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RESEARCH DIRECTORATE-GENERAL
Directorate B : European Research Area : structural aspects
COST

COST 526
EUROPEAN CONCERTED ACTION ON
"Automatic Process Optimization in Materials Technology"
(APOMAT)
Final Report about Working Group 2 (WG2) "Liquid-Solid Processing" by Norbert Hofmann
April 2001 - October 2005

Final Report for WG2 "Liquid-Solid Processing"

Objectives of WG2

The goal of WG2 is to simulate the solidification of liquid materials during the production process. Important process parameters should then be identified and optimized in an automated fashion. The 9 participating projects in WG2 cover 4 different process technologies: Investment casting (4 projects), continuous casting of steel (2 projects), injection die casting (1 projects) and special production processes (2 projects)

The following table shows the projects in WG2:

Project	Members	Project Title
CH 2	Dr. Martin Balliel	Numerical Calculation of the Process Parameters which Optimize the Gas Turbine Blade Coating Process by Thermal Spraying for Given Spray Paths
CH 4	Prof. Dr. Norbert Hofmann	Optimization of EQ Casting for Gas Turbine Blading Using a Database
CZ 1	Dr. Antonin Dlouhy	A Numerically Based Optimization of a Near-g TiAl Precision Casting Process
CZ 5	Prof. Frantisek Kavicka	Optimization of Casting of Corundobaddeleyit (EUCOR)
D 4	Dr. Jürgen Jakumeit	Numerical Optimization of the Brigdman Casting Process for Stationary Gas Turbine Blades
F 2	Prof. Jean-Claude Gelin	From Final Properties of Components to Mould and Process Design in Metal Injection Moulding
FIN 1	Dr. Erkki Laitinen	Optimization of Cooling Parameters in Continuous Casting Processes
SI 1	Dr. Bogdan Filipic	Advanced Parameter Optimization Methods Preliminary Used for Casting Processes
SI 4	Prof. Bozidar Sarler	Modelling and Optimization for Competitive Continuous Casting

Status of Most Advancing Projects in WG2

Due to the increasing competitions in the world market for continuous steel casting and the investment casting industry, the projects in these fields are more advanced in optimisation technologies and process control than the other projects in the WG2. They generate more direct product relevant results for industrial partners. Additionally these projects collaborated intensively with other COST526-projects.

The following projects show significant improvements in the field of process and product optimisation:

- **Dr. E. Laitinen: Optimization of Cooling Parameters in Continuous Casting Process**

  Dr. E. Laitinen has developed an on-line process optimisation technology that uses a program with CORBA-architecture to distribute the process simulation & control to several computers. The goal is to improve the quality of continuous cast steel slabs. Instead of simulating the material properties of the steel slap with fluid flow simulation (long simulation time), Dr. E. Laitinen predicts the microstructure and the properties of the cast slab from the cooling curves.

  The simulation results (cooling curves) have been validated at the Rautaruukki steel work company. Based on the validated process simulation, new quenching devices and new process control strategy have been established at the steel work company.

  During the project there was a good collaboration in the field of optimising continuous casting processes between Prof. B. Sarler (SI), Prof. Dr. E. Laitinen (FI) and Dr. B. Filipic (SI).

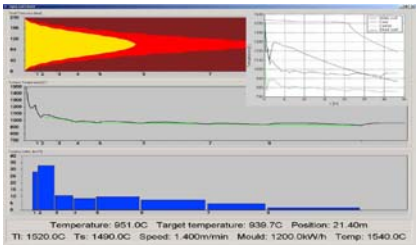

Fig. 1 Dyncool client software for the visualisation and control of the continuous casting process

- **Dr. Jürgen Jackumeit: Numerical Optimization of the Bridgman Casting Process for Stationary Gas Turbine Blades"**

  This project demonstrates an advanced optimisation strategy to simultaneous minimise casting defects and the production time of expensive single crystal components. Figure 2 shows the result of a study of an optimisation of a dummy turbine blades minimizing freckles and single crystal structure break down.

  The optimisation strategy (MA-DES) was successfully used to calibrate different material and process parameters for an industrial Bridgman process for gas turbine blade production. One main outcome of the calibration was that the simulation model underestimated the heat capacity of the Bridgman furnace, because several parts of the furnace were neglected in the model, since they should not directly influence the heat distribution.

  Prof. Dr. Norbert Hofmann and Dr. Dirk Büche supported that project in the field of application integration and optimisation algorithm.

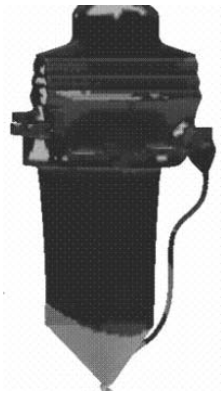

Fig. 2 Merging 3 quality criteria. Nodes showing freckle tendency are shown white, nodes of too high a curvature are shown light gray, and nodes of too low a G/v ratio are shown dark gray.

- **Dr. Jean-Claude Gelin: From Final Properties of Components to Mould and Process Design in Metal Injection Moulding"**

  The project of Prof. Dr. Jean-Claude Gelin and Dr. Th. Barriere displays an excellent work and theoretical background regarding filling simulation. They present a fast new simulation technique for screening analysis for the injection tool development.

  There was a good collaboration between the work of Prof. Dr. Jean-Claude Gelin and Prof. Dr. J. L. Batoz.

Dr. Antonin Dlouhy: A Numerically Based Optimization of a near-g TiAl Precision Casting Process

The project focused on the VIM (cheap) processing route and on the issues associated with macrocracks, nucleation and growth while cooling the cast - mould system down to room temperature.

The goal was to minize the tensile stresses induced into brittle TiAl intermetallic casts while cooling. The optimized process parameters comprise the amount of superheat, the mould preheating, thermal expansion coefficient of different moulding materials and the cooling kinetics were considered.

It is apparent that the numerical modelling and optimization clearly contributed to the technology progress. The damage of the cast components due to the intensive stress state in the cast-mould system has been completely suppressed and the technology is now ready to yield reproducible cast parts.

Fig. 3 Comparison of the quality of the VIM-based cheap precision casting technology from December 2001 (upper picture) and from October 2004 (lower picture)

Summary for WG2

The projects in the field of continuous and investment casting will support the other project teams with knowledge in the field of “designing objective functions” and “optimisation technologies”. The projects demonstrate relevant achievements for industrial partners.

Furthermore in the WG2 open source software was developed to integrated simulators with optimiser and to optimise arbitrary parameter sets. Further information and the software are on the APOMAT web page (Links -> Optimization Algorithms).

Publications

- Patents: 2 (Shell mould mesh generator)
- papers published 79 : 6(CH4), 5(CZ1, 2(FIN1), 47(CZ5), 5(D4), 6(F2), 3(SI1), 5(SI4)
- papers submitted 3: 1(CZ1), 2(CZ5)
- papers in preparation 2: 1(CZ1), 1(D4)