Selective, adaptive and manual (SAM) mesh refinement in injection molding simulations with OpenFOAM®

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Plastic injection molding is one of the most commonly used technologies to manufacture plastic components in a wide variety of industries (e.g. automotive, chemical, medicine, communication etc.). It is of utmost importance to optimize the development time of the required machines and molds to reduce the costs and improve safety already before the stage of assembly. In recent years computer-aided optimization has been proven as one of the key steps in achieving these goals. OpenFOAM® offers an excellent foundation for the development of a tool for the description of the injection process [1,2,3].

The main challenge is the correct description of the interdependence of the highly non-Newtonian behavior of the viscosity of the liquid polymer (~10-10000 Pas), the needed pressure to maintain a certain volume flux during production (~100-2000 bar) as well as the cooling of the liquid melt (~220-320°C -> ~30-50°C). The process can be described in a physically correct way with a known deviation of approximately <5-15% (OpenFOAM® version 4.1)[1,2]. In previous models the mesh was created beforehand and remained static throughout the simulation. For industrially acceptable run times (order of magnitudes of minutes-hours) a coarse mesh was required for arbitrary, curved geometries (e.g. holes, thin fins and gates, see figure 1), however deviations to experiments were outside the acceptable interval (~15-20%). For physically correct results an increased refinement was required with an unavoidable increase of run time for complex geometries.

For the industrial application not only physical correctness is needed, also a certain industrially acceptable simulation run time (~1 minute-18 hours) has to be guaranteed while maintaining the quality of the results. Promising first steps have been made in this direction [3]. In the current work an improved approach for the selective, adaptive and manual (SAM) mesh refinement in injection molding simulations is proposed. For this the already existing adaptive grid refinement model in OpenFOAM® is extended. The basic idea is to start with a coarse mesh and to refine the mesh during run time in regions of interest. Since the pressure drop in the air is negligible compared to the polymer melt, the grid resolution is kept at the coarse level throughout the simulation in regions, where air is present. Regions with polymer melt can be automatically refined in three ways (see figure 2). The implemented algorithm searches selectively for regions, where the thickness of the part is below a pre-defined value (e.g. 1mm). This approach can be used to correctly model the pressure drop e.g. in tunnel and film gates. The location of the flow front can be improved with adaptive refinement and the user can pre-define regions manually, where the simulation is forced to refined the grid resolution (e.g. in sprue gates).
With the SAM approach run time can be decreased by up to ~80% compared to the increased refinement, while maintaining good agreement between experiment and simulation previously found with only the high refinement of the mesh.

Figure 1: Partial filling (~74%) in the injection simulation with OpenFOAM® (a) as well as in the experiment (b)

Figure 2: Initial mesh (a) and selectively, adaptively as well as manually (SAM) refined mesh (b) of the sprue and tunnel gate with the liquid phase fraction of the polymer melt during the injection molding simulation

References