



COST 526

**“Automatic Process Optimization in Materials Technology”
(APOMAT)**

Half-Yearly Report

To be sent to V.Tesch@access.rwth-aachen.de until **August 27, 2004**

| 1. Reporting Period | 1. 1. 2004 – 30. 6. 2004 |
|--------------------------------|--|
| Project title | Advanced Parameter Optimization Methods Preliminarily Used for Casting Processes (SI1) |
| Project leader Organization | Dr. Bogdan Filipič Jožef Stefan Institute, Ljubljana, Slovenia |
| Main collaborators involved | <ul style="list-style-type: none">• Tea Robič Jožef Stefan Institute, Ljubljana, Slovenia• Prof. Božidar Šarler, Robert Vertnik Nova Gorica Polytechnic, Slovenia• Emil Šubelj Acroni Steelworks, Jesenice, Slovenia• Prof. Erkki Laitinen Department of Mathematical Sciences, University of Oulu, Finland |

2. Funding Situation

Amount of money received specifically for COST

1 kEuros

Other resources partially used for the project

3 kEuros

3. International Collaboration

(mention group and type of work done in collaboration during the reporting period)

Participation in the Working Group Meeting in Angers + project progress report

- YES
 NO

Project leader Bogdan Filipič participated in the 5th Joint Working Group Meeting in Angers, France, held 13–14 May 2004. He coorganized a session of WG4 on optimization methodologies and reported on the progress of the project SI1 in WG2.

A bilateral Slovenian-Finnish project *Numerical Optimization of Continuous Casting of Steel*, proposed by Prof. Erkki Laitinen from University of Oulu (COST 526 partner FIN1) and Bogdan Filipič, has been approved and will be supported by the Slovenian Ministry of Education, Science and Sport, and the Academy of Finland from 1 April 2004 to 31 March 2006.

4. Industry participation

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

Collaboration with the Acroni Steelworks, Jesenice, Slovenia, was continued. In optimizing process parameters for continuous casting of steel, we shifted from the original set of mathematically defined metallurgical cooling criteria and the related weighted-sum approach to a more detailed treatment of two practically important criteria, the length of the liquid pool and the slab surface temperature (see description in *Progress within the reporting period*).

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| 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)

Over the previous reporting periods, we performed a number of optimization calculations to improve process parameter settings in continuous casting of selected steel grades and study the performance of various optimization algorithms. The optimization criteria used in these studies were the so-called empirical metallurgical cooling criteria that restrict variations in the temperature field of the slab to assure the highest possible quality of the cast steel. These criteria are defined mathematically and usually optimized through a weighted sum approach. As understanding and interpretation of numerous conflicting criteria is not trivial and determining their weights represents an additional problem, a modified version of the casting optimization task was studied to serve the needs of our industrial partner.

Specifically, two practically important criteria, the length of the liquid pool and the slab surface temperature were analyzed in multi-objective manner. The study was done for the steel grade AC 4016 with the slab cross-section of 1.04 m x 0.20 m. On the continuous casting machine, the slab unbending region starts at 15.63 m and ends at 17.35 m, and the cut-off point is at 25.30 m. A pyrometer was positioned at 19.42 m to measure the slab surface temperature.

Under this setup, the requirement for the length of the liquid pool l was to be as close to the beginning of the starting point of the unbending region at $l_{ref} = 15.63$ m, but not longer, and for the slab surface temperature T at the pyrometer position to be as close as possible to $T_{ref} = 975^\circ\text{C}$, but not lower. The effect of the casting speed as a free process parameter on these two criteria is shown in Figure 1. It can be seen that they both increase with the increasing casting speed, which results in a conflict between the criteria. In other words, reaching the liquid pool length l_{ref} results in too high surface temperature, while reducing the casting speed to T_{ref} generates too short liquid pool.

