Fabrication Simulation Technology Applied to Resin Component Design

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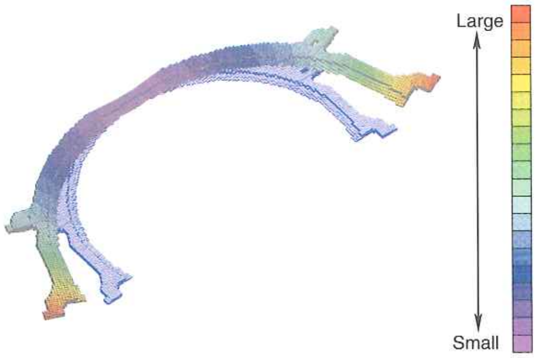

Abstract

Fujitsu Ten has been pursuing advanced resin molding technology, seeking to replace metal parts with resin, integrate multiple parts into single resin molds, and, ultimately, reduce product weight and production cost. However, since resin parts are becoming highly advanced and complex in shape, it has become difficult to take measures to minimize warping and shape deformation during the molding process. To solve this problem, we installed a resin rheological analysis system in 1997. Using rheological analysis, we conduct fabrication simulations in the initial parts design stage, and predict possible generation of flaws. This information helps us take necessary measures against deformation in the design stage, thus allowing us to minimize shape defects in the molding process and reduce resin parts development times.

An outline of the resin rheological analysis system follows, including an example of its successful application in resin parts development for a CD changer deck mechanism. In the case cited, a 20% reduction in the development time was obtained.

1. Introduction

Recently, it has become necessary to replace metal parts with resin parts to reduce parts production costs and weight of parts. Accordingly, demand for resin molding technology has been on the increase year by year, and it is becoming difficult to design products using resin parts and metal molds only by relying on technical experience and instinct. Prototypes are being created more frequently to ensure the quality of resin parts, and the prolongation of parts development times and increases in parts development costs are at issue.

In 1997, Fujitsu TEN installed a resin rheological analysis system for the purpose of reducing parts development times and cutting production costs and ensuring the quality of resin parts. With this system, we were able to conduct fabrication simulations in early stages of product design to evaluate and improve design quality. This system has enabled us to reduce parts development times while improving the quality of parts.

This paper outlines the resin rheological analysis system and cites an example of its application to the simulation of fabrication, for the development of a resin part. In the example cited here, it was possible to reduce the development time by 20 percent.

2. Outline of Resin Rheological Analysis System

2.1 Resin Rheological Analysis System

The resin rheological analysis system (called the "analysis system" in this document) is a computer system for theoretically computing the flow of high-temperature melted resin in a metal mold. This analysis system enables us to conduct a fabrication simulation and predict possible defects in the shape of the part, e.g., warping and deformation, during the molding process.

The prediction functions of the analysis system are generally classified into the following four types:

(1) Prediction of filling process

This function allows us to predict how injected resin will fill the inside of a metal mold. Figure 1 shows an example of a simulated condition in which the resin injected from the gate is filling a metal mold. The mold injection flow sequence is indicated by different colors.

(2) Prediction of weld line locations

This function allows us to predict the positions where different flows of resin collide with each other in the metal mold. (Such positions are called "weld lines" which will appear to be visible line segments on the part surface). Figure 2 shows an example of the predicted locations of weld lines.

