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A STUDY ON INJECTION-STRUCTURE COUPLED ANALYSIS FOR THE PREDICTION OF INTEGRATED METAL INSERT INJECTION MOLDING PARTS

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Abstract:	This study proposes an injection-structure coupled analysis to quickly predict the deformation of the insert parts of small precise connectors. The flow pattern was determined through an analysis of the plastic injection molding of small precise connectors, and a structural analysis was performed using injection pressure. For this purpose, an injection-structure mapping program was developed to use the injection molding pressure as the input to the boundary condition of the structural analysis. The effect of injection molding, which varies according to the process conditions of the metal insert parts of small connectors, was analyzed through structural analysis.

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ABSTRACT

This study proposes an injection-structure coupled analysis to quickly predict the deformation of the insert parts of small precise connectors. The flow pattern was determined through an analysis of the plastic injection molding of small precise connectors, and a structural analysis was performed using injection pressure. For this purpose, an injection-structure mapping program was developed to use the injection molding pressure as the input to the boundary condition of the structural analysis. The effect of injection molding, which varies according to the process conditions of the metal insert parts of small connectors, was analyzed through structural analysis.

INTRODUCTION

As plastic pieces with metal insert parts are small and require high precision, they have been produced by separately creating plastic pieces and metal insert parts and then assembling the final product from these. However, they are often deformed after injection molding due to the fiber orientation, differences in shrinkage, and the injection pressure of plastic molding forms. All of these factors increase the defect rate during assembly.

Recent developments in high-precision molding techniques for micro-precise insert injection molding have enabled the injection molding of integrated metal inserts; this is being actively applied as a method for increase of yield and reduction of the defect rate through the removal of stages of the assembly process. The application of integrated metal insert injection molding could reduce the defect rate from the assembly process, but a new problem—the deformation of internal metal insert parts—has emerged due to the high pressure that exists during injection molding. This is because injection molding is carried out with insert parts. The deformation of the insert parts generally cannot be seen from the outside; it is checked using computer-aided engineering (CAE) analysis of the injection molding. However, since the analysis takes too long and is limited to linear analysis with the consideration of only the elastic region, parts that show nonlinear behavior cannot be analyzed.

This study proposes an injection-structure coupled analysis to quickly predict the deformation of the insert parts of small precise connectors. The flow pattern was determined through an analysis of the plastic injection molding of small precise connectors, and a structural analysis was performed using injection pressure. For this purpose, an injection-structure mapping program was developed to use the injection molding pressure as the input to the boundary condition of the structural analysis. The effect of injection molding, which varies according to the process conditions of the metal insert parts of small connectors, was analyzed through structural analysis.

RESULTS AND DISCUSSION

Injection-Structure Coupled Mapping Program

As the pressure changes over time during injection molding, and because the injection pressure on each element of the insert part is different, a separate program is required to apply the pressure as a boundary condition of structural analysis. Thus, in this study, a mapping algorithm was developed that can use the injection pressure over time as a boundary condition for structural analysis.

Since the injection pressure obtained from injection molding analysis is represented as injection pressure results for nodes, an injection-structure mapping program was developed by applying the principle illustrated in Fig. 1 in order to apply the planar pressure to each element of the structural analysis as a boundary condition.

The developed program was designed to search for the nodes of the injection molding elements that are closest to the nodes of structural analysis, and to map the injection pressure results to the identified nodes. The mapping procedure is as follows:

a) To map the injection pressure results as a boundary condition for structural analysis, the thicknesses of the injection molding products and insert parts are calculated.
b) The finite element planes of the mapped surfaces in the finite element model of the insert parts are extracted.
c) The pressure distributions for the nodes of the injection molding are converted to combination values between the edge length and thickness; these are applied to the finite element planes of the insert parts as a boundary condition.

d) The file for structural analysis, including the finite element model and the boundary condition, is automatically created and a structural analysis is performed.