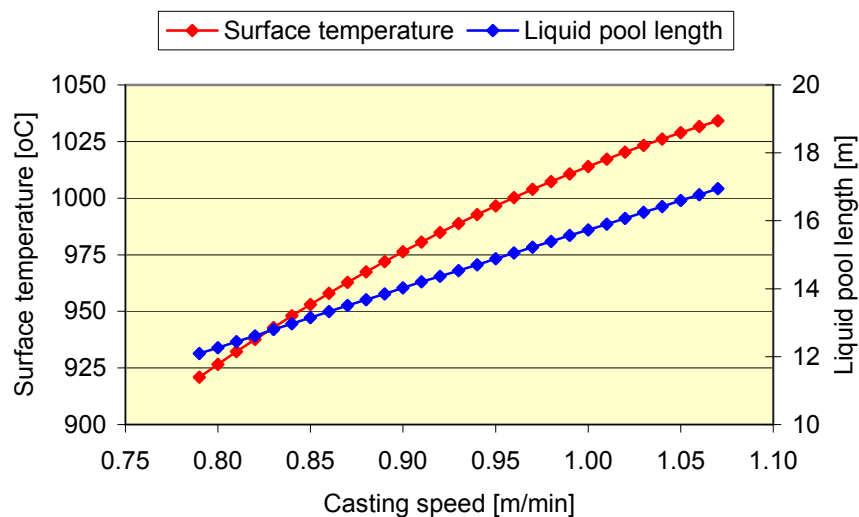


Figure 1: Slab surface temperature at the pyrometer position and liquid pool length as functions of the casting speed

In the next step, a multi-objective evolutionary algorithm coupled with the casting process simulator was applied to search for the Pareto optimal solutions to this problem. In addition to the casting speed,

12 coolant flows in the secondary cooling zone of the casting device were considered as decision variables. The optimization task was to minimize both $|l - l_{ref}|$ and $|T - T_{ref}|$. Figure 2 shows the resulting set of solutions. Among them, feasible settings are the ones satisfying the constraints $l \leq l_{ref}$ and $T \geq T_{ref}$.

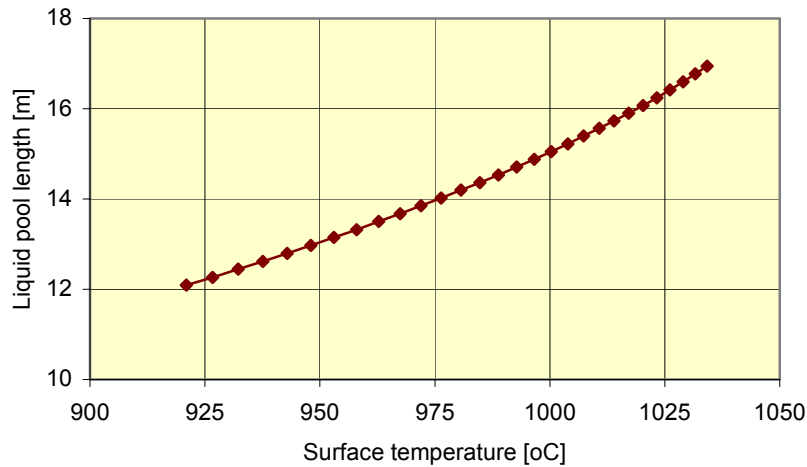


Figure 2: Relationship between the optimization objectives: liquid pool length vs. slab surface temperature at the pyrometer position

The results provided in this way enable better insight into the effects of process parameters on the selected metallurgical criteria and make it possible to apply any of the optimal solutions according to the preferences of the metallurgists. An additional advantage of handling the problem in the multi-objective manner is there is no need for the criterion weights.

7. List of publications

a) Published

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. 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) Submitted for publication

T. Robič, B. Filipič: In search for an efficient parameter tuning method for steel casting. Submitted to the International Conference on Bioinspired Optimization Methods and their Applications BIOMA 2004, Ljubljana, Slovenia.

c) In preparation