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

COST 526

Automatic Process Optimization in Materials Technology

(APOMAT)

Title:

Distributed simulation-based Optimization in Sheet Metal Forming

Keywords: sheet metal forming, deep drawing, multi-stage process, simulation-based optimization, process optimization, distributed computing, direct search methods, parallel/distributed optimization algorithms, finite element analysis, networks of workstations

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1. Duration / run time of the project

IV/2001 – IV/2003

2. Overall cost

450 kEUR

3. Funding situation

A proposal will be submitted for funding by the Ministry of Science of the state of Nordrhein-Westfalen/Germany.

4. Project partners indicated to participate

Industry partners:

- Fischer & Kaufmann GmbH & Co. KG, Finnentrop/Germany (automotive supplier)
- GEDIA Gebrüder Dingerkus GmbH, Attendorn/Germany (automotive supplier)
- Heinrich Huhn GmbH + Co, Drolshagen/Germany (components for sheet metal forming machinery)
- Inpro GmbH, Berlin/Germany (development of simulation software)

Academic partners:

- Prof. M. Kleiner, University of Dortmund/Germany (forming technology)

Collaboration:

- Contribution of practical experiences in sheet metal forming (Fischer&Kaufmann, GEDIA, Heinrich Huhn)
- development of software system and application of new distributed optimization strategies (University of Siegen)
- development of sheet metal forming simulation software and specific interface management components (Inpro)

Benefits:

- reduction of time-to-market (design cycle time)
- reduction of cost spent on prototypes by applying virtual prototyping
- reduction of production cost by determining optimal products with minimal material demand (e.g. minimal blank thickness, optimal blank geometry)

5. Project partners to be found

Experts in sheet metal forming from both academia or industry to extend the expertise in simulation and to transfer the results to industry.

6. Short description of the material process to be optimized

- industrial process of multistage sheet metal forming by deep drawing in automotive supplier industry
- number of stages in the process depends on product's geometry and material properties
- number of stages determines cost for manufacturing of tools (punches and dies)
- optimal process design comprises optimal number of stages, optimal tool geometry design, optimal blank geometry, optimal setting of process parameters (e.g. blank holder force, friction, etc.)
- economic relevance by reducing cost spent on developing and manufacturing of prototypical tools, reducing time-to-market, improving product quality, improved satisfaction of customer's demands

7. Material(s) involved:

- Cold/hot rolled steels
- Aluminum alloys
- Stainless steels

8. Optimization potential of the process or process step

- currently, optimization of processes in industrial practice is based mainly on experience
- simulation of processes gains in importance, but without integration with computer-based optimization
- optimal process design (number of stages, blank geometry, tool geometry) allows major reduction of design cycle time and cost spent on prototyping in/before the offer phase
- optimal process design allows cost reduction in the production phase by reduction of material demand, reduction of process stages, optimal selection of material, etc.

9. Specified material properties to be achieved

- minimal material use of the product while satisfying constraints on geometry/strength/stress of the final product
- avoidance of tearing or wrinkling

10. Process parameters to be optimized

- reduce response time to the client by ca. 40%
- number of stages in a multistage metal forming process
- blank holder force to avoid tearing or wrinkling
- blank geometry
- geometry of pre-formed blanks
- geometry of punch and die
- punch-die clearance

11. Material laws including material dependent coefficients

Determined by the FEM simulation software system.

12. Simulator

INDEED by inpro GmbH., Berlin, Germany is a finite element-based analysis tool for multistage metal forming processes (deep drawing, bending, hydroforming, etc.). It is capable of using shell and membrane elements as well as volume elements. To enable distributed simulation-based optimization using INDEED, the communication and synchronization interfaces between the optimization and the remote INDEED processes in a network of workstations must be developed.

13. Optimizer

To exploit the computational ressources of a network of workstations optimally, a scalable distributed optimization algorithm – the Distributed Polytope Method – will be used. Hybrid optimization strategies combining a variety of algorithms proved in recent projects their applicability to problems from design optimization and are also envisaged to be applied.

14. Competence / activities of proposer:

The proposer is working on the topic of process optimization since the 1980s in various engineering domains. Several distributed optimization strategies were successfully applied in projects with industrial partners from manufacturing, groundwater engineering (WASY GmbH, Berlin, Germany), and aircraft industry (EADS GmbH Deutschland, München, Germany). Design and implementation of distributed problem solving environments for mathematical optimization problems started in 1989. The aforementioned successful application of distributed strategies in industrial projects is based on the development of these software environments and the underlying concepts.

15. International state of the art and references

Automatic optimization of single- and multi-stage metal forming processes is a topic of current research. A distributed problem solving environment for integrated simulation and optimization including load balancing in heterogeneous networks in process design is currently not available. Efficient distributed optimization algorithms for simulation-based problems are a recently developing research issue.