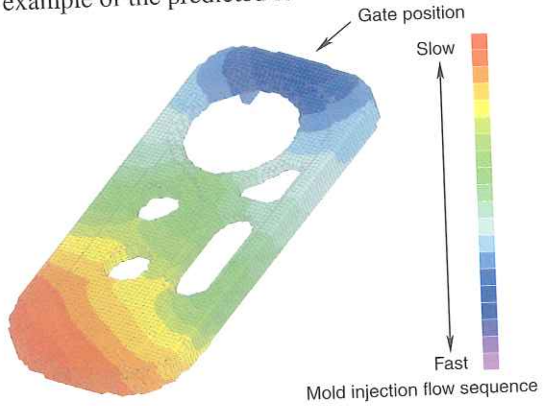

Fig. 1 Diagram of predicted filling process

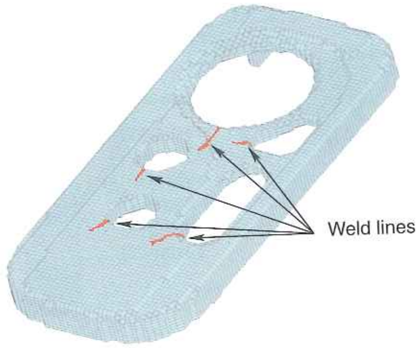

Fig. 2 Diagram of predicted weld line location

(3) Prediction of temperature distribution

This function allows us to predict the distribution of the temperatures of the resin injected inside the metal mold. Figure 3 shows an example of the predicted results. Different temperatures are indicated by different colors.

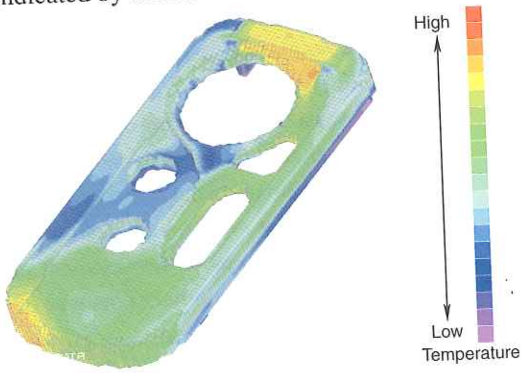

Fig. 3 Diagram of predicted temperature distribution

(4) Prediction of warp and deformation

This function allows us to predict how the molded part will warp and deform. Figure 4 shows an example of the predicted deformed shape of the molded part.

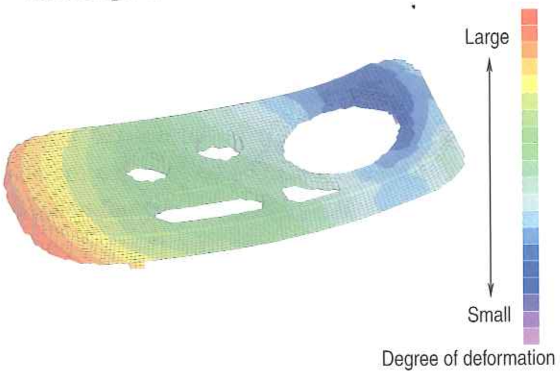

Fig. 4 Diagram of predicted warp and deformation

Based on the results of fabrication simulation, the following four types of measures can be taken to improve the quality of the relevant part:

(1) Modification of part shape
(2) Modification of resin
(3) Modification of molding conditions
(4) Modification of metal-mold structure

2.2 Effects of Fabrication Simulation

Fabrication simulations can bring about the following three effects:

(1) Improvement of parts quality
When defects in molding are predicted and appropriate measures are taken in the initial stage of parts design, the quality of the molded parts can be improved.

(2) Reduction of cost for metal-mold correction
When the quality of design is improved and the number of prototypes to be made is reduced, the cost for metal-mold correction can be reduced.

(3) Reduction of product development time
When prototypes need to be made only a reduced number of times, the product development time can be reduced.

2.3 Processes where Fabrication Simulation can be Used

Fabrication simulations can be applied to the following processes (Figure 5):

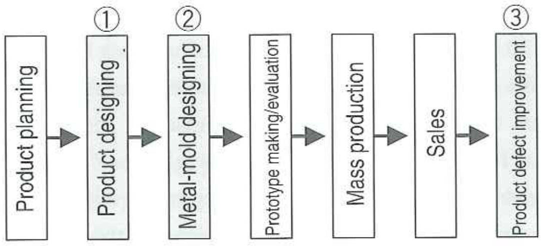

Fig. 5 Process utilizing fabrication simulation

(1) Product designing process
Fabrication simulations can be used to determine the part shapes and resin that will not easily cause defects in molding.

(2) Metal-mold designing process
Fabrication simulations can be used to determine the cooling-pipe layout and molding conditions and correct shrinkage factors.

(3) Product defect improvement process
Fabrication simulations can be used to investigate the causes of defects that occurred in marketed products and that were related to molding, and improve the defective products.

