

Establishment of Rapid Manufacturing System for Dies to Produce Hydraulic Valve Body Prototype

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ABSTRACT

The use of different casting methods causes differences in the detailed shapes of mass-production and prototype models of the hydraulic valve bodies which make up the hydraulic circuits employed for shift control in automatic transmissions. These differences make it necessary to reset the shift control specifications in mass-production models after their initial setting in the prototypes. This issue could be resolved by replacing the sand molds currently used to cast prototypes with the dies used in mass production, but the length of time required to produce prototypes with the dies renders this method impractical. Therefore, new production techniques were proposed and the production workflow was studied in order to reduce the period required to produce dies. As a result, prototype hydraulic valve bodies can now be produced using dies in a shorter period than previously required when using sand molds.

1. Introduction

The hydraulic control units of automatic transmissions are used to perform smooth, shock-free shift control. The hydraulic control specifications are set using hydraulic circuits that are formed by hydraulic valve bodies which are aluminum diecast (hereafter, “diecast”) parts. Differences occur in the detailed shapes of mass-production and prototype models of hydraulic valve bodies such as the draft angles and corner roundness of the bottom of the hydraulic circuit as shown in Fig. 1. As automatic transmission control has become more precise in recent years, these differences in the detailed shapes can affect the hydraulic characteristics. This made it necessary to reset the hydraulic control specifications in mass-production models after their initial setting in the prototypes.

These differences in the detailed shapes of mass-production and prototype models of hydraulic valve bodies are caused by the use of different casting methods for mass-production and prototype models. Figure 2 shows the manufacturing processes for mass-production and prototype models. The product designer creates the detailed 3D model

shown in Fig. 2 by reflecting the parting lines, draft angles, fillet roundness and other specification requests from the manufacturing side to the model using 3D CAD. This detailed 3D model is used in the same manner for both mass-

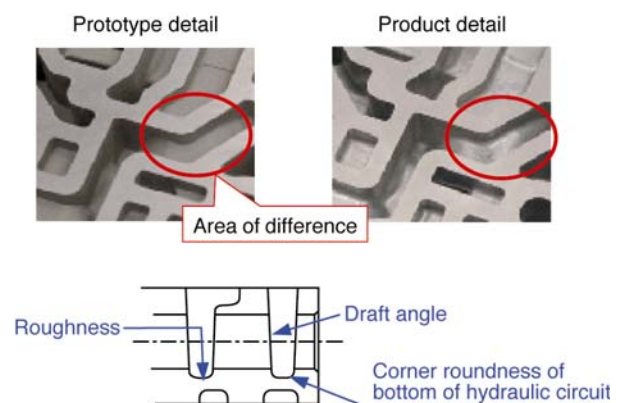


Fig. 1 Comparison of detail shape in prototype, and product

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production and prototype models. In the mass-production model manufacturing process, the detailed 3D model is used for the CAM model, and the die is carved by a CNC machine and used for diecasting. The detailed 3D model is also used for the CAM model in the prototype model manufacturing process, but in this case a wood mold is carved by a CNC machine, and this wood mold is then used to make a sand mold for diecasting. In the prototype model manufacturing process, the sand mold is made manually, and it is in this process that differences occur in the detailed shapes of mass-production and prototype models due to the following factors:

- (1) Wood mold matching defects due to sand entering between the layers of the slice type wood mold. (Fig. 2)
- (2) Slice type wood mold wear.
- (3) Misalignment when joining the sand molds for the hydraulic circuit shape portions to the main sand mold.
- (4) Misalignment when matching the upper and lower sand molds.
- (5) Sand mold tip deformation.

These factors were investigated to propose a countermeasure to make the detailed shapes for prototypes the same as those for mass-production models, but variance in manual work could not be eliminated, so no solution was reached.

Therefore, in order to make the detailed shapes of hydraulic valve body prototypes the same as mass-production models, it was necessary to manufacture prototype models using dies.

2. Goals of Constructing a Rapid Manufacturing System

Normally, a diecast die is manufactured specially for each part type. This is the same when manufacturing prototypes using dies, so the lead time is doubled when compared to manufacturing prototypes using conventional sand molds as shown in Fig. 3. The die manufacturing period in this case accounted for 3/4 of the total manufacturing period from when the Product Design Division issued the detailed 3D model drawings until completion of the prototype as shown in Fig. 4. Furthermore, the manufacturing process for the main die required the most time within the die manufacturing period, and accounted for half of the total manufacturing period.

