SFB 1120

Annual report 2018

Subproject B8

Title
Investigation of precision-determining factors to minimise distortion in the permanent mould and die casting process

Project management/-processing
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Task definition

In the transition year from the first to the second phase, the main focus of the project for the determination of the factors influencing precision was on the completion of the experiments on the topic of heat transfer on the rotationally symmetrical demonstration component and the corresponding processing of the collected data to create an effective HTC (heat transfer coefficient) model.

In the area of the second focal point, the determination - influence of component distortion, the topic of hot crack formation has been added, since this is based on the same material-physical mechanisms. For their empirical investigation, the experimental setup had to be adapted accordingly for in-situ observation of hot crack formation.

Fig. 1 shows the subject areas to be worked on and their causal relationships for classification in the context of the entire process of permanent mold casting.

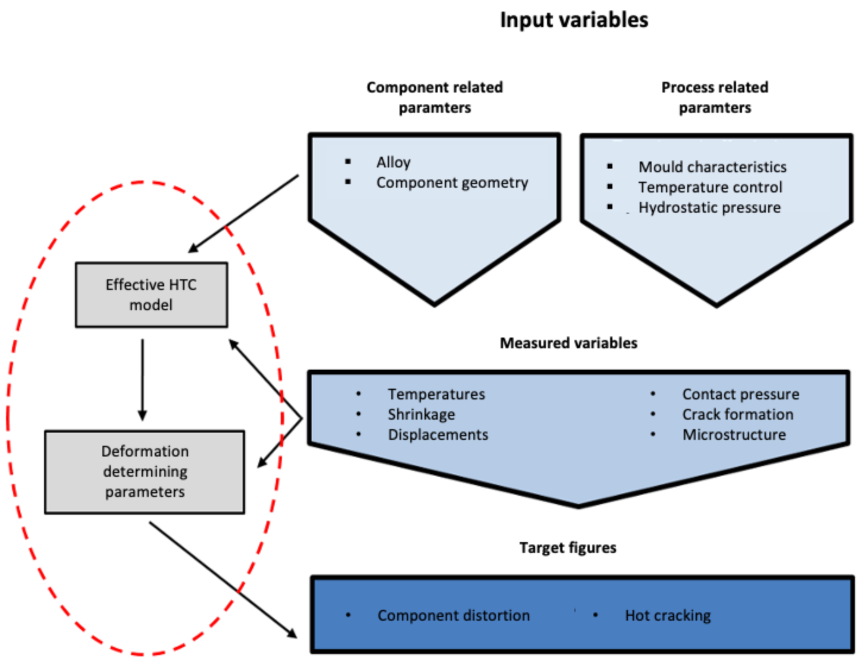


Fig. 1 Input, measurement and target variables and their interrelationships. The areas addressed in the subproject are marked.

Procedure

In the previous project year, the casting tests on the rotationally symmetrical test component were completed to investigate the heat transfer issue. These tests offered the opportunity to investigate the precision-determining factors in gravity die casting without geometrically conditioned influences for the time being. The test stand developed for this purpose (Fig. 2, left) enables in-situ analysis of pressure curves, temperature curves and displacements between the casting and the mould wall. From the recorded data, the HTC, which is strongly dependent on the contact conditions, can be determined. The collected data of the different test series with variation of the process parameters were compiled and a comprehensive database was created. Quantitative values such as heat capacities and heat conductivities were added to this database in order to make it usable for statistical evaluations, e.g. by means of variance analysis. The respective shares of the parameters varied in the test series in the effective total HTC are quantitatively determined by means of a sensitivity analysis.

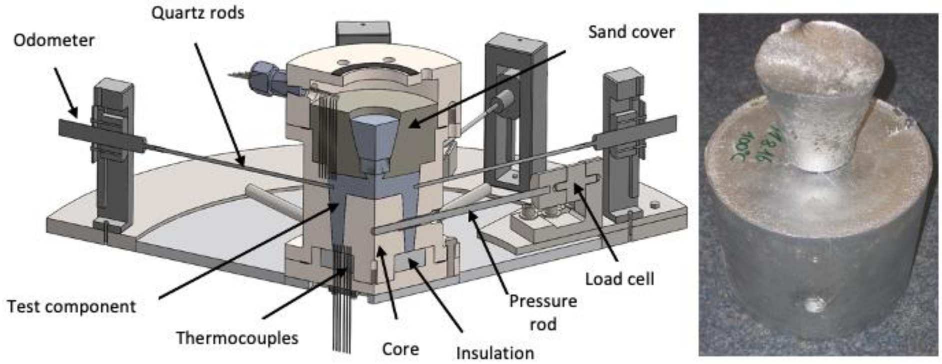


Fig. 2 Sectional view of the test stand for a rotationally symmetrical test component for HTC determination (left) and a corresponding cast test body (right)

