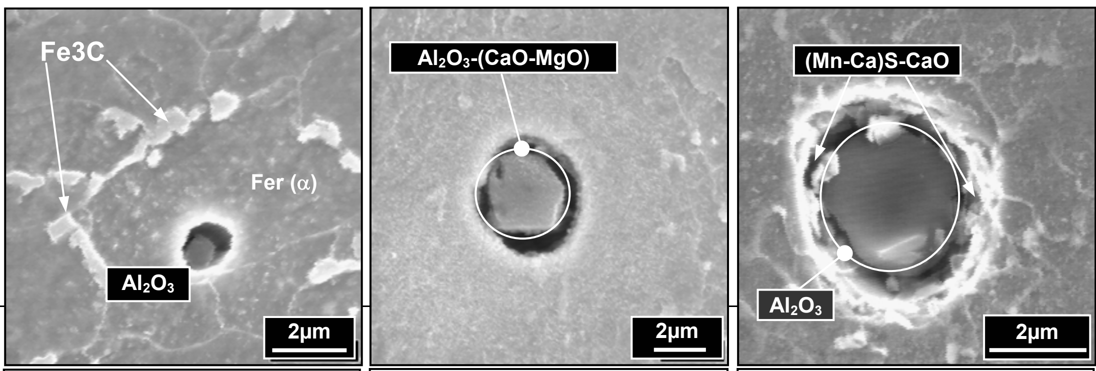
Figure 2- Specimen. Tensile test

The material behavior law is then found to be :

$$\sigma_{eq} = 560 + 800(\varepsilon^{Pl})^{0.745} \qquad \textbf{(1)}$$

1.2- Material damage identification

Some microscopic observations where performed on the material in order to identify the metallurgical aspect and the corresponding risks of failure.



a. Inclusion typique d'alumine logée dans un grain

b. Inclusion à cœur alumine couplé au calcium et au manganèse

c. Inclusion d'alumine couplée au composé (Mn-Ca)S

Figure 3- Type of inclusions into the material matrix

It can be seen in Figure 3 that the inclusions can initiate some cracks leading to the material damage. The load-unload of the specimen Figure 2 and the measure of the elastic Young modulus E corresponding to the slopes of the experimental curves lead to the value of the isotropic damage coefficient *D* as a function of the plastic strain. The damage coefficient is calculated by means of the Lemaitre definition :

$$D = 1 - \frac{E(\bar{\varepsilon}_{pl})}{E_0} \qquad (2)$$

Where $E(\bar{\varepsilon}_{pl})$ is the Young modulus corresponding to an equivalent plastic strain $\bar{\varepsilon}_{pl}$.
E0 is the Young modulus of the initial unstrained material.
From the curves in Figure 2 it was found that D evolves in the followin
Manner in Figure 4 :

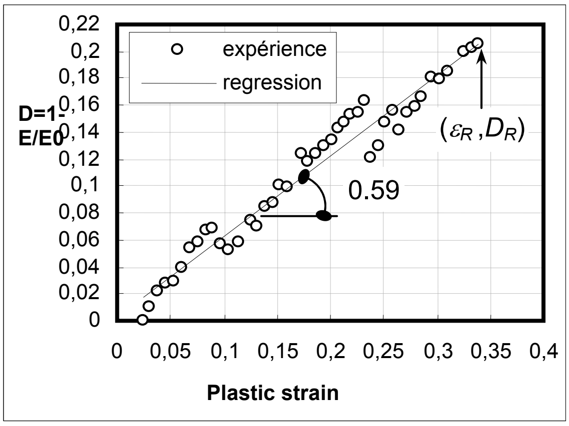


Figure 4- Damage evolution vs plastic strain.

The damage evolution is quite linear.
1.3- Elasto-plasticity coupled with damage
The basic relationship allowing for the mechanical behavior is obtained in the form of :

- Elastic isotropic relation between stress and strain :

  □ = (1-*D*)**C**□
  (3a)

- Yield function coupled with damage :

  $$f = \frac{\sigma_{eq}}{1-D} - R(\bar{\varepsilon}_{pl})$$

- Consistency of the plastic loading :

$\dot{f} = 0$

f

2. Implementation in ABAQUS Finite Element code

An incremental formulation was developed and implemented in the F.E. code Abaqus. The modeling of the blanking process led to the results illustrated in Figure 6 below :

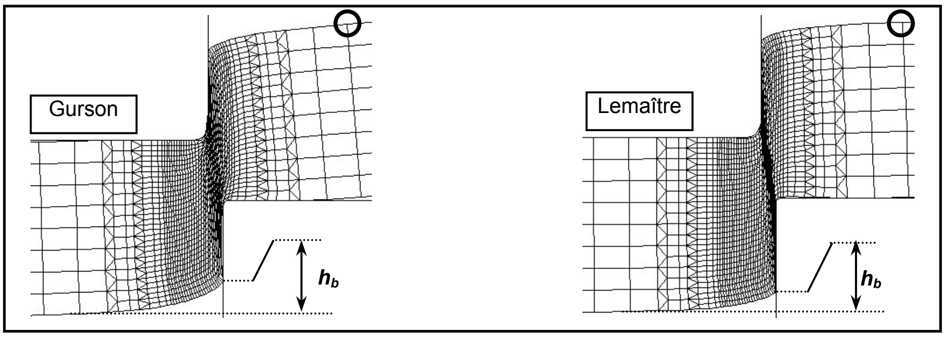


Figure 6- Blanking of sheet metal using Gurson or Lemaître damage models.

The feasibility of the sheet processing modeling is then obtained in a satisfying form and can be used to go ahead in the modeling of the whole process
The influence of the process parameters, punch and die radii and the tool clearance between punch and die, has been identified; It was found for example, that the optimal clearance leading to the more accurate blanked profile, is bout 15% of the sheet thickness.

3. Conclusion

The first stage of the proposed work in COST 526 is then achieved. The identification of the material characterization and the feasibility of the F.E. modeling of the sheet metal blanking and bending.
The process parameters have been identified as the punch and die radii and the tool clearance between punch and die.

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.
b) Submitted for publications
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.
c) In preparation