THREE-DIMENSIONAL INSERT MOLDING SIMULATION IN INJECTION MOLDING

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Abstract

For the recent years, the insert molding in injection molding has been very popular. Insert molding is a more efficient technology to the assembly of discrete parts. It reduces the assembly and labor costs and increases the design flexibility. Its benefits are over the traditional method, such as soldering, connectors…etc. The different insert parts will cause different effect for injection molding process. The metal inserts are used to increase the performance of drawing heat from the cavity. However, the plastic insert reduce the cooling effects. This paper develops a numerical approach to simulating the mold insert molding in injection-molded part of complex geometry. This developed approach is proved from numerical experiments to be a cost-effective method for true 3D simulation in mold insert molding analysis.

Introduction

Injection molding is a process in which the hot polymer is injected into a mold cavity. Heat is removed from the polymer in the mold until it is rigid and stable enough to be ejected. Therefore the design of the part and mold are critical in ensuring the successful molding process. For the recent years, the insert molding in injection molding has been very popular. The mold insert molding process is an efficient technology for injection molding process. The insert material will have a significant effect on the filling phenomena around the insert parts. The insert materials can vary. The metal inserts are used to increase the performance of drawing heat from the cavity. On the other hand, the plastic inserts reduce the cooling effects. Different insert parts have different effects for the injection molding process.

Conventional 2.5D CAE analysis technology adopts the "Mid-plane Model". The basic principal is to create the Mid-plane of the geometry model. After a long-time development, this technology is quite mature and stable. Now it is also good at the analytic speed and efficiency. Besides, it helps to obtain accurate results for most of the plastic parts, especially for the thin shell parts (About 80% of the plastic parts are thin shell ones.). Therefore, the 2.5D analysis technology is widely used and becomes the main stream of the injection molding analysis. Since the mid-plane model is quite approved, lots of defects still exist that may affect the accuracy and the efficiency. Especially for the thick parts, the 3D solid effects are absolutely obvious and cannot be precisely analyzed by the conventional methods. This paper develops a numerical approach to simulating the mold insert molding in injection-molded part of complex geometry. This developed approach is proved from numerical experiments to be a cost-effective method for true 3D simulation in mold insert molding analysis.

Analysis Approach

The injection molding simulation has 3 main processes, includes filling/packing, cooling and warpage. For the filling/packing process, the polymer melt is assumed to behave as Generalized Newtonian Fluid (GNF). Hence the non-isothermal 3D flow motion can be mathematically described. The FVM due to its robustness and efficiency is employed in this study to solve the transient flow field in complex three-dimensional geometry. During the molding cooling process, a three-dimensional, cyclic, transient heat conduction problem with convective boundary conditions on the cooling channel and mold base surfaces is involved. The overall heat transfer phenomenon is governed by a three-dimensional Poisson equation. We assume there is a cycle-averaged mold temperature that is invariant with time. The warpage analysis assumes the mechanical properties are linear elasticity. The stress-strain equilibrium equations enable us to solve the problems.

We involve an integrated analysis procedure in order to simulate insert part effect. The proposed computation framework is schematically shown in Figure 1. The software package first reads the input data (including mesh data, material data, and process condition data), performs 3D filling analysis (based on specified uniform mold temperature or mold temperature distribution obtained from previous mold temperature iteration). 3D Cooling analysis is then conducted to obtain part temperature distribution at the end of cooling stage. Cycle-average mold temperature obtained from the cooling analysis fed back to filling modules for improving calculation or serves as an input boundary condition for warpage analysis. The iteration of mold temperature is continued until the mold temperature variation between iterations is small. This integrated analysis ensures a coupling between mold filling and mold cooling results and is of practical value to improve the accuracy of analysis.

Results and Discussion

A geometry model composed of box part with an insert component and mold base are simulated by the proposed integrated analysis procedure. The insert component is located inside the hole of part. This model is shown in Figure 2. There are 118,326/33,658/595,336 elements for part/cooling channels/moldbase. The gate is at the center of part. The used resin is ABS. The mold material is P6. The melt temperature is 230^{o}C, and the mold temperature is 70^{o}C. The eject temperature is 120^{o}C. The cooling time is 20 sec. The mold material is P6, the heat capacity is 4.6e6 (erg/g.K), the thermal conductivity is 4.7e6 (erg/sec.cm). We use several different insert materials in order to understand the effect of insert part for injection molding. Table 1 shows the selected materials and its properties. The first insert material is the same as the mold. Figure 3 shows the filling melt front. Figure 4-1~4-3 show the temperature distribution of cavity at the end of filling analysis for different insert material. There are different temperature distributions. Figure 5 shows the comparison of temperature at the end of filling. It clearly indicates the simulation with the insert part of Beryllium_Copper material has lower temperature distribution at the region of insert part. This is because of higher thermal conductivity of Beryllium_Copper material. Figure 6-1~6-3 show the temperature distribution of mold base at the end of cooling analysis. Figure 7 shows the comparison of predicted cooling time from cooling analysis. The predicted cooling time means the time as the temperature of plastic part has been cooled enough to be ejected. It also indicates the insert part of Beryllium_Copper has higher cooling efficiency. It can reduce the cycle time of molding. Figure 8 shows the comparison of warpage. The higher cooling efficiency has lower warpage. These results are in good agreement with real world.