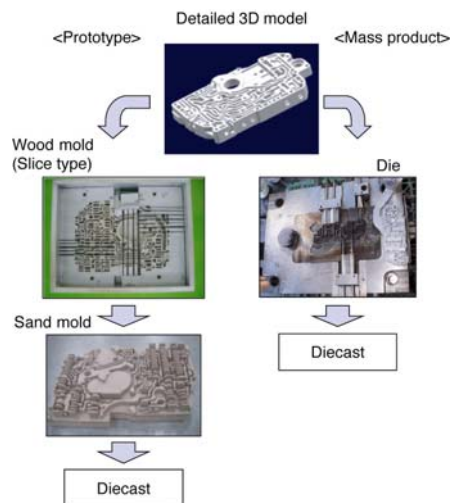


Fig. 2 Manufacturing process

The diecast manufacturing specifications are determined by performing a number of casting tries (Fig. 4) to eliminate casting defects such as casting cavities (Fig. 5), cold shut and surface folding. The various casting try processes are described below.

- (1) Die casting: The die is placed in a diecast machine at the diecast factory, the liquid metal controls such as the liquid metal speed during diecasting are set, and diecasting is performed.
- (2) Machine work: The diecast materials are machined at the machine work factory, and the worked surfaces are inspected for casting defects.
- (3) Casting plan modification: When casting defects are found, the casting plan, which consists of gates, runners, backups, air vents and other die shapes such as shown in Fig. 11, is reviewed and modified at the die factory to improve the liquid metal flow.

A single casting try consists of all three processes (1), (2) and (3) above. In addition, these processes are each performed at a separate factory, and shifting between processes requires time to transport the die and the casting try

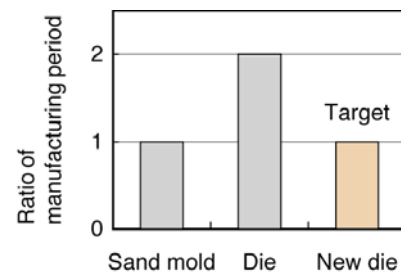


Fig. 3 Comparison of manufacturing periods

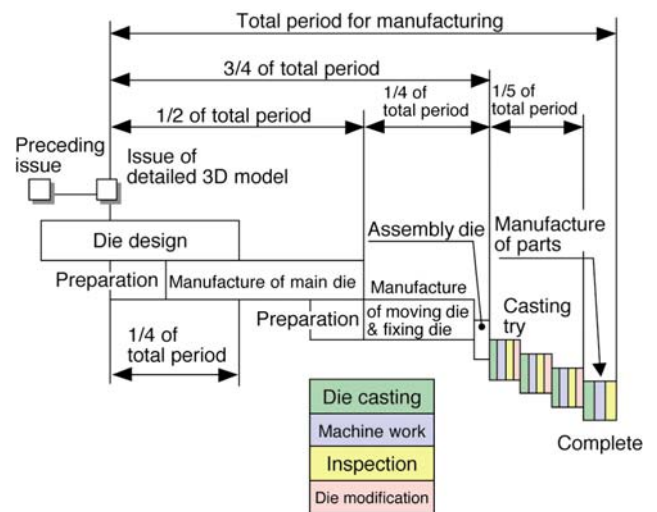


Fig. 4 Workflow of manufacture by die

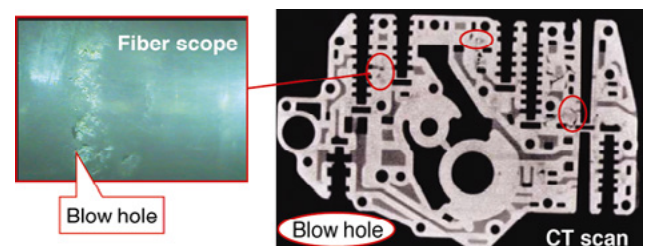


Fig. 5 Casting cavity

product to each factory. Normally around three casting tries are required to eliminate the casting defects. For these reasons, the casting try period accounted for approximately 1/5 of the total manufacturing period. (Fig. 4)

Die design starts when the preceding drawings are received from the Product Design Division. After that, the official detailed 3D model drawings are received and the details are designed. For this reason, the die design process in Fig. 4 was included in the manufacturing period, and accounted for 1/4 of the total manufacturing period.

