COST 526

"Automatic Process Optimization in Materials Technology"

(APOMAT)

Half-Yearly Report

1. Reporting Period	1.1.2002 – 30.6.2002
Project title: **Modelling and Optimisation for Competitive Continuous Casting** Project leader: **Prof. Bozidar Sarler** Organization: **Laboratory for Multiphase Processes** **Nova Gorica Polytechnic** **Vipavska 13, SI-5000 Nova Gorica, Slovenia** Main collaborators involved: **Prof. Bogdan Filipic, SI** **Prof. Jaroslav Horsky, CZ** **Prof. Erkki Laitinen, FI** Industrial partners, steel: **ACRONI, SI** **INEXA-STORE, SI** **NOVA HUT, CZ (through partner CZ)** **RAUTARUUKKI, FI (through partner FI)** Industrial partners, aluminium: **IMPOL, SI**	Project team: Nova Gorica Polytechnic **Dr. Jure Mencinger** **Igor Kovacevic** **Janez Perko** **Robert Vertnik** **Miha Zaloznik** ACRONI **Ales Lagoja** **Jozef Triplat** **Emil Subelj** INEXA-STORE **Gojko Manojlovic** **Janko Cesar** IMPOL **Rajko Safhalter** **Edvard Slacek** **Marina Jelen** **Franci Tomazini**

2. Funding Situation	
Amount of money received specifically for COST	5kEuros
Other resources partially used for the project	45kEuros

3. International Collaboration (mention group and type of work done in collaboration during the reporting period)
Participation in the Working Group Meeting in Saint-Dié des Vosges + project progress report **YES, project presented by Prof. Bogdan Filipic**

4. Industry participation (mention name of companies and work done in collaboration during the whole project)
Already mentioned, see the research group.

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

Regular contacts with project partners.	

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

The project kicked-off from our 10 years of development of simulation systems for continuous casting of steel and aluminium alloys.

Process modeling has been introduced in order to improve quality, reduce production cost, and improve safety. Like most commercial material processes, the continuous casting involves many interacting phenomena of great complexity. Because of this complexity, no model can include all of the involved phenomena at once. The following two types of models are under development and modification within our simulation system in the last decade: Off-line and On-line CC model.

The Off-line CC model for steel calculates the steady temperature distribution in the strand as a function of the following process parameters: strand dimension, steel grade, casting temperature, casting velocity, primary and secondary cooling systems flows, pressures, and temperatures, type and quantity of the casting powder, and the (non)application of the radiation shield and electromagnetic stirring or braking. The Bennon-Incropera mixture continuum formulation is used for the physical model, solved by the Voller-Swaminathan iterative scheme. The finite volume method is used for the solution with non-uniform mesh discretization in all three dimensions. The IDS steel material properties generation package or Jmatpro materials properties outputs can be directly read into simulation system. The thermal conductivity of the liquid phase is artificially enhanced to account for the forced and natural convection effects in the melt. The Off-line model is coded in combination of Compaq Fortran and Delphi and runs on all Windows systems. Since 2001, the code has a user-friendly self-explanatory Windows application for generation of the simulation and plot input data as well as a self-explanatory results browser. A dynamic model of the strand with the dynamic plot browser have been developed by the end of 2001. The simulation output is represented in graphical (around 50 pictures) and alphanumeric (2 tables) form. The results include plots of steel grade enthalpy, specific heat, thermal conductivity, density, thermal contraction, differential thermal contraction, dynamic liquid viscosity, liquid phase fraction, a log file of all generated material properties, and a schematic caster geometry plot. The alphanumeric results represent an overview of the technologically important temperature data of the caster segments and thickness of the solidified shell. The temperature and phase field graphics include corner, centerline, and average temperatures of the four strand surfaces, longitudinal and transversal temperatures and phase fractions of the strand.

The heat transport mechanisms in the mold take into account the heat transport mechanisms through the casting powder, accross the air-gap (if it exists), to the mold surface, in the mold, and from the mold inner surface to the mold cooling water. The heat transport mechanisms in the secondary cooling zone take into account the effects of the steel grade, casting velocity, strand surface temperature, spray nozzle type, spray water flow, temperature and pressure, radiation and cooling through the rolls contact. Different types of the rolls are considered (driving, passive, centrally cooled, externally cooled, etc.). The mentioned basic heat transfer mechanisms are modified with regard to running water and rolls stagnant water at relevant positions.

All involved heat transport mechanisms have been implemented as generic at the first stage of the simulation system development. They are in the process of being systematically replaced by the plant specific ones through data from the plant measurements and laboratory measurements.

The On-line CC model

The On-line CC model is used exclusively in automation of the CC machine. It controls the mold oscillation, electromagnetic stirring, casting speed, and spray flows as a function of format, steel grade, casting temperature, start and stop of the cast. The regulation algorithm is based on the sensitivity coefficients derived from the Off-line CC model. This model is foreseen to be implemented into the caster control systems in the continuation of the project.

7. List of publications

a) Published

B. Sarler, J.Perko, DRBEM solution of temperatures and velocities in DC cast aluminium slabs. C.A. Brebbia, A.Kassab, M.B.Chopra, E.Divo (eds.). Boundary Element Technology XIV, WIT Press, Southampton, 2001, pp. 357-369.

B.Sarler, R.Vertnik, G.Manojlovic, J.Cesar, M.Sabolic-Mijovic, I.Justinek, B.Marcic, B.Filipic, M.Raudensky, J.Horsky, E.Laitinen, Informatisation upgrades of the Inexa-Štore billet caster : phase I, 4th International Metallurgical Conference on Continuous Casting of Billets, Trinec, 30th, 31st October and 1st November 2001, Ceska Hutnicka Spolecnost, 2001, pp. 17-26.

B.Sarler, A.Lagoja, G.Manojlovic, M.Sabolic-Mijovic, B.Filipic, M.Raudensky, E.Laitinen. Informatisation of the continuous casting in ACRONI-Jesenice and INEXA-Štore, Proceedings of the 9. Conference on materials and technologies, 14.-16. november 2001, Portoroz, Slovenija, pp.102.

b) Submitted for publications

c) In preparation