



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, 2003**

1. Reporting Period	1.7.2002 – 31.12.2002
Project title	A Numerically Based Optimization of a Near-Gamma TiAl Precision Casting Process
Project leader Organization	Dr. Antonín Dlouhý Institute of Physics of Materials, Academy of Sciences of the Czech Republic
Main collaborators involved	Department of Casting, Institute of Materials Engineering, BUT

2. Funding Situation	
Amount of money received specifically for COST	11 kEuros
Other resources partially used for the project	0 kEuros

3. International Collaboration (mention group and type of work done in collaboration during the reporting period)
Participation in the Working Group Meeting in Budapest + project progress report <input type="checkbox"/> <input type="checkbox"/> NO
NO

4. Industry participation (mention name of companies and work done in collaboration during the whole project)
NO

5. Meetings, visits, exchange of scientists, short-term scientific missions	Location, date
NO	



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6. Progress within the reporting period

(Not exceeding 3 pages, including tables and figures)

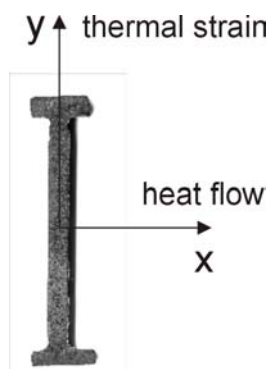


Figure 1: Cross-section of the girder-shape cast plate oriented in the x-y coordinate system.

Model of thermal stresses

Temperature profiles and their time evolution obtained in the first modelling step [1] served as an input of the second step in which the thermal strain and the associated stress state in the y-direction (see Fig. 1a) were analyzed. Figure 2a schematically illustrates length changes in the cast-mould system during cooling to room temperature. The state of the system in the moment when the cast had just solidified (time $t = 0$) is described by the coordinate $y = y_0$ as it is shown in the left situation of Fig. 2a.

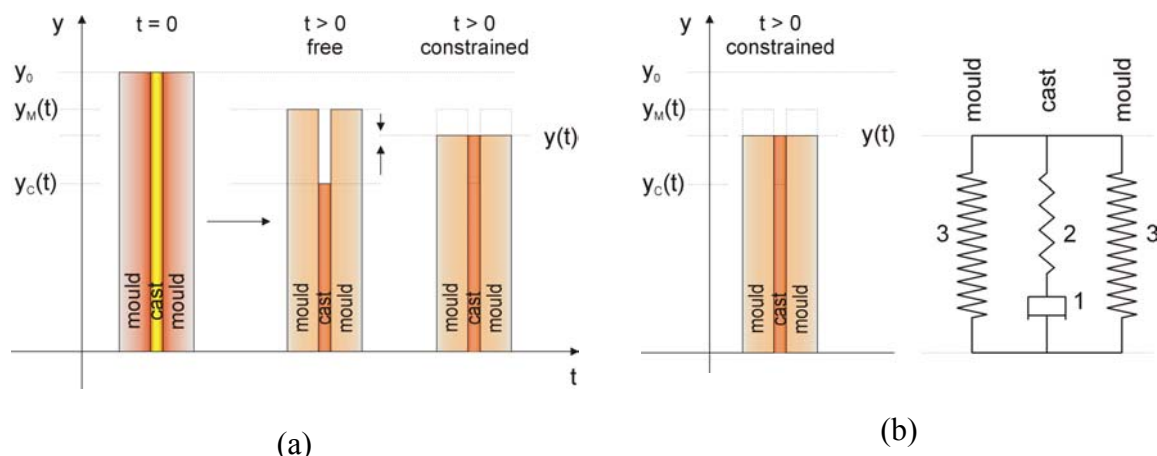


Figure 2: (a) Contractions due to different thermal expansion coefficients of the ceramic shell mould and the TiAl cast during cooling of the cast-mould system from pouring temperature as schematically illustrated for free (middle) and constrained (right) situations. (b) The spring-dashpot model of the constrained case.