2.4 Data Required for Fabrication Simulation

A fabrication simulation requires the following three kinds of data:

(1) Part shape data
Part shape data is created by use of three-dimensional CAD and indicates a part shape with small hexahedrons in mesh form (see Figure 6).

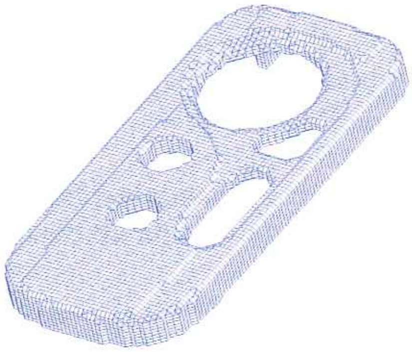

Fig. 6 Mesh network diagram

(2) Resin data
Resin data indicates the physical characteristics (e.g., melting temperature, solidification temperature, and viscosity) of the resin.

(3) Molding condition data
Molding condition data indicates the setup conditions to be input into the molding machine and other data (e.g., injection temperature, metal-mold temperature, cooling time, and gate position) related to metal mold.

2.5 Problems in Fabrication Simulation

In some cases, there may be differences between the results of the fabrication simulation and the results of the actual molding. Three possible causes of the difference are as follows:

(1) Some basic equations are replaced with assumed equations in the analysis system for the purpose of reducing the time required for the fabrication simulation. Use of the assumed equations may cause inaccurate results of computation.

(2) The part shape is approximately represented by hexahedrons in mesh form. Some round sections of a part cannot be represented accurately if the mesh size is inappropriate. This may lead to differences with the actual shape.

(3) In the actual molding process, the metal-mold and molding temperatures change at each molding operation. The actual temperatures may differ with the temperature data input into the analysis system for the fabrication simulation.

The above three items must be improved to increase the accuracy of the fabrication simulation. We have already studied and improved items (2) (mesh size) and (3) (input of molding conditions). However, we, or an end user of the system, cannot modify item (1) (analysis system program). Regarding item (1), we have investigated the accuracy of the results of the simulations by using the present analysis system, and make corrections to the simulation result when using the analysis system.

3. Example of fabrication Simulation Application to the Tray for CD Changer

3.1 Specifications of the Part

We applied the fabrication simulation to the tray (illustrated in the photo at the top of this paper) for a CD changer. This tray is used to hold a CD in the CD changer. The tray requires an accurate width because it holds a CD. The relevant specification in the initial design stage requires the error in the width to be within ± 1.00 mm. Figure 7 shows the prototype shape designed in the initial design stage.

Fig. 7 Prototype shape

3.2 Purpose of Fabrication Simulation

Conventional trays have a dish shape to allow them to hold the entire CD. In the initial design stage, the design of this tray was changed to improve the shape such that the tray would hold only the circumference of a CD. This change was made for the purpose of minimizing the amount of resin required. This tray came to have a narrow width and a small plate thickness. We were unable to predict whether it would be possible to successfully mold it and how many defects would occur during the molding process. To find out, we conducted a fabrication simulation for the tray in the initial design stage to predict what possible defects would occur during the molding process, so as to take measures for such defects.

3.3 Application of Fabrication Simulation

3.3.1 Evaluation of prototype shape

We were able to learn the following two items from the result of fabrication simulation:

(1) The resin can fill every detailed section of the metal mold for the part and molding can be done successfully.

(2) The tray warps and extends its width by 5.22 mm. This deformation prevents the tray from holding a CD properly. (See Figure 8.)

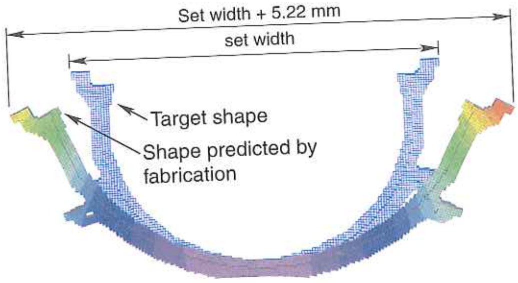

Fig. 8 Diagram of predicted warp and deformation in prototype shape

To analyze the cause of warp and deformation, we predicted the temperature distribution as shown in Figure 9. Our prediction indicated that the temperature difference between the inner edge and outer edge would be 90°C and that the warp and deformation would be caused by shrinkage differences during the cooling stage.