Therefore, the following issues were raised as measures for shortening the manufacturing period using dies to the same as the manufacturing period using sand molds.

- (1) Shortening the die manufacturing period
- (2) Reducing the number of casting tries
- (3) Advancing the die design timing

3. Construction of a Rapid Manufacturing System

3.1. Shortening the Die Manufacturing Period

3.1.1. Characteristics of the hydraulic valve body die shape

The characteristics of the hydraulic valve body shape are as follows.

- (1) Hydraulic circuits are present on the front and reverse surfaces. (Fig. 6)
- (2) Holes for inserting hydraulic valves are present on the right and left sides. (Fig. 6)
- (3) An exclusive shape is used for each type of automatic transmission, but all shapes resemble each other.

In order to support these hydraulic valve body shape characteristics, the die structure consists of a moving die and a fixing die that assemble the die of the product shape to the main die, and slide pins located on the left and right sides of the moving die as shown in Fig. 7. Here as well, all die

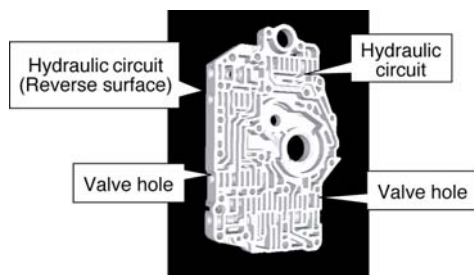


Fig. 6 Shape of hydraulic valve body

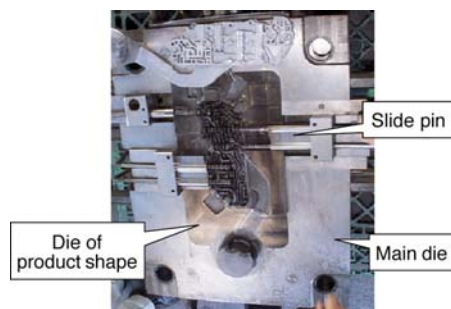


Fig. 7 Moving die

shapes resemble each other. Therefore, a study was made as to whether this similarity in die shape characteristics could be used to create standard main die and slide base units.

3.1.2. Creating standard main die units

Creating a standard main die unit entails standardizing the dimensions of the moving die and fixing die portions that assemble the die of the product shape to the main die, and the width dimensions of the moving die portion that assembles the slide base as shown in Fig. 8. In order to investigate this standardization, a survey was made of all Honda hydraulic valve body types to obtain the maximum projected area of the hydraulic valve body outline and the maximum installation width dimension of the hydraulic valve holes. These results were then used to study the creation of a standard main die unit that supports the maximum projected area of the hydraulic valve body. However, the following issues were found for the hydraulic valve body with the minimum projected area.

- (1) The wasted material area for the product shape die (Fig. 8) increased, resulting in excess material costs.
- (2) Larger diecast machines than the necessary size were required, resulting in excess facility costs.
- (3) The area of the product shape (Fig. 8) that contacts the liquid metal decreases relative to the size of the die, making it difficult for the die to reach the set temperature during the diecast process, which can easily lead to surface folding and other casting defects.

In order to resolve these issues, the standard dimensions of the product shape die were divided into two sets of dimensions for hydraulic valve bodies with large and small projected areas, and two types (large size and small size) of standard main die units were set. In addition, the slide base width dimension was set at the maximum installation width dimension of the hydraulic valve holes to support small-size and large-size main dies.

3.1.3. Creating standard slide base units

Two types of standard slide base unit were also set to support the slide base width dimensions of the standard main die units. In addition to the horizontal direction, an inclined valve hole insertion direction is also present as shown in Fig. 8. For this reason an adapter was set between the slide base and the slide pin.