An industrial parts of complex geometries is analyzed to demonstrate the capabilities of proposed 3D insert molding simulation. The selected model is a screw driver, as shown in Figure 9. Figure 10~14 show the analysis results. From these analysis results, the effects of insert component for filling/cooling/warpage patterns are predicted This proposed analysis approach can efficiently simulate the insert molding process for complicated cases.

Conclusions

In the past, due to the poor hardware demands, it is difficult to simulate an entire injection-molded part using a 3D model. With the hardware progress, anyway it is not a dream to simulate full 3D analysis. At present we can effectively simulate the 3D mold insert molding process. These results are in good agreement with real world. This developed approach is proved from numerical experiments to be a cost-effective method for 3D simulation in mold insert molding analysis.

Acknowledgements

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Reference

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Key Words

Insert Molding Analysis, Mold Insert, Injection Molding

Table 1. Insert materials list

Insert #	Material	Cp (erg/g.K)	K (erg/sec.cm)
1	**P6**	**4.6e6**	**4.7e7**
2	**Beryllium_Copper**	**1.9e7**	**1.5e7**
3	**Polymer**	**2.3e7**	**2.4e4**

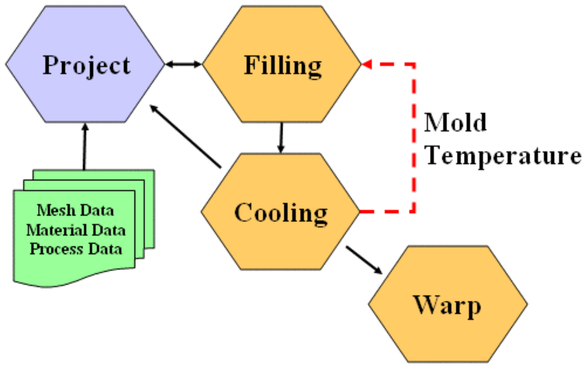

Figure 1. Computational framework of 3D injection molding analysis proposed in this work

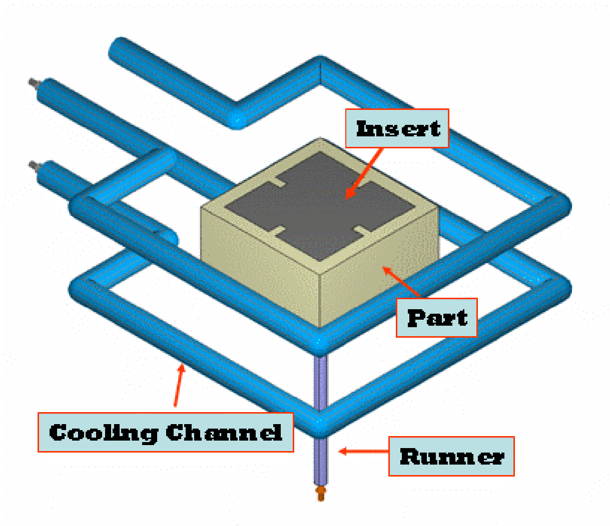

Figure 2. Box model with an insert component

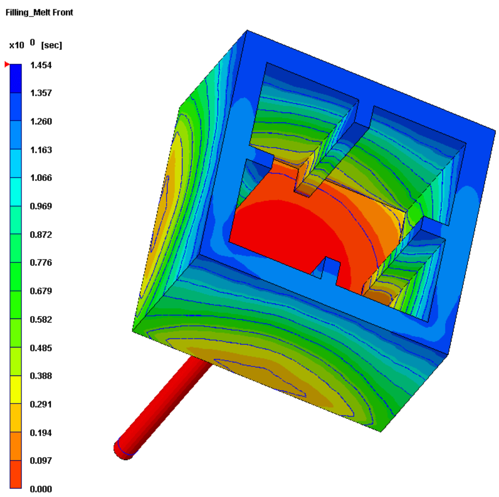

Figure 3. Melt front of filling analysis (Box)