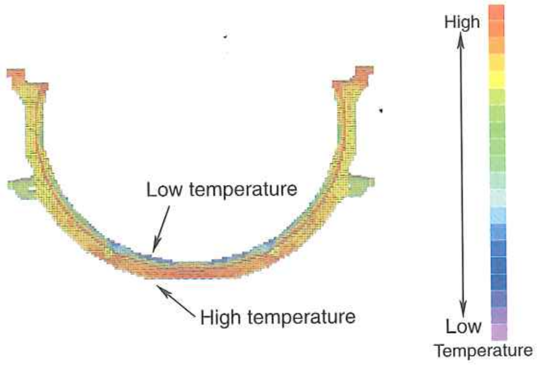

Fig. 9 Diagram of predicted temperature distribution in prototype shape

3.3.2 Preliminary improvement plan

To prevent warp and deformation, we made two improvements to the part shape. (See Figure 10.)

(1) We made a groove on the back side of the part to make all of the sections be of uniform thickness, for the purpose of reducing temperature difference due to differences in thickness.

(2) We made notches on the inner edge to reduce the temperature difference between the inner and outer edges in the section where the largest deformation was found.

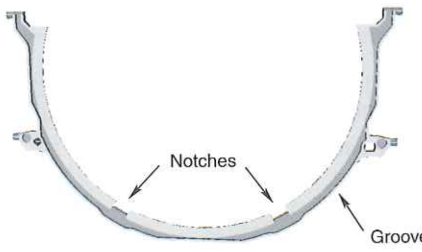

Fig. 10 Component shape (back side) proposed in preliminary improvement plan

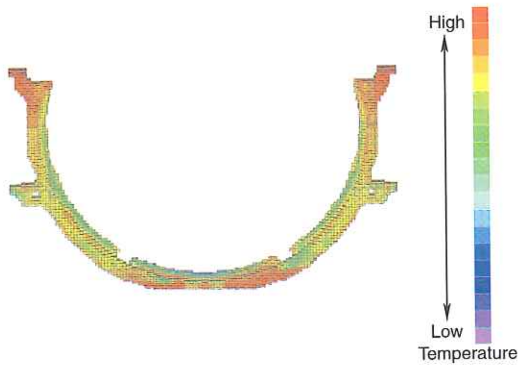

Fig. 11 Diagram of predicted temperature distribution resulting from preliminary

By carrying out these measures, the temperature difference between the inner and outer edges was reduced to 70°C, as shown in the diagram for predicted temperature distribution (Figure 11). It was possible to reduce the degree of deformation to 1.19 mm.

3.3.3 Secondary improvement plan

After the preliminary improvement, the notches on the inner edge where the temperature was high were enlarged as shown in Figure 12 as the secondary improvement.

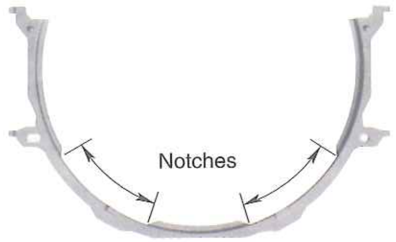

Fig. 12 Diagrams of predicted warp and deformation in each improvement plan

As a result, the temperature difference between the inner and outer edges was reduced to 30°C (Figure 13), and it was possible to reduce the degree of deformation to 0.30 mm. Thus, it was possible to satisfy the requirement (error must be within set width ± 1.00 mm). (See Figure 14.)

