Subprojectt B1

Title
Algorithms for the design of a temperature control layout for injection moulding tools taking into account the local cooling requirements

Project management/-processing
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Task definition
The goal of this subproject is the development of a methodology for the automated and precise design of cooling channel systems in injection molds. At the end of the first funding period and at the beginning of the second funding period, two fundamental aspects were the focus of the research. On the one hand, practical validation experiments were continued in order to analyse further influencing factors and their sensitivity from practical experience to dimensional accuracy, which must be taken into account in a future extension of the methodology. For this purpose, a second test specimen was used, which shows additional typical geometric features of plastic moulded parts, such as wall thickness jumps and centring ribs. On the other hand, an extension of the methodology was worked on in order to consider numerical influences, such as the choice of weighting factors or the offset of the surrounding tool geometry, in addition to the real process influences. As an additional extension for a better representation of the cooling phase in thermal optimization, the aim was to map the process pressure in the cavity with spatial and time resolution.

Procedure
Already in the third project year of the first funding phase, tool inserts for an injection moulding tool were procured, which have now been examined in practical tests. Based on a standard material of engineering thermoplastics, a non-reinforced polybutylene terephthalate (PBT), injection moulded parts for a

typical plastic component with different plastic-specific geometric features were produced by injection moulding. The thermally optimized cooling channel system was compared with a conventionally designed system. An optimal process point for the injection moulding of the moulded part was determined and process parameters such as the melt temperature and the injection temperature were varied in order to quantify their influences and effects on the cooling performance. For this purpose, the manufactured molded parts were precisely measured using a tactile coordinate measuring machine and quality characteristics such as a side wall collapse or a flatness of the base plate were defined (see Figure 1):

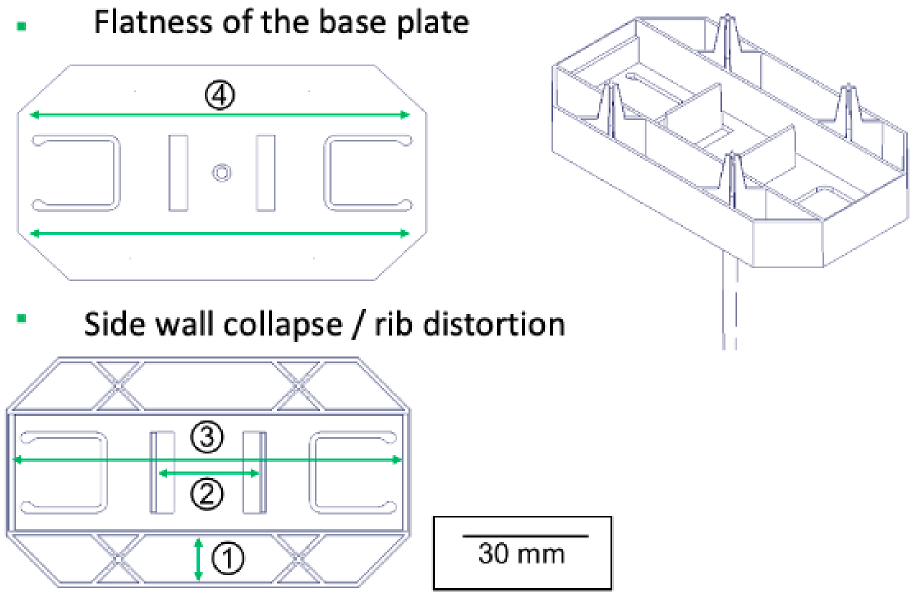

Figure 1: Measured variables on the distortion specimen

In further investigations, a simulative sensitivity analysis was carried out to quantify the influences of the boundary conditions. For this purpose, a representative example part was created and variations of the part wall thickness and the mould volume surrounding the part were carried out. For this purpose, a total of 60 thermal optimizations were carried out.

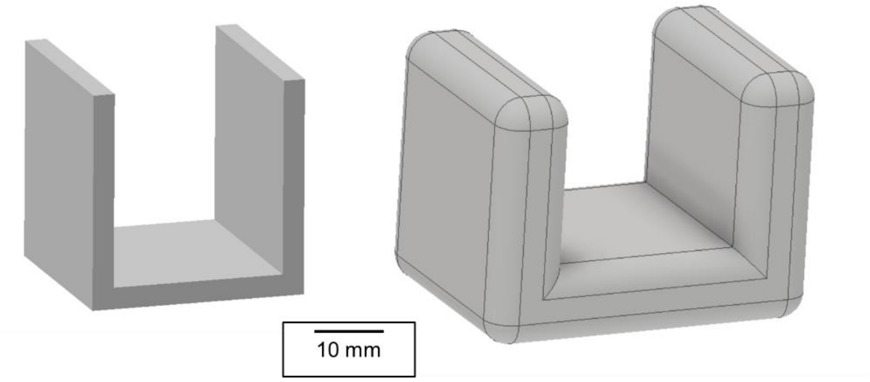

Figure 2: Simple example component and offset geometry of 6.5mm

Since cooling plastic melts are compressible, it is necessary to consider the locally prevailing pressure in the optimization. The data were previously calculated simulatively and are available in four dimensions (x,y,z,t). Subsequently, an efficient interpolation was developed, which calculates the pressure in the melt for each node at a defined point in time.

