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Note:

Flow Analysis of Insert Molding Using Injection Molding CAE

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Injection molding CAE is employed to analyze the flow process of insert molding. The goals of the analysis are to reduce the number of injection processes required in injection molding, to impart greater added value to the product, and to advance injection molding technology. The importance of an analysis for the weld lines that occur when the mold is filled with plastic and that may lead to lower product quality in addition to an displacements in the insert-molded part due to plastic shrinkage is pointed out. This paper will report about the importance of the previous injection molding CAE for actual fabrication to investigate the product shape design and molding conditions.

Keywords: injection molding, insert molding, flow analysis, mold shrinkage, weld line

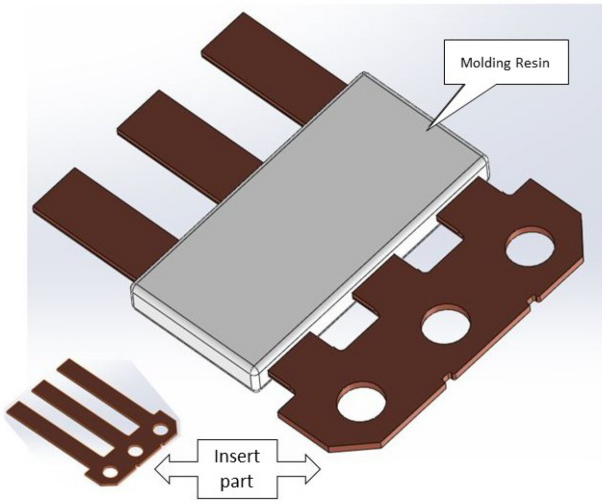


Fig. 1. Flow analysis model part.

1. Introduction

Increased efficiency, downsizing, and weight reduction of communication control systems, electronic devices, wire harnesses, etc., are major issues in next-generation automobiles and personal mobility vehicles. There is an increasing need to develop insert molding technology, i.e., the technology of embedding electrical contacts and other metal parts in plastic, to reduce the size and weight of on-vehicle electronic devices, such as connectors. It is becoming increasingly important to advance injection molding technology, including insert molding, to embed metal inserts, to reduce the number of injection molding processes, and to give products greater added value [1–3].

In this study, we used injection molding CAE to analyze the flow process of insert molding. We examined changes in the flow process due to the deformation of the inserted metal or the flow resistance on the surfaces of metal parts.

2. Method of Analysis

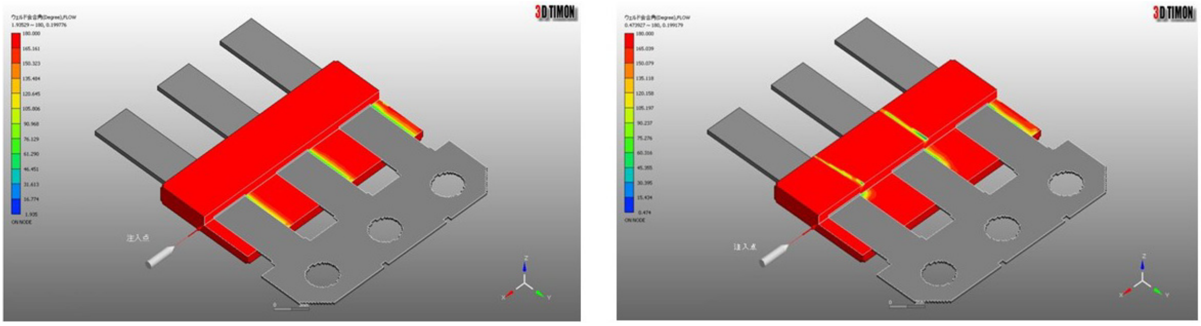
The inserted metal was a 0.64 mm-thick plate of pure copper, which is a difficult-to-machining material in terms of forming but which has low electrical resistance and high electrical conductivity. Two types of plastic were used. The first was grade A504 × 90 (GF 40%) polyphenylene sulfide (PPS) (Toray Industries, Inc.), which is highly heat resistant and has good dimensional stability and chemical resistance. The second was a liquid-crystal polymer (LCP), grade E130i (GF 40%) (Polyplastics Co., Ltd.), which is highly heat resistant and highly liquidity. Using 3D TIMON (Toray Engineering Co., Ltd.) as the injection molding CAE softwere, we did a flow analysis of the insert molding using the model shown in **Fig. 1**. With the flow rate set constant in the flow analysis, the PPS and LCP were analyzed with the standard insert molding module and optional thin-plate model module, respectively.

3. Results and Discussion

3.1. Occurrence of Weld Lines Based on Flow Analysis for each Plastic Material

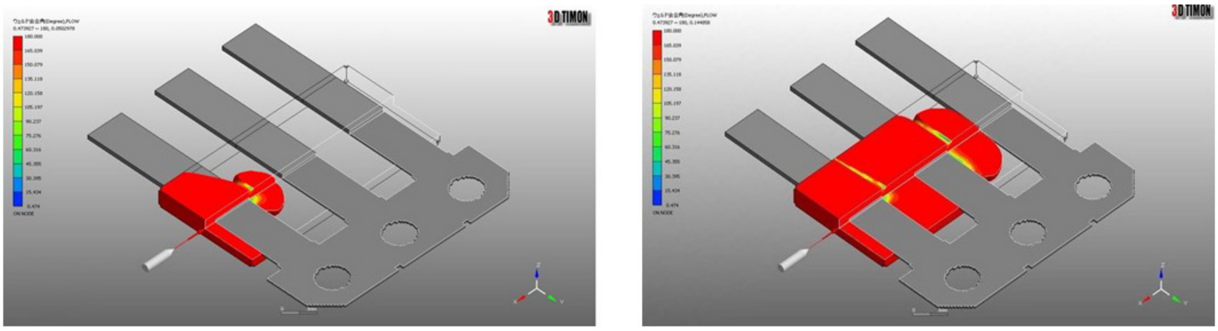
Figure 2 shows the weld lines that appear when PPS and LCP are used, and **Fig. 3** shows the weld lines that appear during the flow process of LCP. As **Fig. 2(a)** shows, when the mold is filled with PPS, weld lines occur around the center of the molded part thickness direction where the plastic near the inserted metal of opposite side of the injection point. They also occur at the center of the surface of the edge of the molded par in the last section filled.