The knowledge gained from the development and operation of the rotationally symmetric test rig was taken up in an iterative process to design the test component with complex geometry. The component geometry was included in the investigations as a further precision-determining factor. Due to its modular design, the mould developed in this way enables both individual temperature control of the various mould areas and their exchange. The modified test setup is shown in Fig. 3. Test series were carried out on the mould temperature control and the influence of the mould material. Furthermore, the transferability of the algorithm developed in subproject B1 of the IKV for the optimization of cooling channel layouts from injection moulding to gravity die casting was validated experimentally. In addition to measurements of warpage as a geometric quantity, the residual stresses on test components were also determined exemplarily in order to further close the causality chain between influencing and target variables

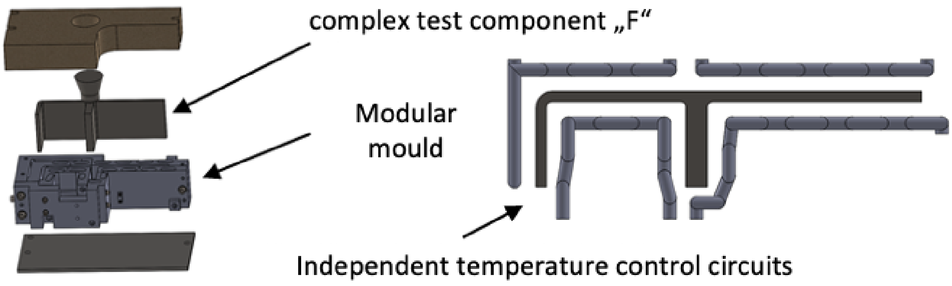


Fig. 3 Design of the test mould for the complex test component "F" (left) and arrangement of the individual temperature control circuits (right).

For the strengthening of the test setup for in-situ observation of hot crack formation, corresponding preliminary tests with variation of the alloy system (Al-Si, Al-Cu etc.) and the targeted generation of "hotspots" were carried out and accompanied by numerical simulations. Hot cracks generated in this way and the simulation of controlled solidification are shown in Fig. 4.

The knowledge gained on solidification, temperatures, heat transfer and microstructure is also exchanged in cooperation with the simulated subprojects B7 and B9, for comparison with the numerical results.

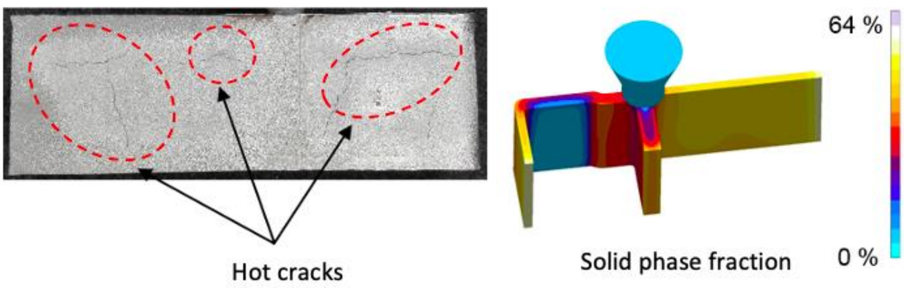


Fig. 4 Hot cracks generated in preliminary tests (left) and controlled solidification in an accompanying simulation (right)

Results

From the tests on the rotationally symmetrical component, with differently adjusted mould temperatures of 30 to 300 °C, different mould materials, coatings and temperature control concepts, the respective local cooling curves, displacements and resulting HTCs could be determined. Appropriate publications were submitted on individual aspects. The ongoing analysis of the collected data shows, for example, the influence of the die coating, shown in Fig. 5, as the difference in HTC between an uncoated and a coated die. Similarly, the combination of the data from the different test series shows correlations between influencing variables and HTC. Fig. 6 shows, for example, that mold material and tempering concepts (conventional or contour-adapted) have a much greater influence on the total HTC with a tempering system set to room temperature than with a mold tempered to 300 °C.