For the injection-structure coupled analysis, a finite element model for injection molding products and insert parts was created, and a flow analysis was performed for the injection molding products. The pressure results during flow were derived through injection molding analysis, and the derived injection pressure results were mapped for application of the boundary condition for structural analysis. Through applying the boundary condition to the finite element analysis model for structural analysis, an evaluation of the effect of the insert parts was carried out. If the insert part was deformed in this analysis, the injection molding conditions were varied to repeatedly analyze the optimum molding conditions. Figure 2 illustrates the injection-structure coupled analysis process.

Injection Molding Analysis of Small Precise Connectors

In this study, the effect of metal insert parts on small precise connectors was examined according to injection pressure through an injection-structure analysis. Figure 3 shows the injection molding finite element model for flow analysis of small precise connectors. Because the gate location is limited due to the very small thickness and functional characteristics of the molding product, and the molding product is small, the volume of the flow transmission system for flowability is relatively large.

In general, for integrated metal insert parts, injection pressure by polymer flow creates the greatest deformation of insert parts. Therefore, the effect of small precise connectors on the metal insert parts was analyzed while changing the injection time. Table 1 lists the molding conditions used for this analysis.

For injection molding analysis, Maps3D V5.0 from VMTech was used; for resin, Vectra E473i(LCP) from Polyplastics was employed. Figure 4 shows the flow pattern of the small precise connector with 0.1 second of injection time. From the connector edge, where there is a metal insert part, it can be seen that the flow at the flow end is faster than the flow at the body, and the small thickness of the connector product has an effect on flow.

Figures 5 and 6 show the injection pressure distribution and the pressure distribution by location over injection time. As the injection time increased, the maximum injection pressure decreased, and short shots were generated at injection times of 0.1 seconds or longer due to the effect of increased frozen layer. Due to the effect of the lesser thickness of the small precise connector, there was a large difference in injection pressure between the gate and the flow end. It could be predicted through analysis that quality change can be caused by high injection pressure in the metal insert part near the gate.

Structural Analysis of the Insert Parts of the Small Connector

A structural analysis was conducted for the metal insert part that was the closest to the gate where the maximum injection pressure was applied. The reason for this is that the maximum injection pressure deforms the metal insert part, which causes a defect in the final product. Figure 7 shows the analytic scope of the metal insert part applied to structural analysis, which was performed for the insert pins in the first row.

As the boundary condition was applied to the interface between the injection molding product and the metal insert part, a three-dimensional, four-node tetrahedron was applied to improve the time and reliability of the analysis. Figure 3 shows the finite element model of the metal insert part to which the boundary condition was applied. For the structural analysis program, Marc from MSC Soft was used. Figure 8 illustrates a metal insert part to which the boundary condition was applied for each element, and Fig. 9 shows the results of the structural analysis. The results show that even though stress was concentrated on the shape changed area, it did not reach the yield stress for any of the injection times: 0.05, 0.075, and 0.1 seconds. However, as the injection pressure increased over time, it could be confirmed through the analysis of stress distribution in the internal inert parts that the proposed method can be effectively used in the design stage for structurally weak parts such as metal core pins in future.

CONCLUSIONS

This study analytically predicted the effects of injection pressure during injection molding on metal insert parts through the combination of injection molding and structural analysis, and arrived at the following conclusions:

1. An injection-structure mapping program was developed to apply the results of pressure over time for injection molding analysis as the boundary condition for structural analysis. The injection-structure coupled analysis found that the developed program could be effectively used for the assessment of the effect of metal insert parts.
2. The stress distribution of a small precise connector could be predicted through the injection-structure coupling, and it was found that the shorter the injection time was, the higher the stress on the metal insert part became.

ACKNOWLEDGEMENT

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KEY WORDS

Insert molding, injection-structure coupled analysis, Connector,

TABLE

Table. 1 Analysis conditions for injection molding of small precise connectors

	Injection Time[sec]	Packing Time[sec]	Packing Pressure[%]	Cooling Time[sec]
Case 1	0.05	0.1	80	7
Case 2	0.075			
Case 3	0.1			