In **Fig. 2(b)**, with LCP, a small weld line occurs near the center of the molded part thickness direction at the



(a) Weld line (PPS) (b) Weld line (LCP)

Fig. 2. Weld line.



(a) Flow process 25% (LCP) (b) Flow process 75% (LCP)

Fig. 3. Flow process.

edge of the inserted metal, away from the injection point, but the weld line grows in size increasingly away from the injection point. A weld line also appears along the center of the surface on the edge of the molded part in the last section filled. In addition, weld lines appear on the outer perimeters of the molded surface near the edges of the first and second metal tongues. The pattern displayed is very different from that seen when PPS is molded.

In the flow process of LCP shown in **Figs. 3(a)** and **(b)**, it can be seen that the plastic flows along the metal tongue, led by a curved shape front, and it fills from those areas closest to the injection point. The two fronts flowing above and below the metal tongue meet between the metal tongues and form weld lines near the center of the molded part thickness direction. Because the viscosity of LCP is about one-fifth that of PPS, the joined plastic flows in the transverse as well as longitudinal directions, restricting the weld lines to the vicinity of the center. The weld lines on the outer perimeters of the surface of the molded part are thought to be caused by the joining of plastic flowing in the transverse direction with that flowing in the longitudinal direction but arriving slightly later. The flow pattern of LCP approaches that of PPS in the final filled state and occur the similar weld lines in case of each plastic. It shows the importance of flow analysis by injection molding CAE.

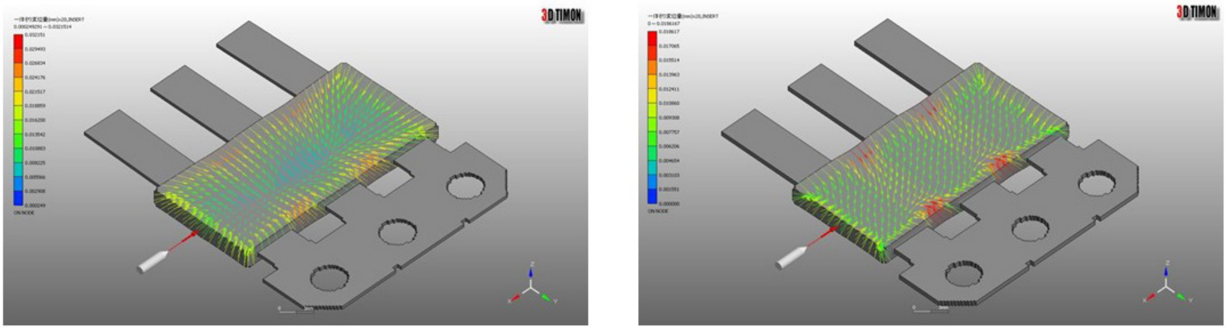
3.2. Displacements due to Shrinkage After Plastic Has Formed

Figures 4(a) and **(b)** show the displacements after the LCP has shrunk. The arrows indicate the direction and amount of displacement due to plastic shrinkage. Note that the displacements in the figure have been magnified 20-times. **Fig. 4(a)** shows the displacements due to free shrinkage of the molded part in areas not affected by the stiffness of the metal insert, areas where it can be seen that the displacements occur toward the center of gravity of the plastic form. In this case, the metal insert is displaced in the same direction as the direction of the shrinkage of plastic, resulting in large displacements at the edges of the open ends.

Figure 4(b) shows the displacements due to plastic shrinkage when the contact surfaces between the metal insert and plastic are constrained to take into account the stiffness of the metal insert. The plastic near the inserted metal is considered to be displaced toward the centers of the respective sections of the inserted metal. In the each molded plastic sections between the metal tongues, there are large displacements toward the centers of the respective sections. In each of these sections, the plastic is thought to shrink toward the center of gravity of the plastic section in a manner similar to that in **Fig. 4(a)**. Displacement of the inserted metal is a very little when the stiffness of the inserted metal is taken into account.

4. Conclusion

Achieving a uniform plate thickness is considered to be an important factor in securing high quality in an injection-molded part. In this study, it was found that weld lines occur at unexpected places in molded parts



(a) Shrinking displacement (LCP) (b) Shrinking displacement (LCP)

Fig. 4. Shrinking displacement.

made from LCP specified for thin wall-thickness, thus leading to lower quality. This demonstrated the need to examine and design the shape so as to achieve, to the extent possible, a uniform plate thickness of the molded part.

Although displacement of the inserted metal due to post-molding shrinkage was a little for the inserted metal used in this study, a 0.64 mm-thick copper sheet, the effect that shrinkage of the plastic has on the metal cannot be neglected. To improve product quality, it is important to carry out flow analysis based on the plastic and metal materials used, check the displacements of the insert-molded part, and examine the product shape design and molding conditions, among other factors.

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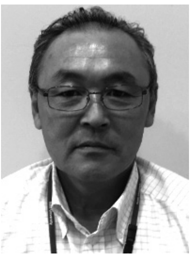

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