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Numerical modelling of castings[1]

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The presented work shows one of possibilities of numerical modelling of castings. The simulation is a base of modern design. The finite difference simulation program enables computer aided calculations of a form filling and solidification. It is possible to analyse thermal behaviour of the casting, cooling, or heating system with the simulation. The optimisation of the process can be handled easily by a user of the software.

The presented simulation program enables to model the process of filling and cooling of a casting and a mold. It is based on finite difference method [3].

The basic input data are: the cast material, the form filling time, the geometry of the form, the casting and the form temperature and the cooling medium respectively. The mechanical properties of the form, cast and the cooling materials are included as functions of temperatures in a database.

At the beginning, the geometry of the cast and form is modelled in a computer. The whole bodies are divided to finite volume elements. The boundary conditions are described. The physical properties of materials are defined with help of a set up database.

It is necessary to know many factors for an exact computation. The knowledge of the whole system is the requirement for building of the correct model.

The output data are the temperature fields in time and place, the curves of cooling, isotherms, temperature gradients, etc.

We can model castings of simple shapes as well as complicated ones. The simulation was used for example for optimization of arranging of metallic molds at a casting bed (on request of NHKG). Other examples are: a heat treating of a tank part (Strojirny nad Vahom), improvements of molds design for ingots casting (NHKG, Vitkovice, Vychodoslovenske zelezarny), a technology plan of centrifugal casting of two layers cylinders (VUHZ Dobra), etc. Our work was used for rating of cooling intensity during the process of continuous casting of steel (Badische Stahlwerke GmbH). This method can be used also in other industrial fields. We have applied it on thermal problems during heating of wood bars in furniture industry (TON).

We have studied the accuracy of the finite difference method in use on our practical problems. The accuracy of results of the numerical computations were compared with analytical solutions on simple cases of a 1D-problem [1]. The error of the numerical solution is dependent on the size of the time and space steps. We are able to determine the time step for done space steps and

[1]This is an extended version of the article presented at the 8th International Conference on Numerical Methods in Continuum Mechanics, Liptovský Ján, Low Tatras, Slovakia, September 19–24, 2000.

