

COST 526 - 'Automatic Process Optimization in Materials Technology' – (APOMAT)  
**Final Report – 31 July 2005**  
**Summary sheet**

Project Code	SI1
Title	Advanced Parameter Optimization Methods Preliminarily Used for Casting Processes
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Main collaborators involved	<ul style="list-style-type: none"> <li>• Tea Robič, Jožef Stefan Institute, Ljubljana, Slovenia</li> <li>• Prof. Božidar Šarler and Robert Vertnik, Nova Gorica Polytechnic, Slovenia</li> <li>• Emil Šubelj, Acroni Steelworks, Jesenice, Slovenia</li> <li>• Prof. Erkki Laitinen, Department of Mathematical Sciences, University of Oulu, Finland</li> </ul>

**Funding Situation** (for the whole project)

Amount of money received specifically for COST	12 kEuros
Other resources partially used for the project	35 kEuros

**International Collaboration** (mention group and type of work done in collaboration during the whole project)

- Department of Mathematical Sciences, University of Oulu, Finland: Numerical optimization of continuous casting of steel at Rautaruukki Steel, Finland, based on the process simulator developed at the University of Oulu, and optimization software developed in our project
- Department of Computer Science, University of Aarhus, Denmark: Development and testing of stochastic optimization methods for engineering applications with focus on dynamic optimization problems and noisy cost functions
- Heat Transfer and Fluid Flow Laboratory, Faculty of Mechanical Engineering, Brno University of Technology, Czech Republic: Laboratory measurements of heat transfer coefficients to calibrate the numerical model of the steel casting process used in our optimization calculations

**Industry Participation** (mention name of companies and work done in collaboration during the whole project)

Optimization of process parameters to improve the quality of continuously cast of steel was performed for various steel grades for two industrial partners:

- Acroni Steelworks, Jesenice, Slovenia
- Rautaruukki Steel, Finland

<b>Meetings, visits, exchange of scientists, short term scientific missions</b> (mention main events during the whole project)	<b>Location, date</b>
Opening COST 526 Meeting	Brussels, 3–4 December 2001
Visit of Prof. Miroslav Raudensky from Faculty of Mechanical Engineering, Brno University of Technology, Czech Republic	Ljubljana, Slovenia, 22 January 2002
1st Joint Working Group Meeting	Saint-Dié des Vosges, France, 21–22 May 2002
Visits of Bogdan Filipic at the Department of Computer Science, University of Aarhus	Aarhus, Denmark, 30 July – 10 August 2002 and 16– 22 November 2002
2nd Joint Working Group Meeting	Budapest, Hungary, 28–29 November 2002
3rd Joint Working Group Meeting	Brussels, 26–27 May 2003
Short-term scientific mission of Prof. Erkki Laitinen from Department of Mathematical Sciences, University of Oulu, Finland	Ljubljana, Slovenia, 22–29 June 2003
4th Joint Working Group Meeting	Krakow, Poland, 27–28 November 2003
Visit of Prof. Thimo Krink from Department of Computer Science, University of Aarhus, Denmark	Ljubljana, Slovenia, 1–5 December 2003
5th Joint Working Group Meeting	Angers, France, 13–14 May 2004
Visit of Bogdan Filipič at the Department of Mathematical Sciences, University of Oulu	Oulu, Finland, 8–15 September 2004
Visit of Prof. Erkki Laitinen from Department of Mathematical Sciences, University of Oulu, Finland	Ljubljana, Slovenia, 9–15 October 2004
6th Joint Working Group Meeting	Brno, Czech Republic, 18–19 November 2004
First Invited COST 526 Conference	Morschach, Switzerland, 30–31 May 2005

<b>Main outcome of the project</b> (mention only the major points)
<ul style="list-style-type: none"> <li>• Systematic design of costs functions for specific optimization problems in continuous casting of steel, including minimization of violations of metallurgical cooling criteria, minimization of differences between target and actual temperatures in the secondary cooling zone, and balancing between the liquid pool length and slab surface temperature</li> <li>• Implementation of a simulation-based optimization software that consists of a set of optimization procedures (local optimization, downhill-simplex, evolutionary algorithm, differential evolution) and enables incorporation of various process simulators</li> <li>• Comparative studies of process parameter optimization in continuous casting of steel with different optimization methods and process simulators</li> <li>• Optimization calculations performed for and improved parameter settings delivered to Acroni Steelworks, Jesenice, Slovenia, and preliminary calculations done for Rautaruukki Steel, Finland</li> </ul>

