*EUROPEAN COOPERATION IN THE FIELD OF SCIENTIFIC AND TECHNICAL RESEARCH - COST*

**COST 526**

Automatic Process Optimization in Materials Technology

(APOMAT)

Title:

# Optimization of sheet and tube metal forming processes

**Keywords:** sheet metal forming, tube metal forming, elasto-visco-plasticity, kinematic hardening, frictional contact, springback

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**1. Duration / run time of the project**

3 years, starting October 1st, 2001

**2. Overall cost**

- Manpower: 180 kEURO (36 m.m.)
- Computing equipment: 25 kEURO
- Travel + subsistence: 12 kEURO

**3. Funding situation**

Funding by Walloon Region and Groupe Usinor

**4. Project partners indicated to participate**

- RDCS (RD center of Cockerill-Sambre/Usinor)
- Samtech (software company)

**5. Project partners to be found**

Potential cooperation with other research groups (e.g. for conducting experimental tests for determining precise material parameters for aluminium). For example, cooperation with Prof. Batoz (UTC) and Prof. Gelin (UFC) would certainly bring a lot to the project.

**6. Short description of the material process to be optimized**

In this project we focus on sheet metal forming processes. More specifically, special attention will be given to springback effects upon unloading (i.e. after withdrawal of all forming tools).

In this context, an efficient numerical optimization of the process parameters and tools geometry can have a significant economic impact by reducing the design time of products with new shapes, as well as by improving the processing of existing products.

A possible extension to tube hydroforming processes, still with an emphasis on springback effects, is currently under negotiation.

**7. Material(s) involved:**

High strength steels (HSS), very high strength steels (VHSS), aluminium

**8. Optimization potential of the process or process step**

The main benefits of the proposed optimization are to ensure the compliance with geometrical specifications for the final product, with the additional possibility to verify its mechanical qualities and/or improve the processing efficiency.

As mentioned in point 6, a special point of interest will be springback effects on forming processes. Indeed, while these effects are well mastered by the industry in the case of parts made of mild steel, this is not the case at all for high strength steels or aluminium. Thus, a better understanding of the influence of process parameters, including material properties, on the net shape of these parts will be of great value to the industry.

**9. Specified material properties to be achieved**

The material properties to be achieved in the final product are its geometry after tool removal (i.e. including springback effects), as well as the absence of local defects such as wrinkles or local thinning.

Additionally, the deformed material should stay inside the forming limit diagram (FLD) during the whole process.

**10. Process parameters to be optimized**

The process parameters to be optimized are the geometry of the tools, the initial geometry of the part and loading cycle parameters (e.g. pressure, tool displacement, ...). From the material point of view, design variables would include hardening characteristics, as well as lubrication conditions (friction being considered as a material behavior).

**11. Material laws including material dependent coefficients**

The material laws which will be used are elasto (-visco)-plastic models with kinematic and mixed hardening, taking anisotropy into account (Hill for steels, Barlat for aluminiums), as well as friction models.

Precise material parameters are known for steel, but are to be defined for aluminium.

**12. Simulator**

METAFOR: in-house non-linear finite element code for the simulation of quasi-static and dynamic processes involving contact and large deformations. In particular, it is intensively used for the simulation of metal forming processes.

The only specific developments which might prove necessary for this project are concerned with the interfacing between the simulation and the optimization engines.

**13. Optimizer**

- Mathematical programming methods (Levenberg-Marquardt, CG, GC3MA, ...), already implemented in METAFOR, with semi-analytical evaluation of gradients.
- BOSS/Quattro (Samtech - commercial product)

**14. Competence / activities of proposer:**

LTAS-MCT has been working on metal forming simulation since 1987. The result of this research work is a set on numerical tools for analysing a wide range of processes involving large strains, with contact and friction, both in quasi-static and dynamical settings. In addition, a recent thesis (Kleinermann, 2000) has demonstrated the applicability of optimization techniques to inverse problems such as material parameter identification as well as geometry and process parameter optimization.

**15. International state of the art and references**

A recent state of the art in material parameter identification and optimization can be found in:

- Proceedings of Filed Analysis for Determination of Material Parameters, Experimental and Numerical Aspects, IUTAM Symposium, July 31-August 4, 2000, Abisko National Park, Sweden.
- Literature survey in the doctoral thesis of J.P. KLEINERMANN (see below).

Some recent (2000-2001) relevant publications of the group on process optimization:

- KLEINERMANN J.P., "Identification paramétrique et optimisation des procédés de mise à forme par problèmes inverses". Doctoral thesis, University of Liège, 2000.
- KLEINERMANN J.P., PONTHOT J.Ph., "Parameter identification and shape/process optimization in metal forming simulation". To be published in "Journal of Material Processing Technology".
- KLEINERMANN J.P., PONTHOT, J.Ph., "Optimization methods for inverse modeling of forming processes". Keynote lecture, Proceedings of the 4th Int. ESAFORM Conference on Metal Forming, A.M. Habraken (ed), Liège, Belgium, 23-25 April 2001.
- KLEINERMANN J.P., PONTHOT J.Ph., HOGGE M., "Parameter identification for inverse problems in metal forming simulation". Invited paper, Proceedings of Filed Analysis for Determination of Material Parameters, Experimental and Numerical Aspects, IUTAM Symposium, July 31-August 4, 2000, Abisko National Park, Sweden.
- KLEINERMANN J.P., STAINIER L., PONTHOT J.Ph., "Parameter identification using inverse problem methodology in metal forming simulation". Proceedings of ECT 2000, 6-8 September 2000, Leuven, Belgium, Finite Element Techniques and Developments, pp. 263-272.
- KLEINERMANN J.P., STAINIER L., PONTHOT J.Ph., "Metal forming processes optimization using inverse problems". Proceedings of ECCOMAS 2000/COMPLAS VI, European Congress on Computational Methods in Applied Sciences and Engineering, Barcelona, 11-14 September, 2000.
- KLEINERMANN J.P., STAINIER L., PONTHOT J.Ph., "Damage model identification using inverse problem methodology". Invited paper, Proceedings of PLASTICITY'00, Int. Symposium on Plasticity and its current applications, Khan et al. (ed), Whistler, Canada, July 17-21, 2000, pp. 413-415.
- KLEINERMANN J.P., PONTHOT J.Ph., "Optimization methods for inverse problems in metal forming simulation". Proceedings of SACAM 2000, Int. Conf. on Applied Mech., 11-13 January 2000, Durban, South Africa, pp. 685-690.

and on sheet metal forming simulation itself:

- GOHY S., PAPELEUX L., COLLARD X., PONTHOT J.P., "Accurate prediction of springback in sheet metal forming". Proceedings of the 8th Int. Conference METAL FORMING 2000, Pietrzyk et al (ed.), Krakow, Poland, September 3-7, 2000, pp. 411-418.
- PONTHOT J.P., PAPELEUX L., GOHY S., COLLARD X., "Numerical simulation of springback in sheet metal forming". Invited paper, Proceedings of ECCOMAS 2000/COMPLAS VI, European Congress on Computational Methods in Applied Sciences and Engineering, Barcelona, 11-14 September, 2000.