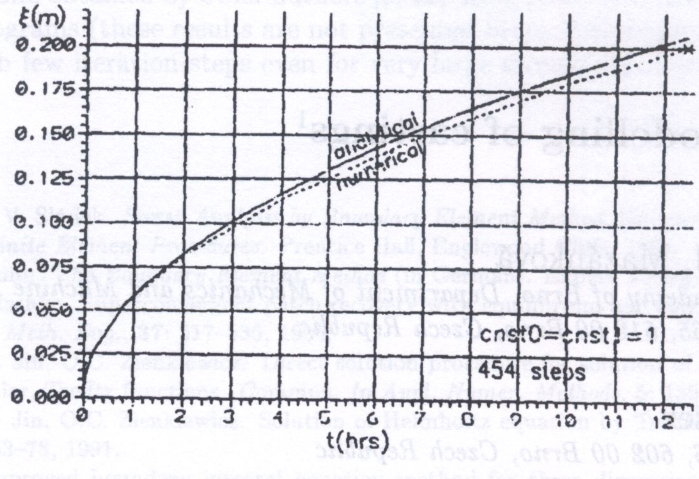

Fig. 1. Comparison of analytical and numerical computations

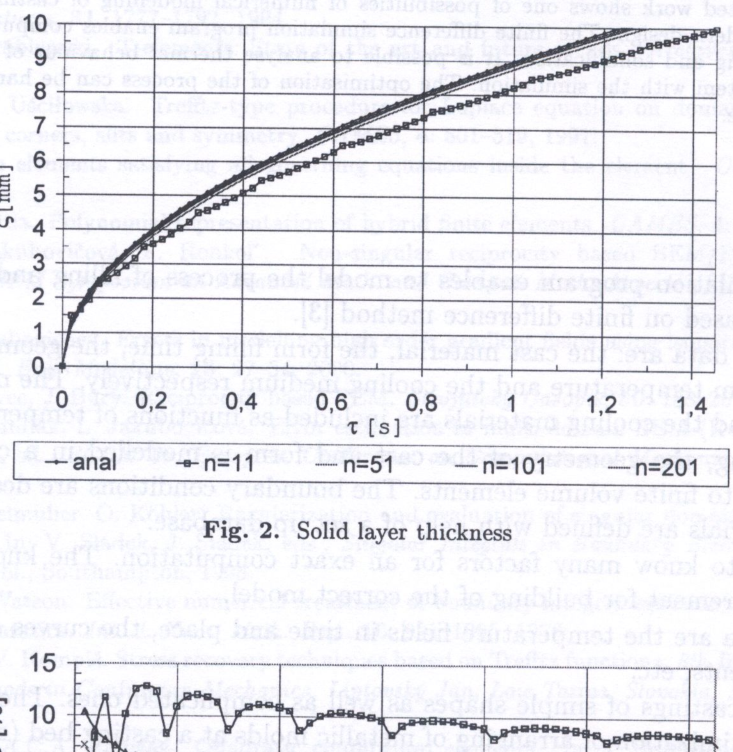

Fig. 2. Solid layer thickness

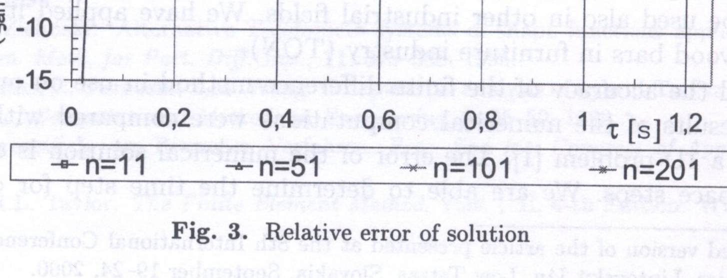

Fig. 3. Relative error of solution

constant material properties. In case of material properties dependent on temperature, it is possible to calculate the needed time step too.

One of simple examples was the calculation of the solid shell thickness grow of the steel casting in the sand mold. The contact between the casting and the mold was supposed to be ideal. The casting and the mold were semifinite. We can see an example of results of calculations in Fig. 1.

Another example is a solution of solidification of aluminum desk in the infinite steel mold (1D). The thickness of the desk is 0.02 m. One half is solved because of axis symmetry. The time change of the solid layer thickness is depicted in Fig. 2.

There are analytical and numerical solutions with different size of space steps. The numbers of the nodes are 11, 51, 101, and 201. As the number of the nodes increases the solution is nearer to the analytical one. The size of relative errors of the numerical solutions is in Fig. 3.

In present, we evaluate precision of models of castings at the Military Academy of Brno. We model castings and compare them with experimental results got from real aluminum castings.

Our programs were used for calculations of temperature fields of classical castings as seen in Fig. 4.

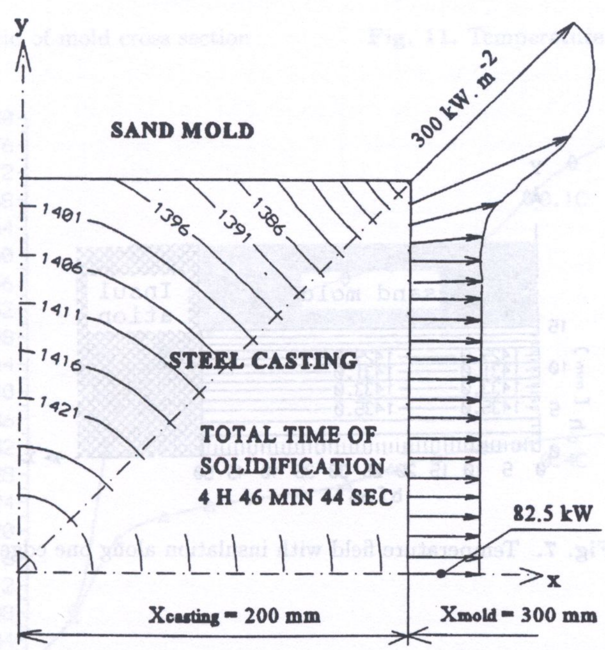

Fig. 4. Temperature field of square casting

There is depicted the temperature field of the steel casting in the sand mold. The heat fluxes are drawn along the edge of the casting. Results of similar calculations are in Figs. 5 to 7.

The application of the computation was used also on more complicated problems, for example for the solution of the heat transfer problems in the mold of the continuous caster with the pipe cooling system (Fig. 8) and another one with the desk cooling system (Fig. 9) [2]. The mold walls are cooled by water. The billet (casting) moves down with a defined velocity.

Let us see some results of calculations for the continuous caster with the pipe cooling system (Podbrezova). The cross-section of the billet was a rectangle 103×100 mm. The height of the mold was 700 mm. 3D-computations were made in this case. One fourth of the system was solved because of two plane symmetries. The temperature field of the mold and liquidus and solidus isotherms in the billet at the outlet edge of the mold are shown in Figs. 10 and 11.