The test series on the complex test component show that component distortion can be influenced by different mould temperature control, materials and temperature control concepts in different mould areas. Fig. 7 on the left shows the measuring points used to evaluate the distortion as red lines, so that the component distortion can initially be viewed as a two-dimensional phenomenon. There the measuring points for the exemplary residual stress measurement are also marked with the numbers 1, 2, 3 for measuring points at the freely contracting end of the test component and the numbers 4, 5 and 6 on the side with hindered contraction. However, the measurements, Fig. 7 on the right, showed no discernible differences at either measuring point.

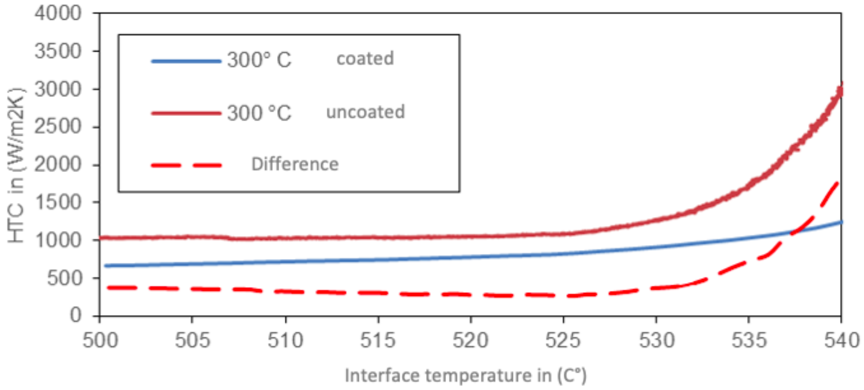


Fig. 5 HTC in a coated and an uncoated mould and the influence of the coating applied on the cast side Interface temperature

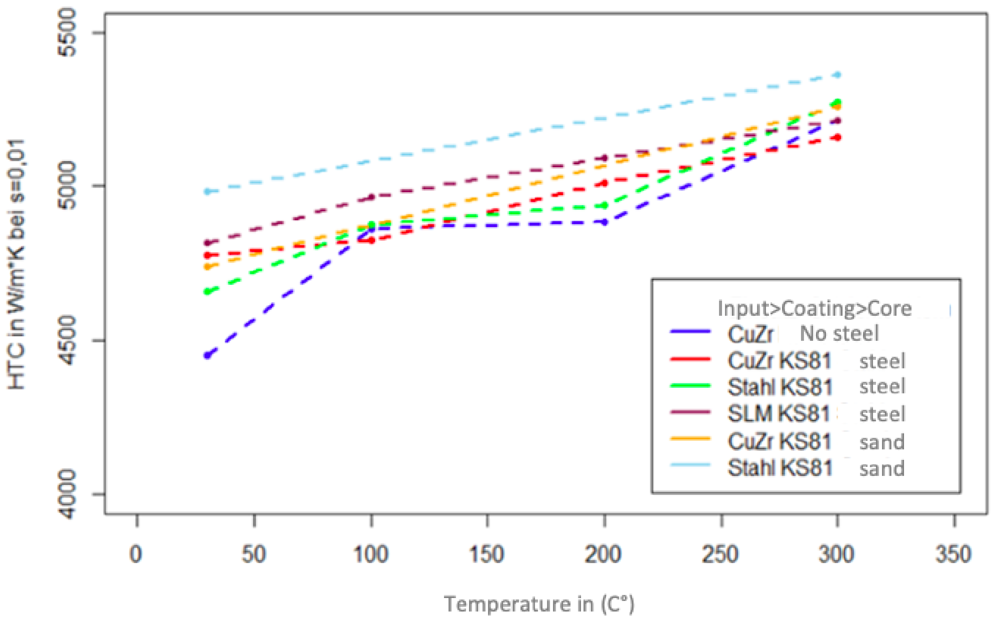


Fig. 6 Influence of the mould material and the cooling channel geometry on the HTC applied via the mould temperature control.

