

Establishment of Design Method for Transmission by 3D Media

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ABSTRACT

Design trials with 3D media in the product development of transmissions revealed that increased design times became an issue. Consequently, research was performed on measures to resolve this issue, including the building of a 3D design process, development of the necessary 3D CAD functions needed for such a process, establishment of 3D drawing rules, and review of the development process. Design methods were then built that utilize 3D media consistently from layout to product drawing. With use of the newly built 3D design methods, design time was reduced to the level of design using conventional 2D media or even less. This made it possible to build a highly efficient development system for use from design to manufacture.

1. Introduction

In recent years, the use of 3D media in product development has quickly become widespread among automobile developments in the hope that it will improve their efficiency. Improvements in the following are expected from the introduction of 3D media throughout the process from design to manufacture:

- (1) Improvement in analyses of design by application of 3D modeling to CAE.
- (2) Improvement in analyses of interference between neighboring parts in 3D model layout.
- (3) Analysis of the shapes of parts using rapid prototyping of real shapes.
- (4) Reduction in die production times due to use of 3D models in CAM (prototypes, mass production) for dies.

To achieve the above effects in transmission development, design with 3D media (3D design) was used in a trial design of a transmission case, a basic transmission part. The case is shown in Fig. 1. However, the test result

was anything but promising, as illustrated in the bar graph in Fig. 2: the 3D design trial took 3.3 times as much design time as it would have required while using conventional design with 2D media (2D design). The following countermeasures were established, but did not result in much reduction in design time:

- (1) Thorough re-training of designers in use of 3D design.
- (2) Improvement of 3D CAD functions.



Fig. 1 3D model of a transmission

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Accordingly, it was concluded that a fundamental review of design methods would be necessary in order to reduce the 3D design time and to establish 3D design, and this study was instituted.

2. Aim of Study

The aim of this study is to draw about appropriate methods of measures and to conceive a highly efficient design method, based on an analysis of the factors causing

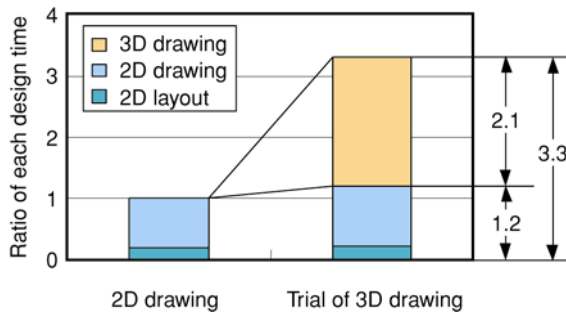


Fig. 2 Comparison of design times

the increase in design time during the 3D design trial. The target was set of reducing 3D design time below 2D design time.

3. Analysis of Factors in Increase in Design Time During the 3D Design Trial

3.1. Analysis of the Design Work

The first step in analysis of the factors increasing design time was to study the design works. These are shown in Fig. 3.

(a) 2D layout:

The transmission is laid out in 2D in accordance with the basic specifications.

(b) Creation of 2D drawings:

Product shapes are studied on the basis of the 2D layout, and 2D drawings are made.

(c) Creation of 3D drawings:

3D product shapes are studied on the basis of the 2D drawings, and 3D drawings (the formal designation for the 3D models at the drawing issuance) are made.

In the above process, the 2D design process consisting of (a) the 2D layout and (b) creation of the 2D drawings in 3D design process was assumed to be a factor increasing design time.