FIGURES

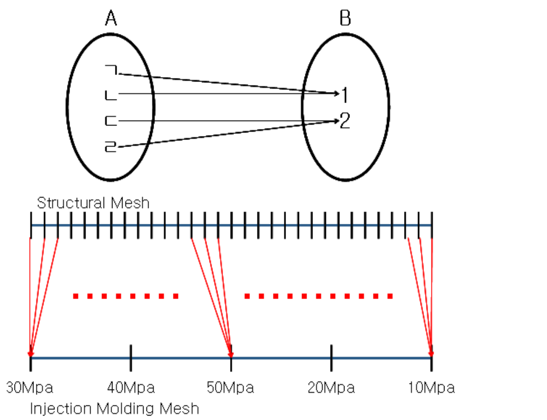


Fig. 1 A mapping algorithm for the injection-structure analysis results

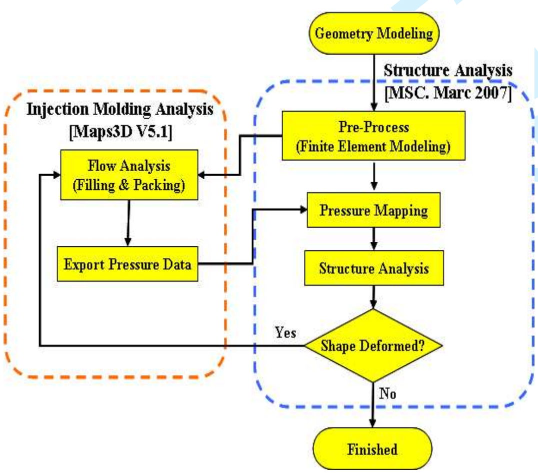


Fig. 2 Injection-structure analysis process

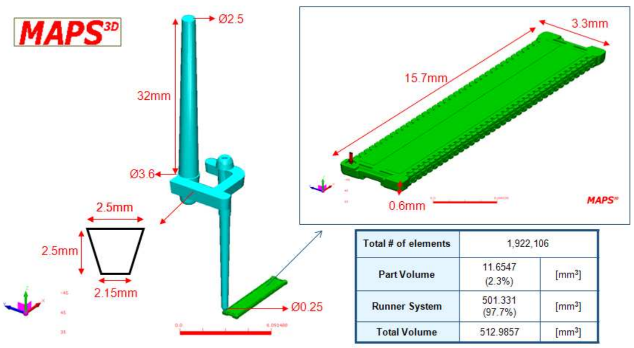


Fig. 3 Injection molding analysis model for small precise connectors

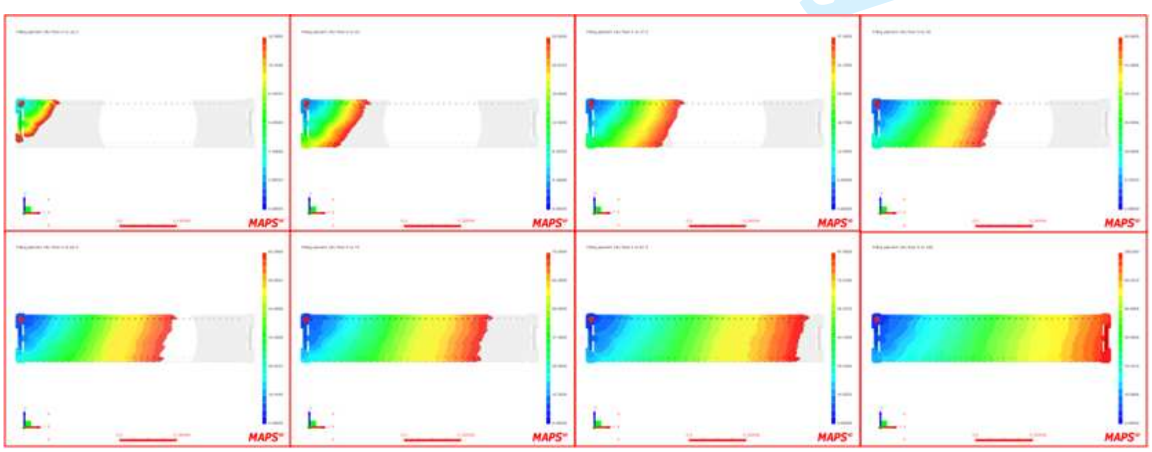


Fig. 4 Flow pattern of small precise connector (injection time: 0.1 s)