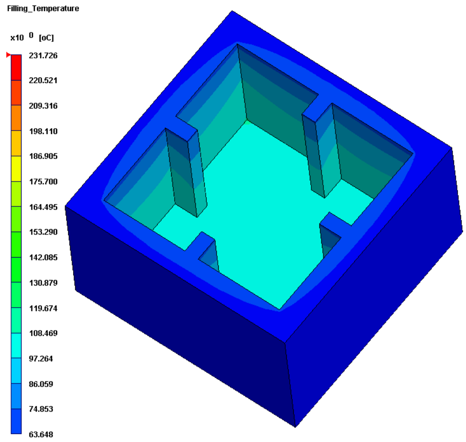

Figure 4-1. Temperature of cavity at EOF (Insert Part: P6)

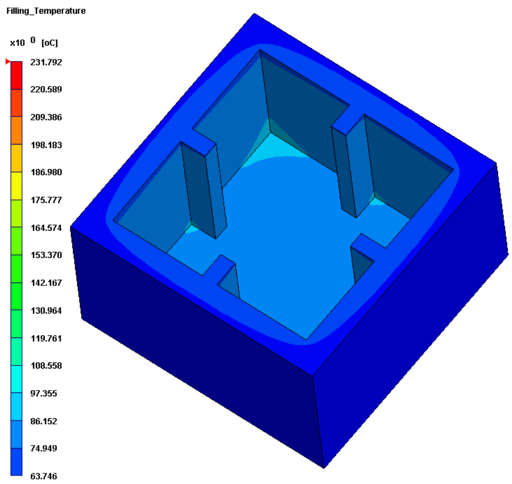

Figure 4-2. Temperature of cavity at EOF (Insert Part: Beryllium_Copper)

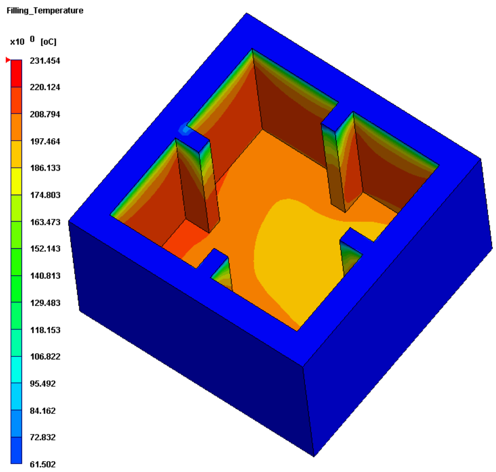

Figure 4-3. Temperature of cavity at EOF (Insert Part: Polymer)

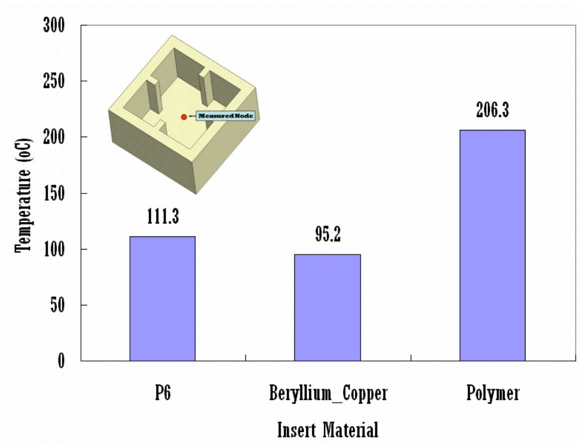

Figure 5. Comparison of temperature at EOF between different insert materials

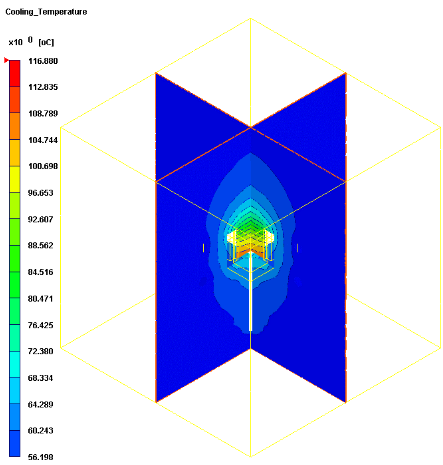

Figure 6-1. Temperature of moldbase at EOC (Insert Part: P6)