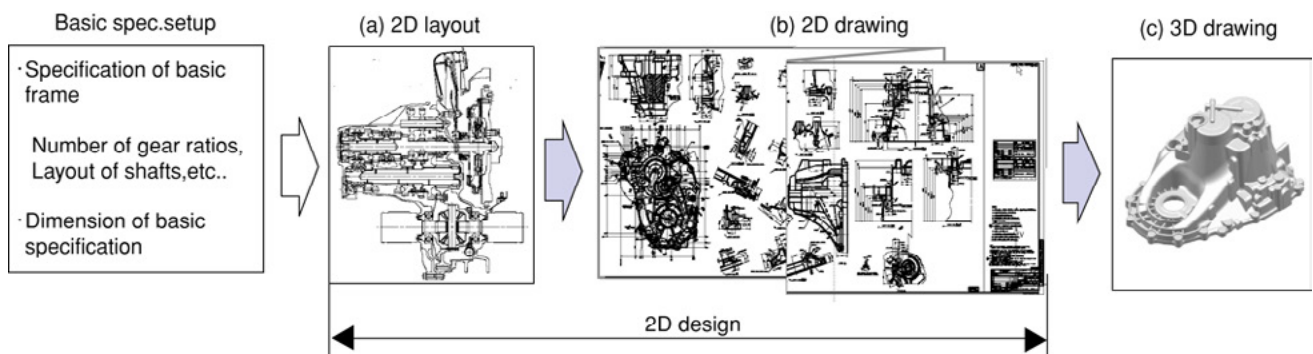


Fig. 3 Design work with the trial of 3D design

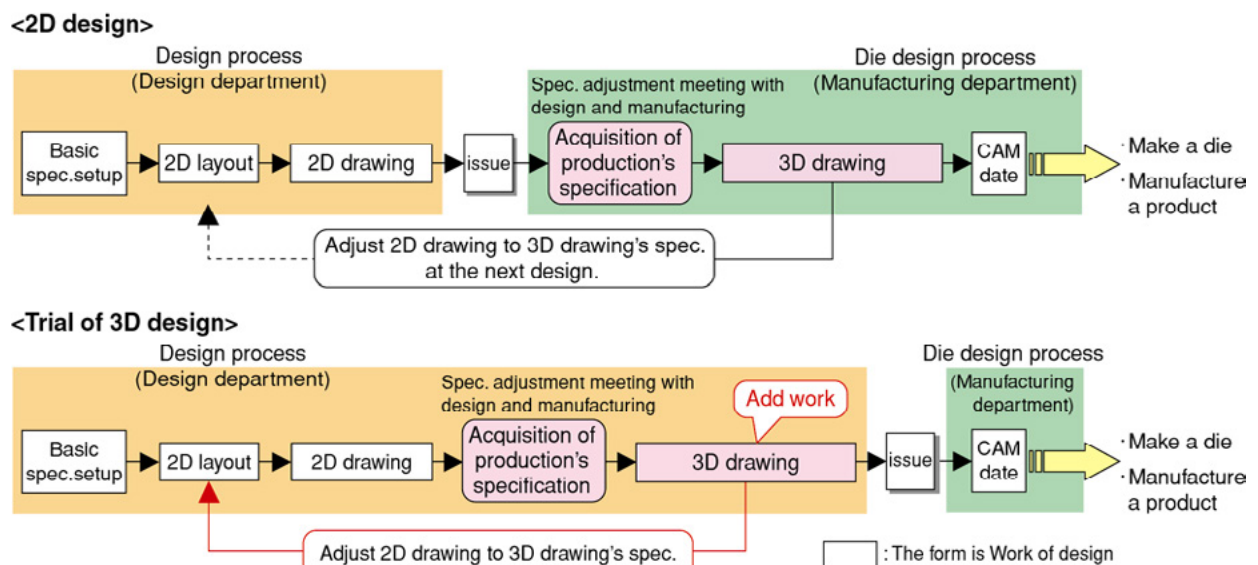


Fig. 4 Comparison of development process with 2D design, and the trial of 3D design

3.2. Factors Due to Design Process

The 3D design trial and the 2D design process were compared to examine the design time in the various design processes and works. As shown in the design process in Fig. 4, the largest factor in design time increase was the addition of 3D drawing creation to the process of 2D design. It was also noted in Fig. 2 that the design time for 3D drawing made up 2/3 in the total time of the 3D design trial.

3.3. Factors in Work of Creating 3D Drawings

3.3.1. Analysis of shares of design time for works in creation of 3D drawings

The work times necessary for the various works in 3D design of the transmission case shown in Fig. 6 were analyzed for the reasons causing 3D drawing to consume 2/3