Results

Practical validation tests have shown that it is possible to achieve an improvement in component distortion by means of thermally optimized cooling. However, the tests also show a considerable influence of the flow rate. This is visualized in Figure 3 by the deflection of the base plate:

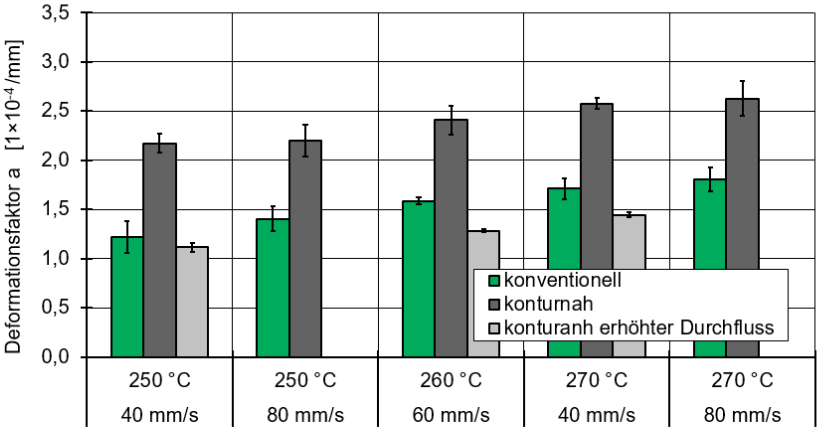

Figure 3: Deflection of the base plate

As in previous tests, it is shown that the cooling effect was overestimated in areas with complex temperature control. The fineness of the cooling channels, the complex windings as well as production-related increased surface roughness on the cooling channel wall lead to an increased pressure loss as a consequence. In order to counteract this effect, a more powerful temperature control unit was used, which could partially compensate for these problems. However, the increase in flow rate did not always lead to an improvement in warpage in all cases when sufficient cooling capacity was already available. The aspect of the coolant flow rate has been underestimated so far, because in the first approximation in thermal optimization a uniform heat dissipation through the cooling channel was assumed.
In addition to the practical work, the methodical work was continued. As a result of the sensitivity analysis, a tool is now available with which an optimum offset can be derived for a given wall thickness. The simulative validation of this work is currently taking place.

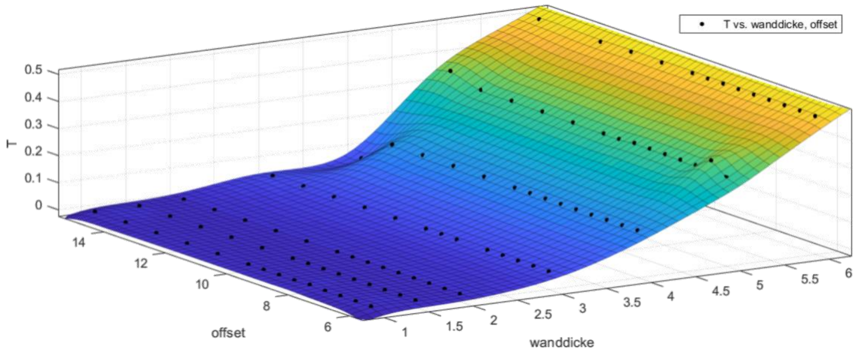

Figure 4: Relationship between optimization quality, wall thickness and tool offset

For the four-dimensional representation of the process pressure it could be shown that the cooling channel systems designed with these calculations achieve a lower distortion. This must be bought by increasing the computing time by a maximum of 10%.

Summary and Conclusion

In the course of the fourth project year, practical tests were carried out, which showed the strengths and current challenges of the design. Here it became obvious that fluid-mechanically optimized challenges currently still have to be checked manually whether the simplifications used in the calculations (such as e.g. constantly high cooling capacity of a cooling channel) really apply.

On the basis of the sensitivity analysis carried out, flexible offsets can be generated in the next step for the moulded parts to be calculated, so that a better prediction of the cooling behaviour is possible. Furthermore, more complex material models are to be developed and applied for a better representation of the real heat quantity in the molded part.

Publication

HOPMANN, CH.; NIKOLEIZIG, P.; DORNEBUSCH, H.; SCHNEPPE, T.: *Minimization of Warpage for Injection Molded Parts by Inverse Thermal Mold Design.* International Journal of Polymer Processing. 33 (2018) 1. S. 110-116

ZWICKE, F.; SCHNEPPE, T.; HOPMANN, CH.; ELGETI, S.: Numerical Design for Primary Shaping Manufacturing Processes. *Proceedings in Applied Mathematics and Mechanics.* 22. Mai 2018. München, 2018.