## Publications, related to this project

### Published

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B. Šarler, R. Vertnik, G. Manojlovič, J. Cesar, M. Sabolič Mijovič, I. Justinek, B. Marčič, B. Filipič, M. Raudensky, J. Horsky, E. Laitinen: Informatisation upgrades of the Inexa-Store billet caster, phase I. *Proceedings of the 4th International Metallurgical Conference on Continuous Casting of Billets*, Třinec, Czech Republic, 2001, pp. 17–26.

B. Filipič: Simulation-based optimization of material properties. In: M. Bohanec, M. Gams, D. Mladenič, M. Grobelnik (Eds.), *Proceedings of the 5th International Multi-Conference Information Society 2002*, Jožef Stefan Institute, Ljubljana, Slovenia, 2002, pp. 94–97.

B. Filipič: Numerical optimization of coolant flows in continuous casting of steel. In: B. Šarler, D. Gobin (Eds.), *Heat and Mass Transfer in Solid-Liquid Phase Change Processes: Proceedings of the Seminar Eurotherm 69*, Ljubljana, Slovenia. Nova Gorica Polytechnic, 2003, pp.180–185.

T. Krink, B. Filipič, G. B. Fogel, R. Thomsen: Noisy optimization problems – a particular challenge for differential evolution? *Proceedings of the 2004 Congress on Evolutionary Computation CEC 2004*, Portland, Oregon. IEEE, Piscataway, 2004, Vol. 1, pp. 332–339.

B. Filipič, T. Robič: A comparative study of coolant flow optimization on a steel casting machine. *Proceedings of the 2004 Congress on Evolutionary Computation CEC 2004*, Portland, Oregon. IEEE, Piscataway, 2004, Vol. 1, pp. 569–573.

T. Robič, B. Filipič: In search for an efficient parameter tuning method for steel casting. In: B. Filipič, J. Šilc (Eds.), *Bioinspired Optimization Methods and their Applications, Proceedings of the International Conference BIOMA 2004*. Jožef Stefan Institute, Ljubljana, 2004, pp. 83–94.

B. Šarler, R. Vertnik, B. Filipič: Automatic process parameter optimisation in continuous casting of steel. *Fourth International Conference on Solidification and Gravity*, Miskolc-Lillafüred, Hungary, 2004, pp. 121–122.

G. Gantar, K. Kuzman, B. Filipič: Increasing the stability of the deep drawing process by simulation-based optimization. *Journal of Materials Processing Technology*, Vol. 164/165, 2005, pp. 1343–1350.

T. Robič, B. Filipič: DEMO: differential evolution for multiobjective optimization. In: C. A. Coello Coello, A. Hernandez Aguirre, E. Zitzler (Eds.), *Evolutionary Multi-Criterion Optimization: Proceedings of the Third International Conference EMO 2005*, Guanajuato, Mexico. Lecture Notes in Computer Science, Vol. 3410, Springer, Berlin, 2005, pp. 520–533.

B. Filipič. Efficient simulation-based optimization of process parameters in continuous casting of steel. In: D. Büche, N. Hofmann (Eds.), *COST 526: Automatic Process Optimization in Materials Technology: First Invited Conference*, Morschach, Switzerland, 2005, pp. 193–198.

### Submitted for publication

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B. Filipič, B. Šarler: An Empirical Investigation into the Properties of Coolant Flow Optimization in the Steel Production Process. Submitted to the 14th International Electrotechnical and Computer Science Conference ERK 2005, Portorož, Slovenia.

### In preparation

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Will you continue the actual cooperation with your partners after the end of the action?

Yes

No

Would you participate in a possible "spin-off" action continuing the present one?

Yes

No

Will you continue your present work/collaboration with another European action?

Yes

No