There are two pipes at each side of the depicted one quarter of the mold. It can be observed in Fig. 10, where the locations of the pipe are inside closed curves.

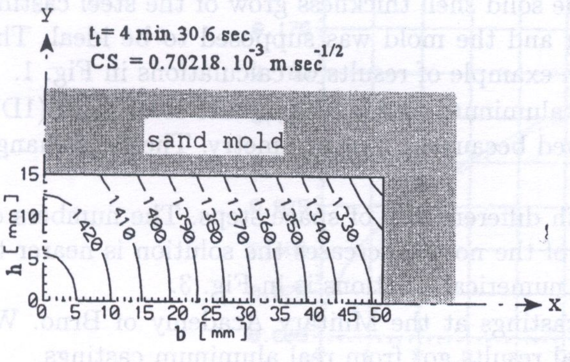

Fig. 5. Temperature field of casting without insulation

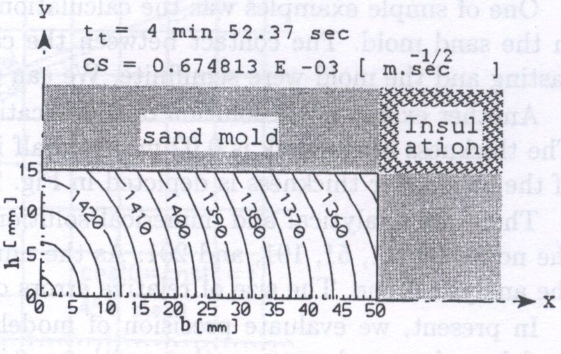

Fig. 6. Temperature field of casting with insulation in corner

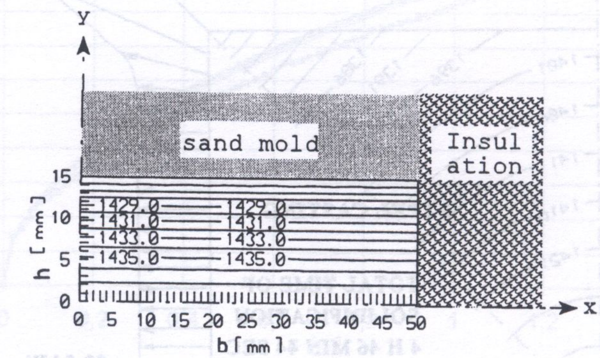

Fig. 7. Temperature field with insulation along one edge

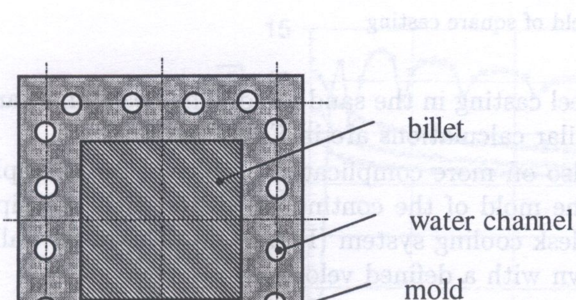

Fig. 8. Top view of mold with pipe cooling system

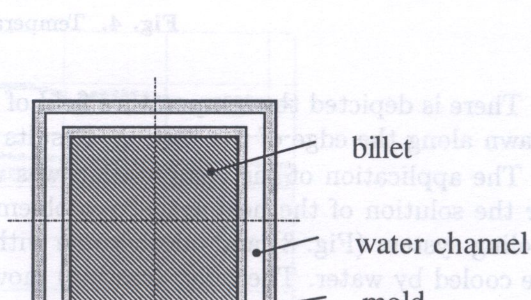

Fig. 9. Top view of mold with desk cooling system

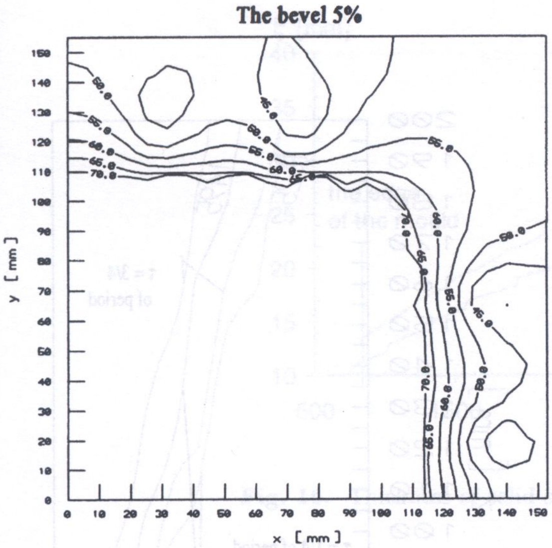

Fig. 10. Temperature field of mold cross section

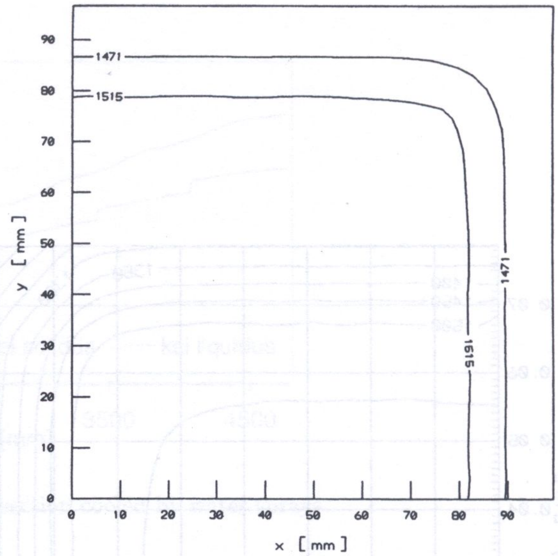

Fig. 11. Temperature field of billet cross-section

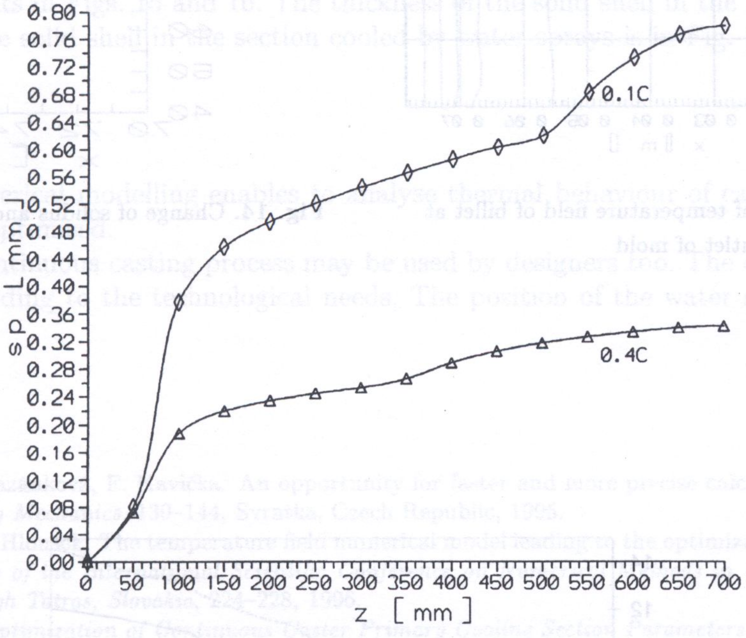

Fig. 12. Gap size along mould height

A comparison of the gap grow at the billet-mould contact for the same cooling conditions and different cast steel is made in Fig. 12. The gap is thicker when the 0.1% C steel is cast. Thicker gap is a consequence of a bigger value of the contraction coefficient.

Later the calculations of the mould of the continuous caster with the desk cooling system were done. At the beginning, the computations were made without oscillations of the mould. The temperature field of the billet at the outlet of the mould is in Fig. 13. The cross-section of the billet is a square 158×158 mm. The cast steel is AISI 1026.

Then, the oscillation of the mould was included into the model. The change in the positions of the isotherms for the temperatures of solidus and liquidus in the billet is shown in Fig. 14. There are the isotherms for 1/4 and 3/4 of the period. Between the two time instants the temperature distribution change the most.