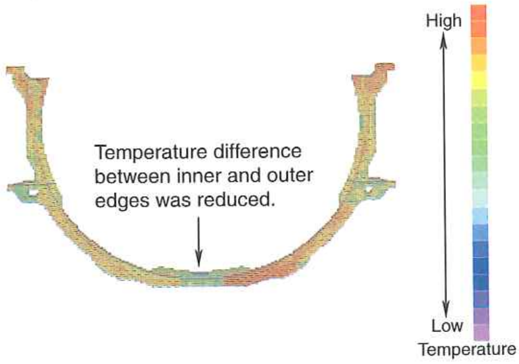

Fig. 13 Component shape proposed in secondary improvement plan

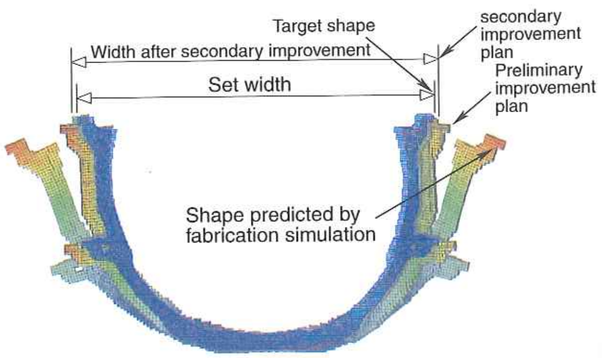

Fig. 14 Diagram of predicted temperature distribution resulting from secondary improvement plan

3.4 Effects of Fabrication Simulation

With three-dimensional CAD, the analysis system, and fabrication simulation, we were able to improve the design quality for a part having a brand-new shape. In other words, we were able to minimize the deformation of the part shape before making a prototype.

A molded-parts maker initially said that this part would warp so that its width would be reduced. On the contrary, the fabrication simulation indicated that this part would warp so that its width would be extended. Later, we checked the actually molded part and found that it warped so that its width was extended. This time, the prediction made by fabrication simulation was correct.

Because we were able to improve the design quality before making prototypes, we had to make prototypes only a minimized number of times. As a result, we were able to reduce the total development time by 20 percent as shown in Figure 15.

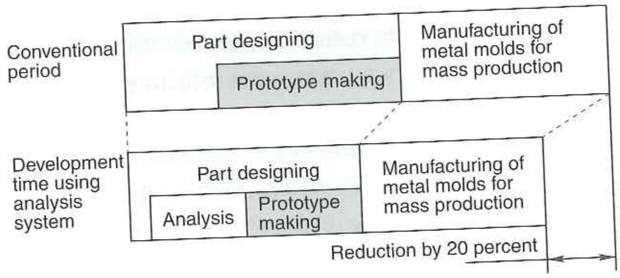

Fig. 15 Development period reduction based on analysis

Thus, the analysis system can be a powerful tool for designers who intend to improve design quality and reduce the development time. Fabrication simulation using the analysis system prior to making the prototype will likely increase its importance further.

4. Future Issues

4.1 Accuracy of Fabrication Simulation

The result of fabrication simulation is not always accurate enough. If improper data is input, the system may predict a warp direction that is actually in a direction opposite to the actual warp direction or expansion of a part that is actually shrinks. To obtain as high degree of accuracy, we need to compare the predicted results with the actual molding results, analyze the causes of differences, and improve the method of using the analysis system. The analysis system may sometimes be generate an error owing to internal causes. If such an error occurs, we must analyze the error, report it to the maker of the analysis system, and cooperate with the maker in improving the accuracy of such system.

4.2 Standardization of Resins

As described before, resin data is required for the fabrication simulation. Various types of resins are registered in the internal database of the analysis system. However, an increasing number of new types of resins appear in the market every year, and supplies of not a few types of resins are running short. When we need an unregistered type of resin, we usually send a request for the resin to a resin maker or consign its analysis to an external organization. In some cases, it takes much time to obtain resin data, and our analysis period ends up being prolonged. For this reason, we are planning to standardize the types of resins classified by the resin parts usage, and their use environment, and arrange the data on such standard resins. This standardization will allow us to know more easily what the characteristics of each resin type is, resulting in an increase in the accuracy of fabrication simulation and less hurdles in making improvements to parts with predicted defects. The standardization of resins will also likely have the large effects of reducing resin stocks at molded-parts makers and reducing material costs as a result of bulk purchases of the same type of resin.

5. Conclusion

This paper explains the application of fabrication simulation using the resin rheological analysis system. In the example of simulation reported here, we were able to predict possible defects in the molding process in the initial parts design stage and improve the parts quality before making prototypes. We will keep engaging in fabrication simulations concurrently with parts development processes from the initial design stage for the purpose of reducing parts development times. We will also make efforts to eventually apply fabrication simulations on a company-wide basis to maximize its effects.

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