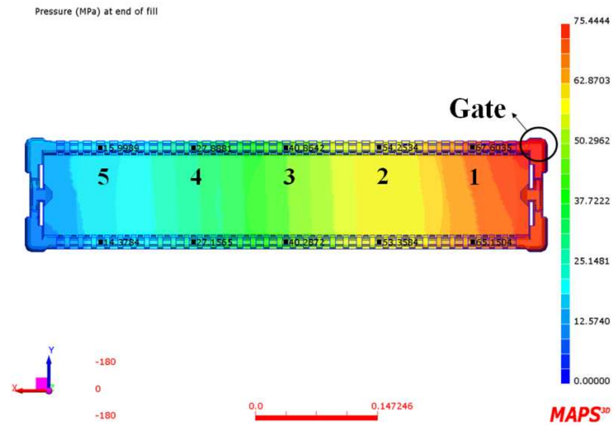


Fig. 5 Pressure distribution of the small precise connector (injection time: 0.1 s)

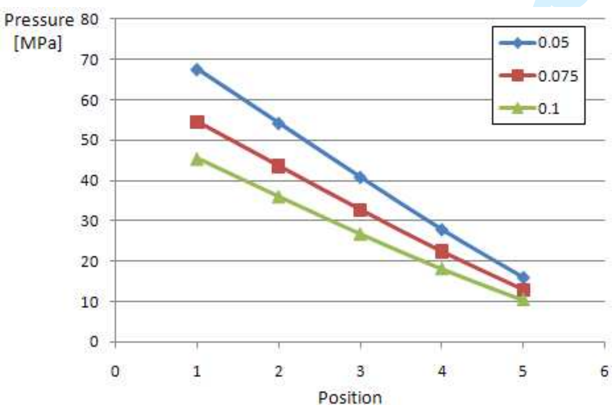


Fig. 6 Pressure distribution over time by location

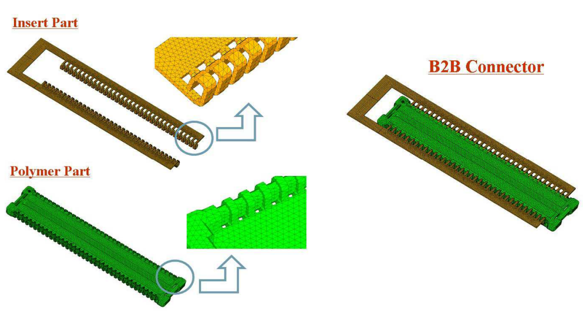


Fig. 7 Structural analysis area for the insert parts of the small precise connector

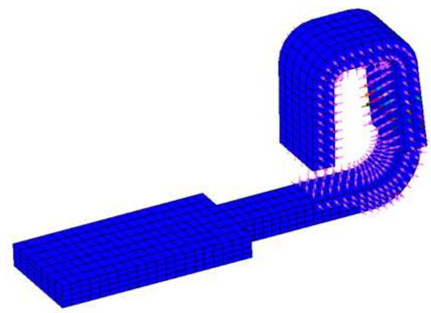
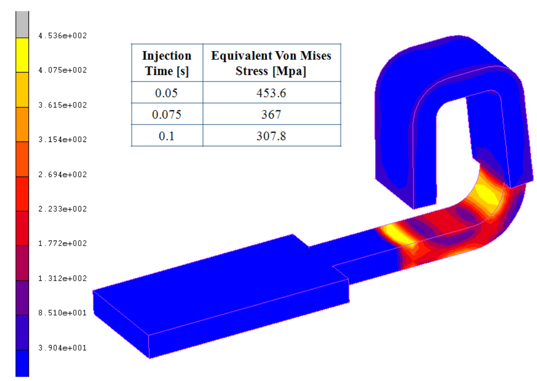


Fig. 8 Boundary condition of the metal insert parts applied through injection pressure mapping



Injection Time [s]	Equivalent Von Mises Stress [Mpa]
0.05	453.6
0.075	367
0.1	307.8

Fig. 9 Structural analysis results for metal insert parts