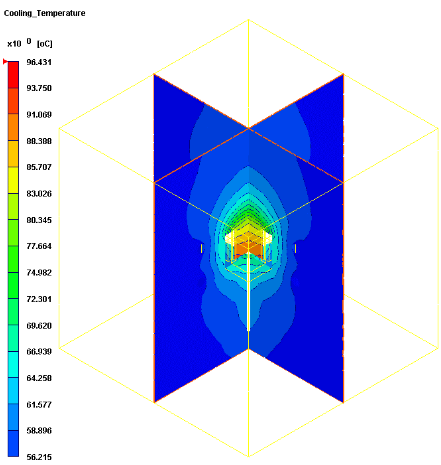

Figure 6-2. Temperature of moldbase at EOC (Insert Part: Beryllium_Copper)

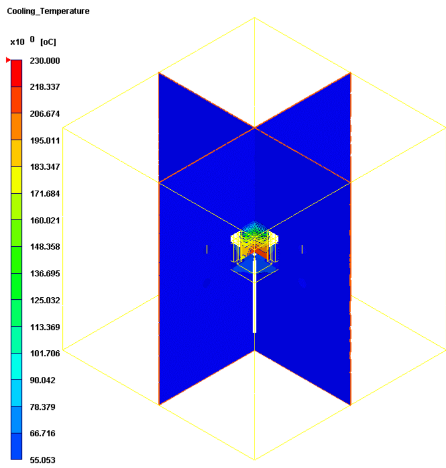

Figure 6-3. Temperature of moldbase at EOC (Insert Part: Polymer)

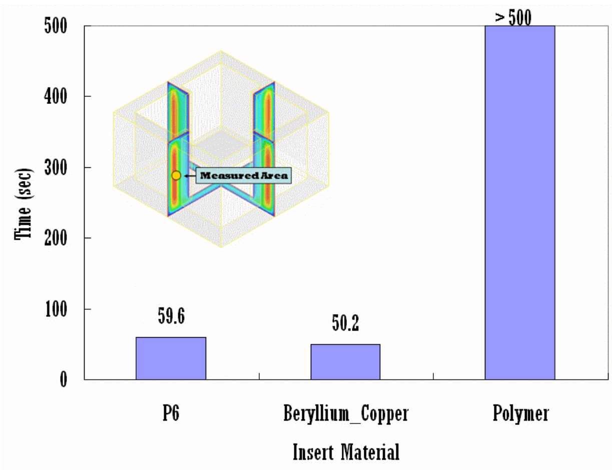

Figure 7. Comparison of predicted cooling time between different insert materials