3.1.4. Exclusive die parts

When manufacturing a hydraulic valve body prototype die using standard main die and slide base units, it is necessary to newly manufacture or perform additional machine work only for the following die parts which are exclusive to each hydraulic valve body type.

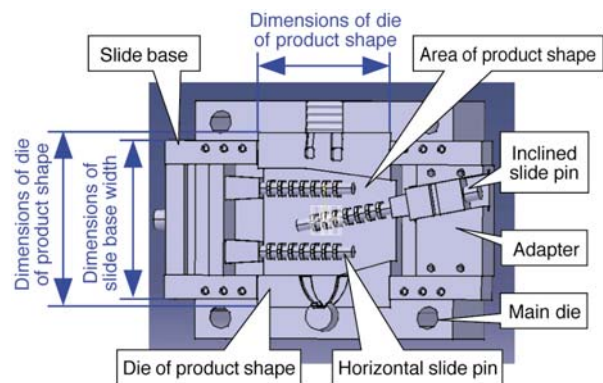


Fig. 8 Standard main die unit

- (1) Newly manufacture the product shape die (Fig. 9)
- (2) Newly manufacture the slide pins (Fig. 8)
- (3) Perform additional work as necessary for the cooling hose holes in the back block (Fig. 9)
- (4) Newly manufacture an adapter as necessary (Fig. 8)

Creating standard main die and slide base units and reducing the number of exclusive die parts reduced the die manufacturing period to 1/3 the previously required period. As a result, the total manufacturing period was halved. Fig. 10 shows an example of a hydraulic valve body prototype die manufactured using standard main die and slide base units.

3.2. Reducing the Number of Casting Tries

3.2.1. Hydraulic valve hole casting cavities

The greatest issue in terms of hydraulic valve body casting defects is that of casting cavities occurring on the inner surface of the machine-worked holes where the hydraulic valves are inserted (Fig. 5). The cause of these casting cavities is that these parts are located at deep positions from the outside of the die, so cooling is slow during the diecast process. In addition, these parts are the hydraulic valve sliding surfaces, so the quality standards for casting cavities are quite strict. Therefore, methods for improving the cooling performance and reducing the machine work allowance around the valve holes were investigated to resolve the above issue and reduce the number of casting tries.

3.2.2. Reducing the number of casting tries to one time

The following methods were investigated to reduce the number of casting tries.

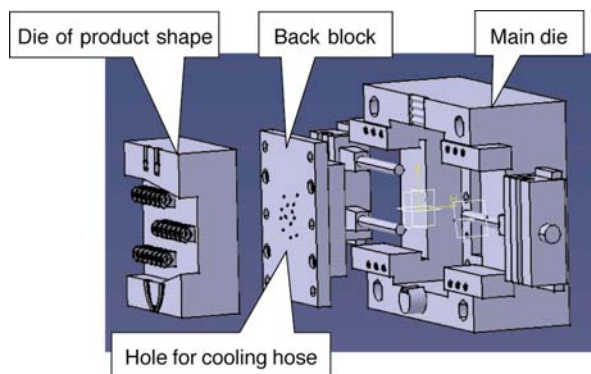


Fig. 9 Configuration of main die unit



Fig. 10 New prototype die produced by standard main die unit

(1) Application of specifications that prevent casting defects to dies Casting plans with proven results in mass-production and prototype dies were used, and the following new specifications were applied to new prototype dies in order to prevent casting defects and especially hydraulic valve hole casting cavities from occurring during the casting tries.

a. Improvement of cooling performance around the valve holes Cooling in the slide pins, line cooling and spot cooling were added as shown in Fig. 11.

b. Reduction of the machine work allowance The depth from the casting surface at which casting cavities occurred was analyzed, and the results showed a correlation between casting cavity occurrence and depth, with fewer casting cavities forming near the cooling surface. Reducing the slide pin draft angle to the low angle at which raw cast can be removed from a die was also studied as shown in Fig. 12. This reduced the machine work allowance.

These measures made it difficult for casting cavities to occur on the machine-worked surfaces of the valve holes during the casting tries.