With increasing time and decreasing temperature, the length of the cast would decrease to $y_c(t)$ and the length of the mould to $y_m(t)$ provided there were no anchoring points between the cast and mould (situation in the middle of Fig. 2a). In the constrained case with anchoring (right part of Fig. 2a) the

cast and mould must shrink equally to the length $y(t)$ in time $t > 0$. Thus, in the comparison to the free shrinkage, the constrained state of the system during cooling is characterized by a balance between the tensile force in the cast and compressive forces in the corresponding mould walls. A mechanical representation of the constrained case is shown in Fig. 2b. Here we further assume that the cast can deform both plastically by creep (a dashpot element 1) and elastically (a spring 2) while the adjacent mould walls deform only elastically (two springs denoted as 3). The analysis yields an ordinary differential equation for the stress inside the cast σ_c in the form

$$A \cdot \frac{d\sigma_c}{dt} + B \cdot \sigma_c^n = \alpha_m \cdot \frac{dT_m}{dt} - \alpha_c \cdot \frac{dT_c}{dt} \quad (1)$$

where T_m and T_c are average temperatures of the mould and cast in the time t , respectively. The parameter A can be expressed as a combination of mould and cast elasticity moduli E_m and E_c and their area fractions $X1/X2$ and $(X2-X1)/X2$. The second term on the left side of Eq. 1 represents plastic strain rate due to creep in the cast (Norton law); data concerning parameters B and n were obtained in an earlier study [2]. Finally, strain rate difference due to different thermal expansion coefficients of the mould (α_m) and cast (α_c) constitutes the right hand side of the Eq. 1.

Assessment of stresses in TiAl casts

The numerical simulation of tensile stresses in the experimental TiAl casts [1] requires the analysis of two coupled processes of heat flow [1] and the generation of thermal mismatch strains (Eq. 1) during cooling. Due to the coupling, different initial and boundary conditions set for the heat flow in terms of the initial mould temperature, the amount of superheat and the external temperature influence not only the cooling kinetics itself but also the generation of tensile stresses in the casts. The primary objective of the present study was the minimization of stresses created in the TiAl casts during cooling. Consequently, we have been looking for the set of the initial and boundary conditions that would minimize the stress state present in the experimental cast plate at room temperature. Results of some preliminary calculations are presented in Fig. 3. Combinations of two different initial mould temperatures (870 and 1300 K) and two different cooling paths (either air or furnace cooling) were considered in these numerical experiments. It is clear from Fig. 3 that the combination of 1300 K as the initial temperature of the ceramic shell mould and the furnace cooling yield so far the smallest tensile stress in the TiAl investment cast plate [1].

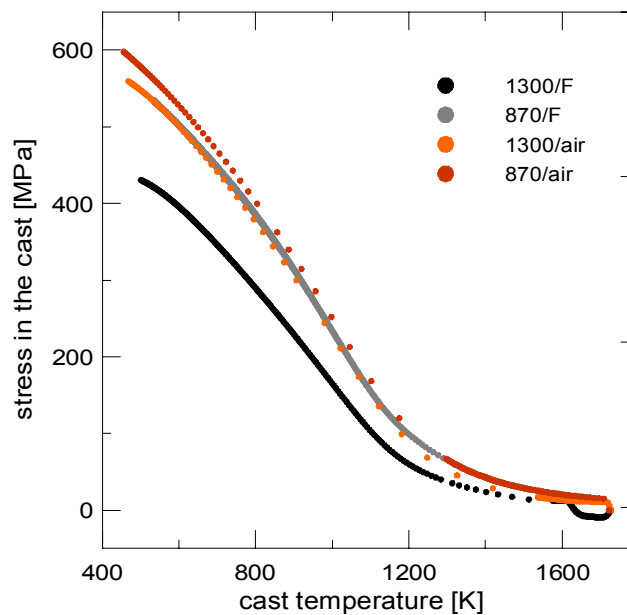


Figure 3: Stresses induced into the investment cast Ti-48Al-2Cr-2Nb-1B plate shown in [1] during cooling to room temperature - different combinations of the initial mould temperature and the cooling path are considered.

References

- [1] A. Dlouhý, 1st IPM COST 526 Progress Report, Brno 2002
[2] A. Dlouhý, K. Kuchařová, and T. Horkel, "Creep and Microstructure of Near-Gamma TiAl Intermetallics" in: *Materials for Advanced Power Engineering 1998*, Proceedings of the Sixth Liège Conference - Part III, ed. J.Lecomte-Beckers et al., (Jülich, Germany: Forschungszentrum Jülich, 1998), 1219-1228.

7. List of publications

a) Published

b) Submitted for publications

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Near-gamma TiAl Investment Casting and Its Optimization,
submitted to Gamma Titanium Aluminides 2003

c) In preparation

Minimization of Processing Stresses in TiAl Investment Cast Parts