References reflecting the state of the art in optimisation of the sheet metal forming process:

Ohata, T., Nakamura, Y., Katayama, T., Nakamichi, E., Nakano, K., Development of Optimum Process Design System by Numerical Simulation, J. of Materials Proc. Tech., Vol. 60, Elsevier Science, pp. 543-548, 1996.

Ohata, T., Nakamura, Y., Katayama, T., Nakamichi, E., Nakano, K., Improvement of Optimum Process Design System by Numerical Simulation, J. of Materials Processing Technology, Vol. 80-81, Elsevier Science, pp. 635-641, 1998.

v. Schöning, K.-V., Müller, M., Bogon, P., Simulation Tools in Sheet Metal Forming - Today's Possibilities, Tomorrow's Demands, in: Proc. of the 6th ICTP, pp. 2113-2130, 1999.

Sünkel, R., Pautsch, C., Planning of Forming Processes - Time and Cost Reduction Applying the Simulation Program INDEED, 15th IMACS-World Congress, Berlin 1997.

Zimniak, Z.: Problems of Multi-Step Forming Sheet Metal Process Design, Journal of Materials Processing Technology, Vol. 106, 2000, pp. 152-158.

Zimniak, Z.: Application of a System for Sheet Metal Forming Design, Journal of Materials Processing Technology, Vol. 106, 2000, pp. 159-162.

Selected publications of the proposer’s research group:

Load Balancing:

Barth, T., Flender, G., Freisleben, B., Thilo, F.: Load Distribution in a CORBA Environment, Distributed Objects and Applications’99 (DOA’99), Edinburgh/UK, 1999, IEEE Press, pp. 158-166.

Barth, T., Freisleben, B., Grauer, M., Thilo, F.: Distributed Solution of Simulation-Based Optimization Problems on Networks of Workstations, Runtime Systems for Parallel Programming (RTSPP’2000), Cancun/Mexico, 2000.

Problem Solving Environments:

Boden, H.; Gehne, R.; Grauer, M.: Parallel Nonlinear Optimization on a Multiprocessor System with Distributed Memory, in: Grauer, M., Preßmar, D., (eds.): Par. Computing and Math. Optimization, Springer 1991, pp.65-78.

Boden, H.; Grauer, M.: OpTiX-II: A Software Environment for the Parallel Solution of Nonlinear Optimization Problems, Annals of OR, 1995, pp.129-140.

Brüggemann, F.; Grauer, M.: OpTiX – an Object-Oriented Environment for Parallel Optimization, in: Grauer, M.; Preßmar, D. (eds.): Parallel Computing and Mathematical Optimization, Springer 1991, pp.133-153.

Eschenauer, H.; Grauer, M.: Decomposition and Parallelization Strategies for Solving Large-scale MDO Problems, in: Design Optimization, Vol. 1, No. 1, MCB University Press 1999, pp.24-43.

Grauer, M., Albers, S., Frommberger, M.: Concept and First Experiences with an Object-Oriented Interface for Mathematical Programming, in: Sharda, R., Golden, B., Wasil, E., Blaci, O., Stewart, W. (eds.): Impacts of Recent Computer Advances on Operations Research, North-Holland, 1989, pp. 474-483.

Grauer, M.; Barth, T.: Multidisciplinary Optimization and Cluster Computing using the OpTiX-Workbench, Proc. Conf. On Opt. In Industry, Palm Coast/Florida, 1997, pp.73-80.

Grauer, M.; Barth, T.; Kaden, S.; Michels, I.: Decision Support and Distributed Computing in Groundwater Management, in: Savic, D., Walters, G. (eds.): Water Industry Systems: Modelling and Optimization Applications, Research Studies Press, 1999, pp.23-38.

Grauer, M.; Boden, H.: On the Solution of Nonlinear Engineering Optimization Problems on Parallel Computers, Advances in Design Automization, ASME Pub., Vol. 65, Nr.2, 1993, pp. 235-242

Optimization Algorithms:

Barth, T.; Freisleben, B.; Grauer, M.; Thilo, F.: A Scalable Algorithm for the Solution of Simulation-based Optimization Problems, Proc. Of Par. & Distr. Progr. Tech. & Appl. (PDPTA 2000), Las Vegas, 2000, pp.469-475.

Grauer, M., Barth, T., Beschorner, C., Bischopink, J., Neuser, P.: Distributed Scalable Optimization for Intelligent Sheet Metal Forming, accepted for publication in: Proc. of Conf. On Intelligent Manufacturing and Processing of Materials 2001 (IPMM'2001), Vancouver/Canada, 2001.

Grauer, M., Gruhn, G., Richter, C.: Design and Application of the GRG-Algorithm for Process Optimization, 11th CACE'78, Paris/France, 1978.

Schneider, G., Barth, T., Stettner, M., Grauer, M., Hörnlein, H.R.E.M., Kereku, E., Multidisciplinary Design Optimization of an Aircraft Wing by Applying a Hybrid Optimization Strategy, presented at Optimization in Industry III, Barga/Italy, 2001