(2) Integration of casting try processes to the diecast factory Applying specifications that prevent casting defects to dies eliminated the need for major modifications to the casting plan that were formerly performed at the die factory. This made it possible to integrate the following processes that were formerly performed at the machine work and die factories to the diecast factory. (Fig. 13)

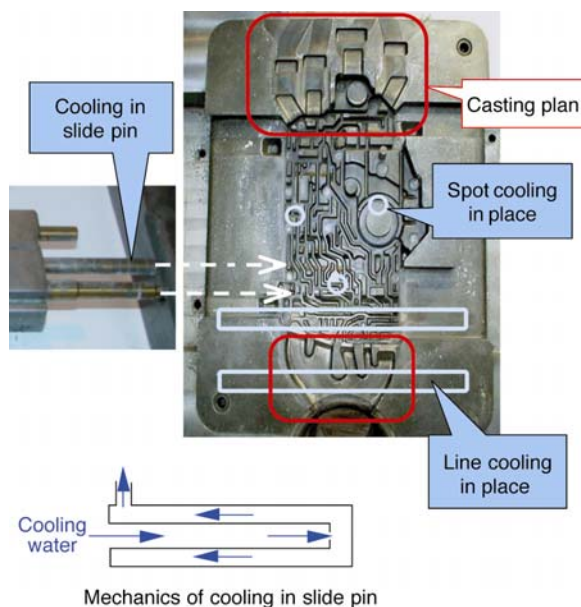


Fig. 11 Improvement of cooling capability of die

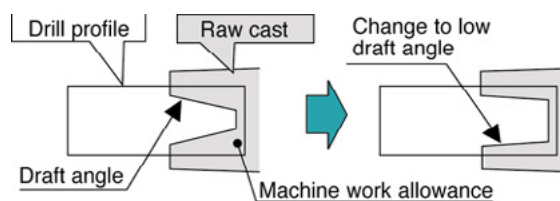


Fig. 12 Low draft angle slide pin

- (a) Machine work for valve hole and other inspections
 - (b) Casting defect inspections of the valve holes and other machine-worked surfaces
 - (c) Modification work of the casting plan
- This eliminated the need to transport dies and casting try products between factories when shifting processes.

By applying specifications that prevent casting defects to dies and integrating the casting try processes to the diecast factory, the number of casting tries could be reduced from three times to just one time. This in turn reduced 1/8 of the total manufacturing period.

3.3. Advancing the Die Design Timing

3.3.1. Utilization of product shape layout drawings

Advancing the die design start timing in the workflow shown in Fig. 4 was investigated. Die design performed in the initial stages consists of investigating the die concept and designing the material procurement and other preparation processes shown in Fig. 4. These processes are preparation for manufacturing the moving die, fixing die, slide pins and other parts (manufacture of the moving die and fixing die in Fig. 4). In order to start these die design processes, product shape layout drawings that show the hydraulic valve body profile, the number of valves and the valve positions are required. Therefore, the new workflow shown in Fig. 14 added a process for sending the layout drawings from the Product Design Division to the Die Design Division before the preceding drawings.