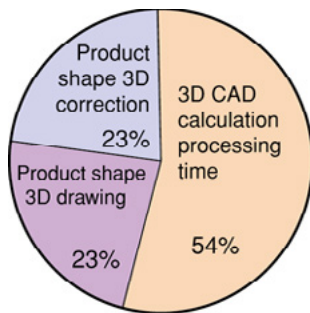


Fig. 5 Percentage of each time taken by 3D drawing work

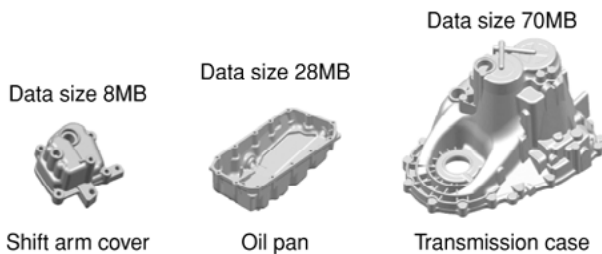


Fig. 6 Cases of various shapes

of the design time during the 3D design trial. As shown in the pie chart in Fig. 5, creation of the 3D drawings of the product shape accounted for only 23% of the work time. Other than this factor, simply waiting for the calculation processing necessary for 3D CAD (computer-aided design) accounted for about 1/2, and corrections to the product shapes in the 3D drawings, about 1/4, of the time.

3.3.2. Factors in time required for calculation processing of 3D CAD

As shown in Fig. 6, there are a variety of shapes in the transmission cases. The relation between the data size of 3D drawing and calculation processing time in 3D CAD was examined. The results are graphed in Fig. 7; it is clear that the processing time increases in what resembles a curve of 2nd-order relation with the data size of 3D drawing. The transmission case used for this factor analysis has 70 MB of data size; that is why calculation time took up 54% of 3D drawing design time.

3.3.3. Factors in time required to correct product shapes

Creation and correction of the product shape 3D drawings were the works performed in die design; analysis of these works showed that the most time-consuming portion was setup of part thickness during drawing corrections. The results of this analysis are given below, with reference to Fig. 8.

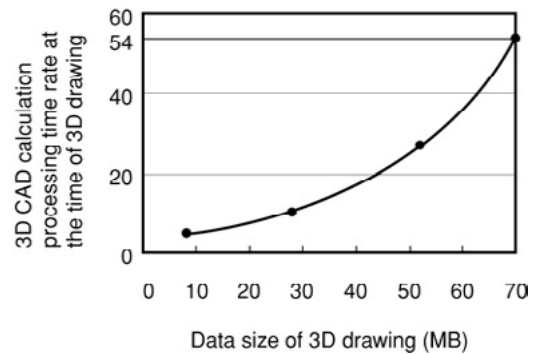


Fig. 7 Relation between data size of 3D drawing and 3D CAD calculation processing time

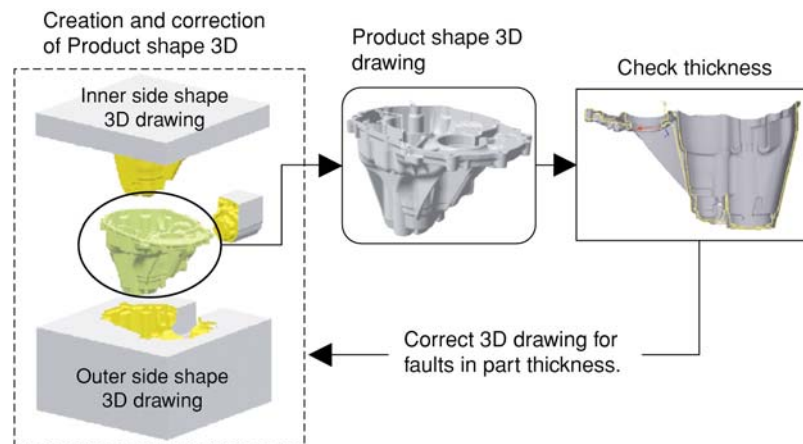


Fig. 8 “Product shape 3D drawing” and “Product shape 3D correction” work

- (1) Creation of the product shape 3D drawings
3D drawings of both the exterior shape and the interior shape of the case were made from 2D drawings. The interior shape was deleted from the exterior shape, a process resembling casting a product by die, in order to make the 3D drawing of product shape.
- (2) Correction of the product shape 3D drawings
The part thickness was verified on the product shape 3D drawings and the locations with the wrong thickness were identified. Mismatches between the exterior and interior drawings turned out to be factors in these locations, so these mistakes were corrected to complete the drawings.

