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THREE-DIMENSIONAL SIMULATION FOR THE INJECTION OVER-MOLDING PROCESS

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ABSTRACT

Injection over-molding has become a popular fabrication process in recent years. Since the inserts have different thermal and mechanical properties relative to the polymer melt and mold, the presence of plastic or metal inserts can significantly affect the filling, packing, cooling and warpage behavior of the component. A complete three-dimensional simulation system has been developed to simulate the whole overmolding process. The insert and cavity geometries are modeled and meshed independently using tetrahedral elements. Special techniques are used in the cooling, filling/packing and warpage solutions for forcing consistent physical results at the unmatched cavity-insert interface.

The solution sequence begins with a mold cooling analysis using the specified initial temperature for the insert and the specified melt temperature for the cavity as initial conditions. A fully transient three-dimensional finite element temperature solution is solved in both the cavity and insert models. A cycle averaged steady state temperature solution is calculated in the mold model with a steady state one dimensional pipe network solution for the coolant temperatures in the mold circuits. The temperature of the cavity and the insert model are solved iteratively at each time step. Once this solution is obtained the cavity and insert model are treated as a single entity for the boundary element analysis.

The flow solver uses the temperatures from the cooling analysis as boundary conditions for its temperature calculations. Flow determines the temperature solution during filling using the same iterative approach as the cooling analysis at each time step mapping both temperatures and fluxes across the interface. After the temperature solution in both the cavity and insert converge, the flow front position, velocity and pressure in the cavity are solved [1]. This sequence is repeated for each time step of the simulation. Another particular issue with the insert overmolding is the spatial deviation of the position of the insert during the molding from its original position in the mold before the plastic was injected into the cavity space insert. Uneven distribution of melt flow around a slender insert during injection molding can result in insert position shift. In turn the shift affects the melt flow pattern as it changes the boundary conditions of the flow. The insert

position shift and its effect on melt flow are considered using the same apparoach as in the core-shift simulation[2].

The shrinkage, temperature and insert position shift results from the flow solution are used as input to the warpage solution. A different approach is employed for handling the cavity-insert interface in the warpage solution. The analysis starts by identifying the interface area between the insert mesh and the cavity mesh. It assumes that the insert nodes at the interface are the master nodes, and the cavity the slave nodes. - Based on the relative geometric position and the displacement interpolation function of the element, the relationships between the degrees of freedom at the slave node and at the master nodes can be established. The relationships are typical multi-point constraint (MPC) equations. The elimination method based on the Lagrange multiplier formulations is used for dealing with MPC equations.

It is worth mentioning that the different meshes are used for the flow and warpage simulation. The dense first-order tetrahedral element mesh is used for the flow and mold cooling simulations, in which at least 6-layers elements are used through the thickness to catch the variation of temperature and velocity. The coarse second-order tetrahedral element mesh is used for the warpage analysis to avoid shear locking and other problems of the first-order tetrahedral element and reduce the computation cost. A mapping algorithm is developed for mapping the material property and shrinkage results between two meshes.

The cooling, filling/packing and warpage results from the simulation system are presented and compared with the actual overmolding cases.

REFERENCES

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