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

COST 526
Automatic Process Optimization in Materials Technology
(APOMAT)

Title:

Optimization of Process Parameters in Sheet Metal Forming

Keywords: sheet metal forming, finite element modelling, simplified inverse approach, incremental dynamic explicit approach, design variables, sensitivities, quality functions

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1. Duration / run time of the project

- 2001-2004

2. Overall cost

- 150 K euros

3. Funding situation

- A part of the funding is already assured by a governmental organization(Scholarship from the Ministery of Education).
- Thinking about funding by industrial companies.

4. Project partners indicated to participate

Several companies and organizations have shown collaborative interest in our research project:

- the ESI group in Rungis (F)is involved in the development and/or marketing of OPTRIS /PAMSTAMP, QUICKSTAMP, SIMEX and is interested in the software aspect,

- the Chausson Outillage company (200 persons) designing and producing sheet metal forming tools in Reims (F) is interested in the tools and products developments,

The CETIM, in Senlis (F) involved in a national project in sheet metal forming analysis and design for small and medium size companies, might be interested in the organization (knowledge management) and the industrial aspects.

Project partners to be found

- academic and/or industrial partners (die makers, sheet metal product companies) besides France

6. Short description of the material process to be optimized

The production, in a short time and at low costs, of high quality thin walled shell structures obtained by stamping and drawing is an ultimate goal for manufacturing companies in automotive, aerospace and consumer goods. As an example leading car manufacturer companies are introducing about 10 new models every three years. To reach this goal continuous progress are made at the design and at the floor shop levels of forming tools. To avoid time consuming trial and error tryout procedures, the use of computer tools and simulation is in constant progress in the stamping industry to evaluate the forming paths and the forming defects such as fracture, wrinkling, surface unevenness and geometrical inaccuracies.

Computer simulation can also be very attractive and helpful at the preliminary design stage for the process and tooling engineers to define the initial blank (thickness, contour and surface), some parameter process (boundary conditions, holding forces, lubrification conditions, draw bead types and positions,…) and the material properties (thickness, yield stress, hardening, anisotropy,…)

7. Material(s) involved:

Mild steel

High strength steel

Aluminium

8. Optimization potential of the process or process step

The global optimization in sheet metal forming will lead to :

- economy of material quantity to produce a defect free part (this concerns both the workpiece but also the tools)
- reduction of the cost and time to market new products by increasing the part devoted to virtual prototyping compared to experimental (trial and error tryout procedures)
- possibility to produce new type of parts by using virtual optimization for design

9. Specified material properties to be achieved

Among other process parameters (see section 10), some material parameters can be considered as design variables. These are the average anisotropy coefficient, the hardening exponent of the Hollomon uniaxial law for a given yield function (Hill criteria for example). These quantities can be assumed continuous, independant, corresponding to a virtual material, or assumed to be characteristics of an existing material.

The defects to be avoided are mainly :

- the excessive thinning leading to diffuse necking and rupture,
- the development of permanent folds (wrinkles), often associated with thickening,
- the surface uneveness due to insufficient straining,
- the geometrical inaccuracies after tools removals and blanking operations due to springback

Quality functions have to be defined and tested based on thickness distribution (a good indicator of quality is a „ uniform “ thickness), on Forming Limit Diagrams, on wrinkling risk factors, on geometrical requirements, on fatigue life prediction of structural parts obtained by deep drawing, etc…

10. Process parameters to be optimized

The process parameters to be optimized are of :

- geometrical type (initial thickness of the blank, shape of the blank contour, shape of the die and punch, shape of the blankholder surface, position and shape of the drawbeads)
- material type (parameters of the elasto-plastic constitutive equation (anisotropy coefficients, hardening parameters, …)
- process conditions, single or multiple forming stages, blankholding and restraining forces, …)

The restraints (limitations) on these parameters depend on the design variables thmselves, and depends on the definition of the optimization problem. They can be justified for technological, mechanical or economical reasons.

11. Material laws including material dependent coefficients

The material laws including material dependent coefficients are the elasto plastic laws, based on Hill quadratic yield function for the mild or high strength steels and based on Barlat (non quadratic yield function) for aluminium sheets.
These laws are directly related to Forming Limit Curves which can be used to define quality functions.
The parameters of the material laws are available for a large range of metal sheets.

12. Simulator

The software to be used for the process simulation are either :

- a simplified inverse approach code such as REFORM (our in house code developped since 1987), a commercial code developped by SIMTECH and saled also by the ESI group. The description of these codes is done in the references (section 15)
- an incremental dynamic explicit code based on shell elements, large elasto-plastic strains and contact conditions such as OPTRIS or PAMSTAMP from the ESI group.

13. Optimizer

The use of simplified inverse approach generally allows the computation of analytic sensitivities. So, the optimization algorithms can be Mathematical Programming ones such as SQP, which is known to be very efficient for non linearly constrained problems (requiring a small number of functions and gradients evaluations).
With incremental approaches, the cost of the process simulation and the use of „ black boxes “ commercial codes suggests to consider response surface techniques : the process simulation is performed for some specified values of the design variables, giving the „ response “ (quality functions and constraints) at these points. The optimization is based on these values only, and can be carried out independently of the process simulation code.

14. Competence / activities of proposer:

The proposer belongs to a research laboratory of 100 persons (material science, acoustic, computational mechanics) supported by the Ministry of Education and Research and also by the CNRS of France. The proposer has been working on the sheet metal forming numerical simulation since 1987 and did published around 40 papers/communications and six theses on the subject..

15. International state of the art and references

The state of the art and last innovations in CAD/CAM/CAE in sheet forming simulation and their impact in the transport and packaging industries can be found in several papers published in the proceedings of recent international meetings [1], [2], [3], [4]

One can notice the important contributions made by french industries, software companies and universities to develop industrial tools for the forming simulation of sheet metal parts: OPTRIS, PAMSTAMP by the ESI Group, ISOPUNCH by ISOFORM/SOLLAC, SIMEX by SIMTECH, RADIOSS by MECALOG.

The University of Technology of Compiègne (UTC) greatly contributes since 1987 to the development of the simplified inverse approach for analysis and preliminary design of stamped parts.

The first attempts to combine an analysis tool with optimization algorithms in the field of sheet metal forming simulations were published by researchers from universities in 1996 :

- Some geometrical parameters of die shapes in the two stage forming process were optimized by combining the sweeping simplex method or simulated annealing method with a static explicit incremental code by Ohata et al. [5], Nakamura et al. [6]. in Japan.
- The optimum design of the blank contour to minimize the thickness variations was first performed by Barlet et al. (France) by combining their inverse simplified approach (ISA) with a sequential programming algorithm (SQP) [7]
- Geometrical parameters such as die radius were optimized to control the shape of a workpiece after springback by combining static implicit or dynamic explicit FE codes and optimization algorithms based on gradients by Ghouati et al.. (France) [8]
- Restraining force distributions under the blank holder have been optimized (before designing the drawbeads) by combining the ISA and a SQP algorithm by Naceur et al., Batoz et al., Delameziere et al., (France) [9], [10], [11], [12], [13], [14], and by combining the AUTOFORM incremental software and modified gradient method (Hillman et al.,[15]).
- Material properties such as hardening parameter and average anisotropy coefficient were optimized to reduce the risk of rupture, by combining the ISA with SQP, by Batoz et al., Delameziere et al. [11], [12], [13], [16]

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