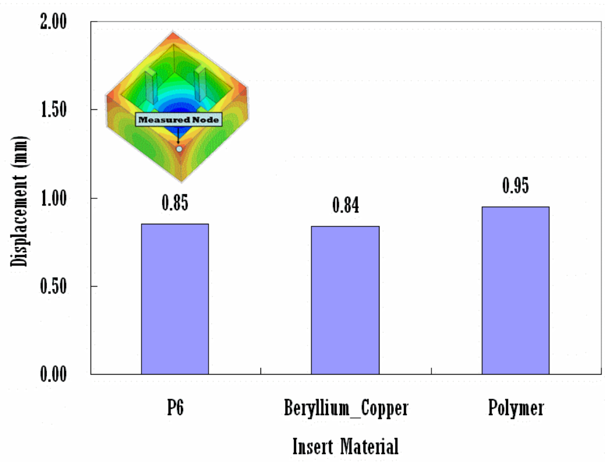

Figure 8. Comparison of warpage between different insert materials

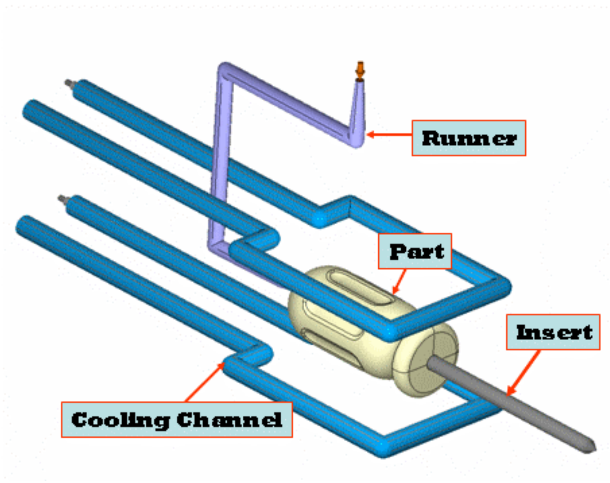

Figure 9. Screw driver model

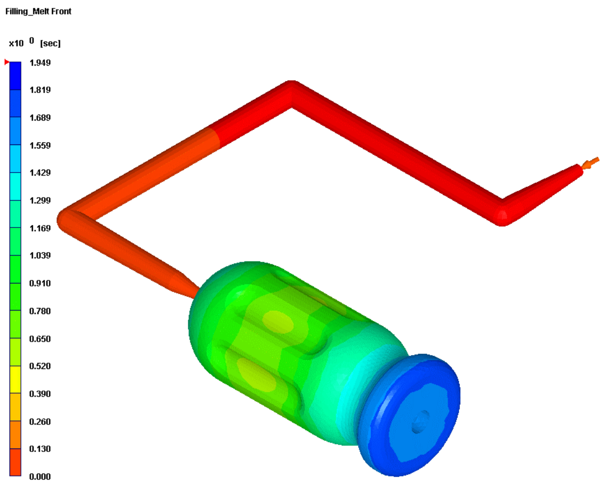

Figure 10. Melt front of filling analysis (Screw driver)

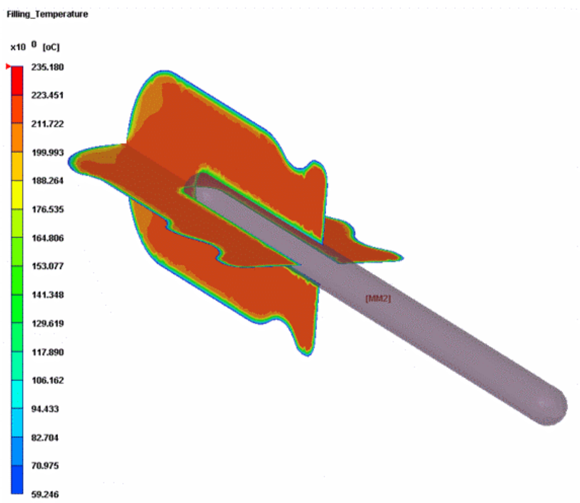

Figure 11. Temperature of cavity at EOF

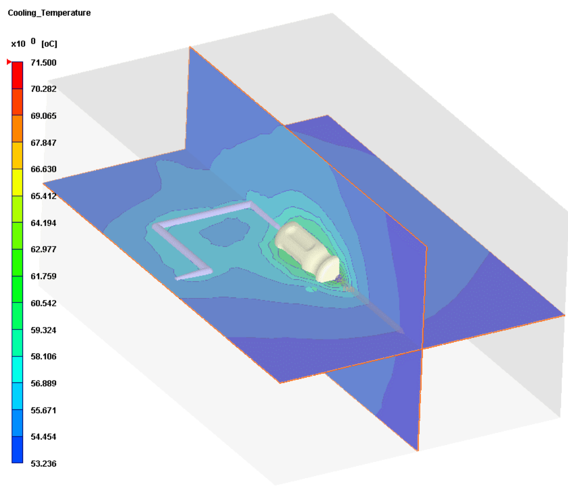

Figure 12. Temperature of moldbase at EOC

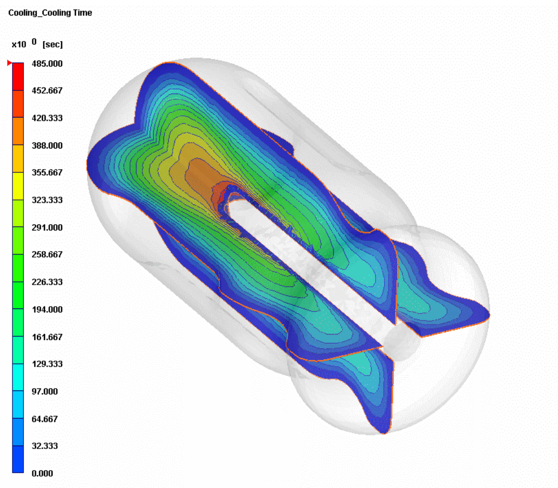

Figure 13. Predicted cooling time at EOC

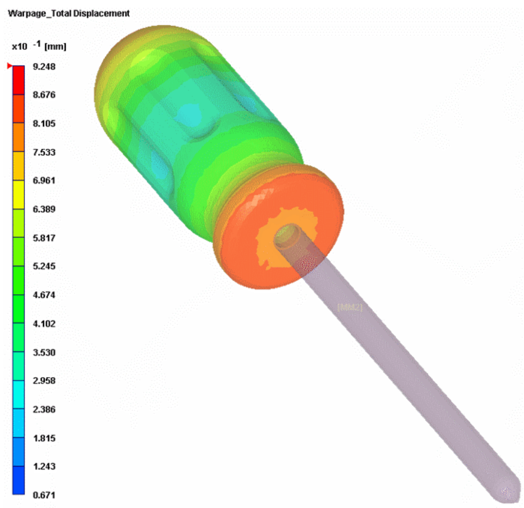

Figure 14. Total deformation of warpage analysis