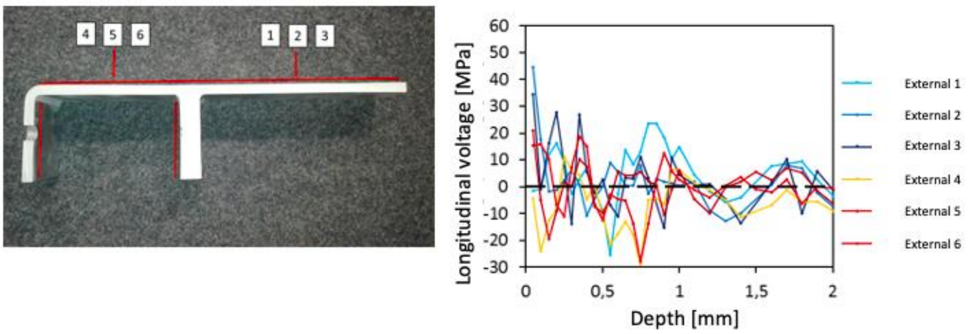
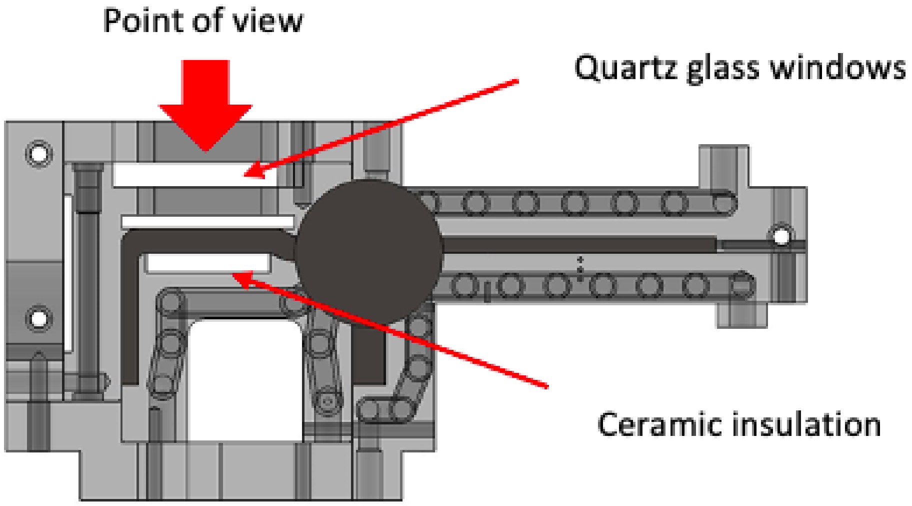


Fig. 7 Cut open complex test component with red marked measuring points for distortion measurement and numbered measuring points for the residual stress measurements (left). On the right side the corresponding residual stresses are plotted over the depth.

In an iterative process, a concept for mould modules could be developed from the preliminary tests with accompanying simulations as well as associated literature research. This was transferred into a corresponding design and released for

Fig. 8 Modular mould design, extended by modules for creating a "hotspot" in the casting and a window for in-situ video recording of hot crack formation production. The arrangement of insulations and windows in the experimental setup of the complex component is shown in Fig. 8.



Summary and Conclusion

The test series on the rotationally symmetrical test component have provided a wealth of data for determining the heat balance in continuous casting processes. In the next steps, the data will be processed and examined for causal relationships between input, process and target variables using statistical methods. An effective HTC is derived from these findings and published.

From the results of the test series on the complex test component, the knowledge gained is expanded and the influencing variables for component distortion and hot cracking are derived. Furthermore, investigations on partial aspects such as the influence of the optimized cooling channel layout developed with TP B1 will be continued and the expected results will be published.

In further steps, the in-situ observation of hot crack formation will be put into operation and corresponding test series will be planned and carried out. The expected results will be exchanged with the subprojects B7 and B9 for a better understanding of the underlying mechanisms and transferred into a corresponding modelling.

Publication

N.Wolff, J. Krampe, U. Vroomen, A. Bührig-Polaczek: *Comparison of the Thermal Properties of Industrially Used Die Coatings and a Plasma Sprayed YSZ Coating for Gravity Die Casting Applications,*
AFS 2019 (eingereicht)