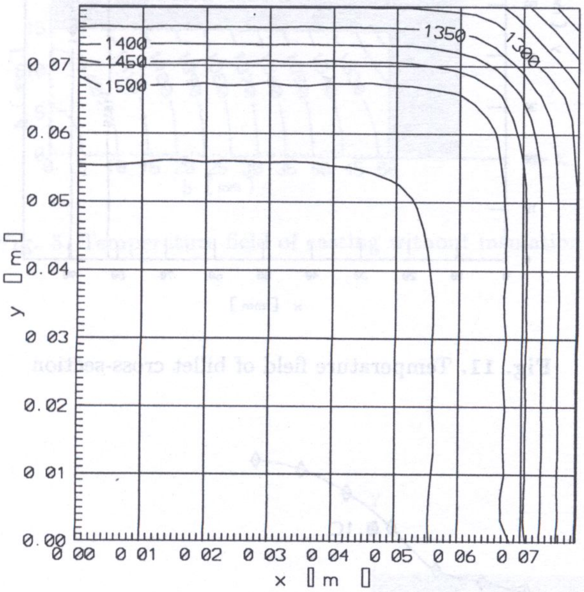

Fig. 13. Top view of temperature field of billet at outlet of mold

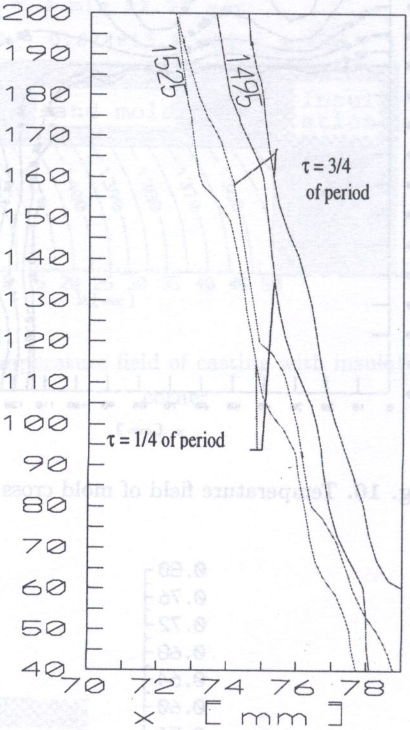

Fig. 14. Change of solidus and liquidus isotherms

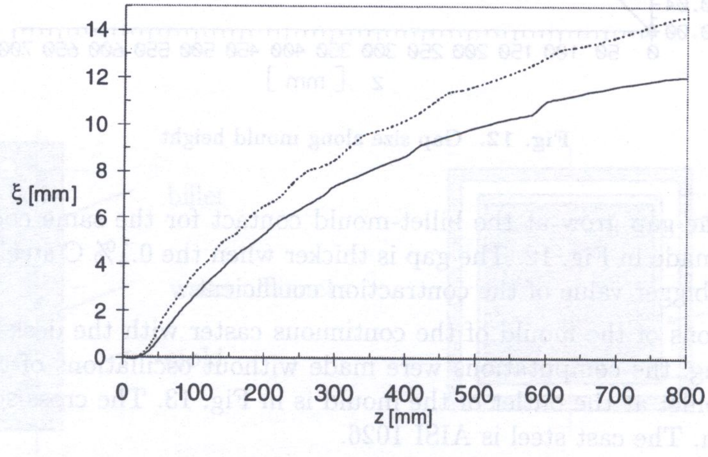

Fig. 15. Thickness of solid shell in mould

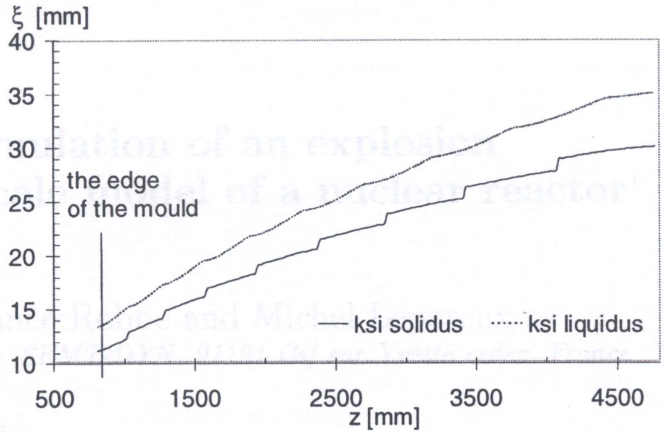

Fig. 16. Thickness of solid shell in section cooled by water sprays

The simulation was used in more complicated cases, for example, for a prediction of longitudinal cracks in the mould of the continuous caster of steel.

Now, we have included also calculations of water cooling of the billet below the mould. there are depicted some results in Figs. 15 and 16. The thickness of the solid shell in the mould is in Fig. 15. The thickness of the solid shell in the section cooled by water sprays is in Fig. 16.

Conclusion

The presented numerical modelling enables to analyse thermal behaviour of castings. The process of casting may be optimised.

The model of continuous casting process may be used by designers too. The design of the mould may be made according to the technological needs. The position of the water sprays may be controlled,

References

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