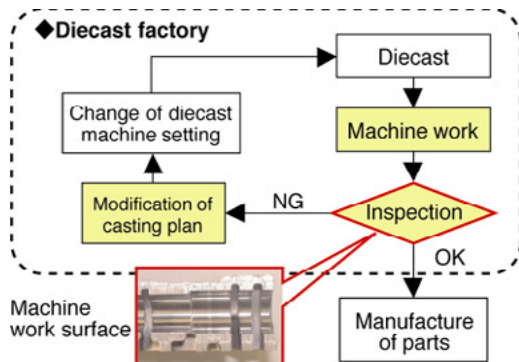


Fig. 13 Flow of casting try for one time

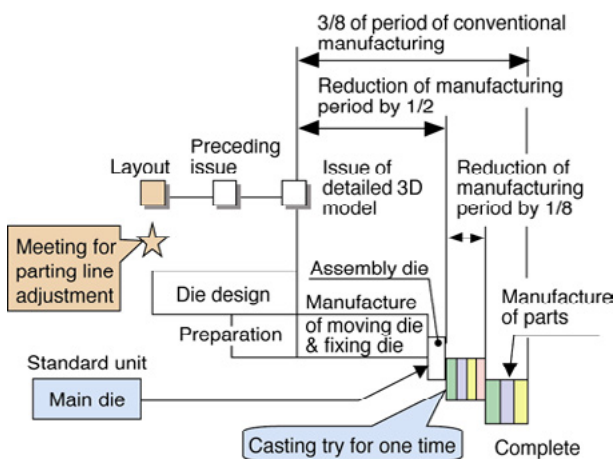


Fig. 14 Workflow of manufacture by new die

3.3.2. Setting meetings for parting line adjustment

In order to make the detailed die design, the parting lines must first be set. Therefore, the new workflow shown in Fig. 14 set a meeting to coordinate between the product designers and the die designers at the same time as the layout drawings are sent from the Product Design Division to the Die Design Division. In addition, the mass-production die designers also attend this meeting to ensure that the parting lines are the same in the mass-production and prototype dies.

As a result of these changes, the die design process was moved before the manufacturing process as shown in Fig. 14. This eliminated the need to consider the die design period as part of the manufacturing period.

4. Effects of the Rapid Manufacturing System

4.1. Shortening the Manufacturing Period

By shortening the die manufacturing period and reducing the die design period, the prototype manufacturing period using dies was shortened to half the previously required manufacturing period as shown in Fig. 14. In addition, reducing the number of casting tries further shortened the manufacturing period by 1/8, which resulted in a manufacturing period only 3/8 as long as the conventional prototype manufacturing period using dies as shown in Fig. 15. This period is also just 3/4 the conventional prototype manufacturing period using sand molds.

4.2. Equalizing the Detailed Shapes of Mass-production and Prototype Models

The detailed shapes such as the hydraulic circuit draft angle, hydraulic circuit bottom corner roundness, and surface roughness that differed between mass-production and prototype models of hydraulic valve bodies were normalized by manufacturing the prototype models using dies. In addition, having prototype and mass-production die designers coordinate the parting lines also equalized the detailed shapes of mass-production and prototype models.

5. Conclusion

The following techniques were established and the workflow was reviewed in order to manufacture prototype models of hydraulic valve bodies using dies.

- (1) Creation of standard main die and slide base units
- (2) Reducing the number of casting tries to a single time
- (3) Advancing the die design timing

These improvements have resulted in the creation of a system that can manufacture prototype models of hydraulic

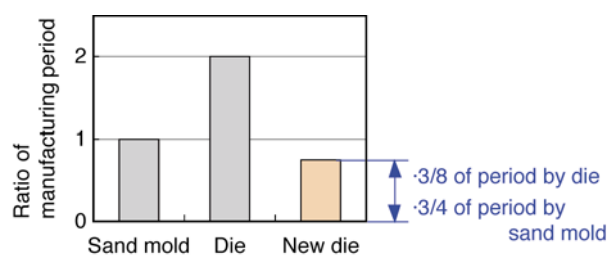


Fig. 15 Period required for manufacture by new die

valve bodies using dies in 3/4 the manufacturing period using conventional sand molds. In addition, the prototype models of hydraulic valve bodies have the same detailed shapes as mass-production models, which helps to increase the specification setting accuracy for hydraulic control in the development of automatic transmissions.

The manufacturing system presented in this report is a comprehensive technology consisting of 3D design technology capable of accurately expressing product shapes, high-speed die manufacturing technology, technology for preventing casting defects in diecast products, and workflow design technology. Construction of this type of technology is still limited to injection molding fields such as diecast and plastics. However, it is thought that comprehensive technology combining 3D design technology and manufacturing technology will also be established in other manufacturing fields such as machine working, and that this will foster workflow innovation that will spread throughout the manufacturing industry in the future.

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References

- (1) Uchida, T., Nagai, S., Koyama, S.: Practical Examples and Future Directions for CAE-Based Development for Automobile Transmission by Designers, Honda R&D Technical Review, Vol. 15, No. 1, p. 109-114 (2003)
- (2) Shimada, H., Ishihama, Y., Kubota, N., Uchida, T.: Establishment of Design Method for Transmission by 3D Media, Honda R&D Technical Review, Vol. 14, No. 2, p. 107-114 (2002)
- (3) Uchida, T., Nagai, S.: Practical Examples of Virtual Development for Automotive Transmission, JIDOSYA-GIJUTSU, Vol. 56, No. 6, p. 71-76 (2002)

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