



COST 526

“Automatic Process Optimization in Materials Technology”
(APOMAT)

Half-Yearly Report

To be sent to V.Tesch@access.rwth-aachen.de until **February 28, 2004**

1. Reporting Period	1.7.2003 – 31.12.2003
Project title	Optimization of cooling parameters in continuous casting process
Project leader Organization	Dr Erkki Laitinen University of Oulu, dept. of mathematical sciences P.O. Box 3000 90014 UNIVERSITY OF OULU
Main collaborators involved	Helsinki Univ. of Technology, lab. of metallurgy, Finland Lab. for multiphase processes, Nova Gorica Polytechnic, Slovenia Josef Stefan Institute, dept. of Intelligent Systems, Slovenia Banki Donat Polytechnic, Dept. of Material sci. and Tech., Hungary Rautaruukki steel company, Finland Outokumpu steel company, Finland

2. Funding Situation	
Amount of money received specifically for COST	0 kEuros
Other resources partially used for the project	60 kEuros

3. International Collaboration
(mention group and type of work done in collaboration during the reporting period)
Participation in the Working Group Meeting in Krakow + project progress report
YES
<i>Application for bilateral Finland-Slovenia research project</i> projects FIN1 (Laitinen), SI1 (Filipic). To compare the solution methods and the optimisation methods used for continuous casting of steel.

4. Industry participation
(mention name of companies and work done in collaboration during the whole project)
Rautaruukki steel, Finland: The new dynamic secondary cooling program for controlling cooling water flow rates is installed at casters 4, 5 and 6 at Rautaruukki steel works. The work of Rautaruukki consists of making required process communication for control program.

5. Meetings, visits, exchange of scientists, short-term scientific missions	Location, date

6. Progress within the reporting period
(Not exceeding 3 pages, including tables and figures)

During the last half year we have worked for installing and testing the new software at Rautaruukki steel works.

The main progress of 3D simulation model

The 3D simulation model is tested on-line at Rautaruukki steel works. The computational speed of the new software is enough for real time use (see Fig. 1).

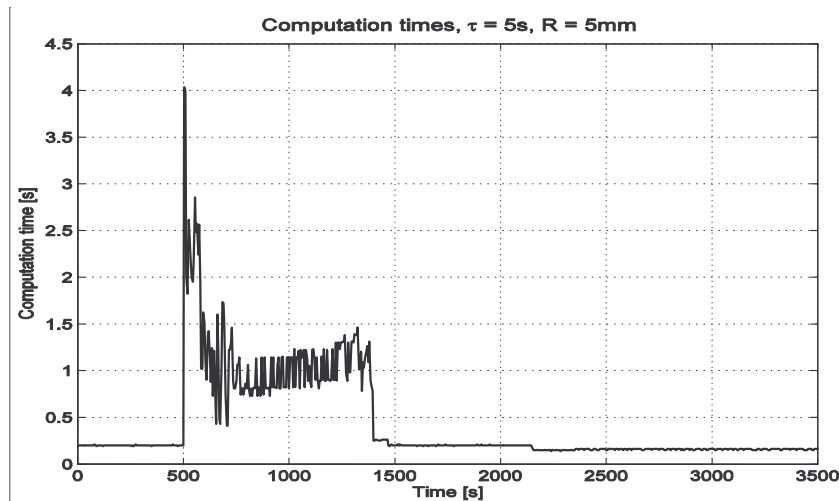


Fig. 1 Computation time when casting speed is decreased from 1.4 m/sec to 0.8 m/sec within 15 sec. Time step is 5 sec.

The main progress of optimization model

The optimization model has been installed at Rautaruukki steel works for on-line tests. The control parameters are the water flow values for the centerline and corner cooling zones described in the Figure 2.

The objective of quality function is to avoid surface and internal cracks of cast. The quality function is defined mathematically as follows:

$$\left\{ \begin{array}{l} J(T) = \frac{1}{2} \int_0^{L_z} (T - T^{tar})^2 dz \\ J(T) = \frac{1}{2} \sum_{i=1}^{N_z} h_z^i (T(z_i) - T^{tar}(z_i))^2 \end{array} \right.$$

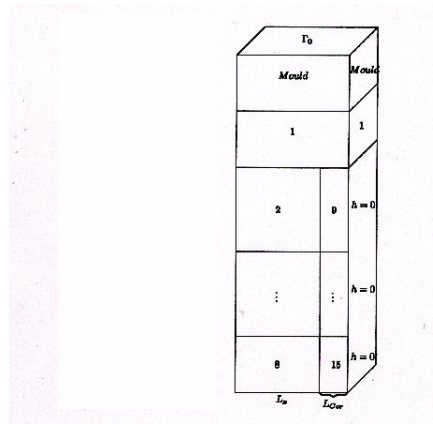


Figure 2. The illustration of the centerline and corner cooling zones.

7. List of publications

a) Published

E. Laitinen, A.V. Lapin and J. Pieskä: "Numerical experiments with multilevel subdomain decomposition method", Lobachevskii Journal of Mathematics, Vol.13, pp.67-80

R.F. Kadyrov, E. Laitinen, and A.V. Lapin: "Using explicit schemes for control problems in continuous casting process", Lobachevskii Journal of Mathematics, Vol.13, pp.25-38

R. Dautov, R. Kadyrov, E. Laitinen, A. Lapin, J. Pieska, V. Toivonen: "On 3d dynamic control of secondary cooling in continuous casting process", Lobachevskii Journal of Mathematics, Vol.13, pp.3-13

Laitinen E., Lapin A., Pieskä J., Predictor-Corrector methods for solving continuous casting problem, Proceedings of the DD15 International Conference on Domain Decomposition Methods, **Berlin**, Germany, 2003.

E. Laitinen, J. Pieskä and V. Toivonen: "On 3D Dynamic Control of Secondary Cooling in Continuous Slab Casting Process", in proc. Of Moving Boundaries 2003, Seventh International Conference on Computational Modelling of Free and Moving Boundary Problems, 4-6 November 2003 Santa Fe, **New Mexico**, USA.

b) Submitted for publications

c) In preparation