3.4. Factors Due to Development Process

In order to create 3D drawings of the product shapes in the course of actual use of the die manufacturing CAM data created by the design department, it is necessary to obtain information of production's specification from the Manufacturing department such as the location and shape of the die parting line (see Fig. 9), draft angle, and corner roundness⁽¹⁾. In the development process in the trial of 3D design shown in Fig. 4, after the 2D drawings had been made, there was a specification adjustment meeting performed by the 2D drawings between Design and Manufacturing. Once the information of production's specification had been obtained, the 3D design was initiated. At the same time, it was necessary to reconcile differences in specifications between the 2D and 3D drawings during this part of the process. As a result, there was an increase in design time for creating the 2D layout and drawings, 1.2 times that required in conventional 2D design, as shown in Fig. 2. By the way, the specifications for 2D design were adapted to those of the 3D drawings of the Manufacturing department in the next design cycle, as shown in Fig. 4.

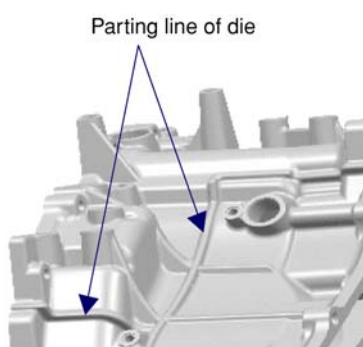


Fig. 9 Parting line of die

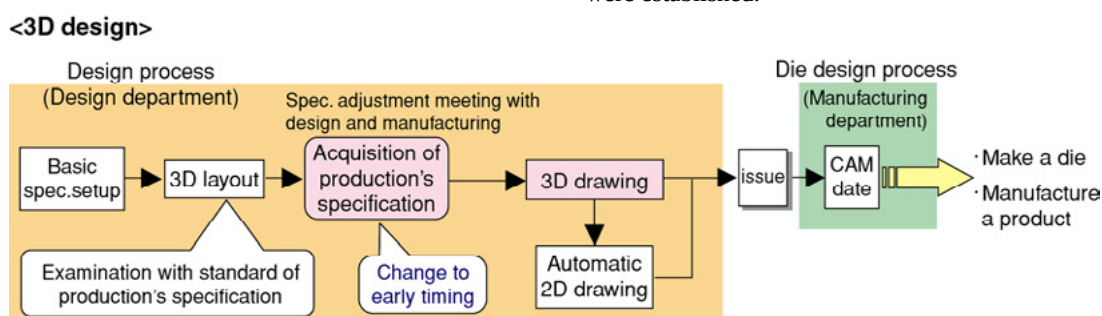


Fig. 10 Change of a development process

3.5. Summary of Factors in Increase of Design Time

As a result of this analysis of the factors affecting design time, the increase in time was attributed to the following items:

- (1) The work of creation of 3D drawings was added after 2D design.
- (2) Calculation processing time in 3D CAD accounted for about half of work time in creating 3D drawings.
- (3) Part thickness setup accounted for 1/4 of work time in creating 3D drawings.
- (4) Acquisition of production's specification information was late.

4. Methods for Reducing 3D Design Time

4.1. Issues in Establishing the Method for Reducing 3D Design Time

In consideration of the above factors in increased design time, the following issues were identified for establishing a method for reducing the design time.

- (1) Establishing a 3D design method
 - 3D design process
 - Method for creating 3D drawings from 3D layout
- (2) Development and application of 3D CAD functions
 - Development of 3D CAD functions offering convenient thickness setup
 - Reduction in 3D CAD calculation processing time by dividing 3D drawings
 - Improving functionality of automatic creation of 2D drawings from 3D drawings
- (3) Obtaining information of production's specification at the layout stage
 - Reconsidering development process

4.2. Establishment of 3D Design Method

4.2.1. 3D design process

A fundamental of the design process is that product shapes are investigated in the layout stage, then manufacturing drawings are made. Therefore, this was also a fundamental of the 3D design process, as shown in Fig. 10; layouts were made using 3D media, the shapes of the products were verified, and then, 3D drawings were created. Also, a method was established for creating 2D drawings automatically using the 3D drawings at the same time.

4.2.2. Method of creating 3D drawings from 3D layouts

In order to create 3D drawings from the 3D layouts and to furnish a convenient method for creating walls with uniform thickness in the drawing, the method and system using 3D CAD functionality shown in Fig. 11 and described below were established.

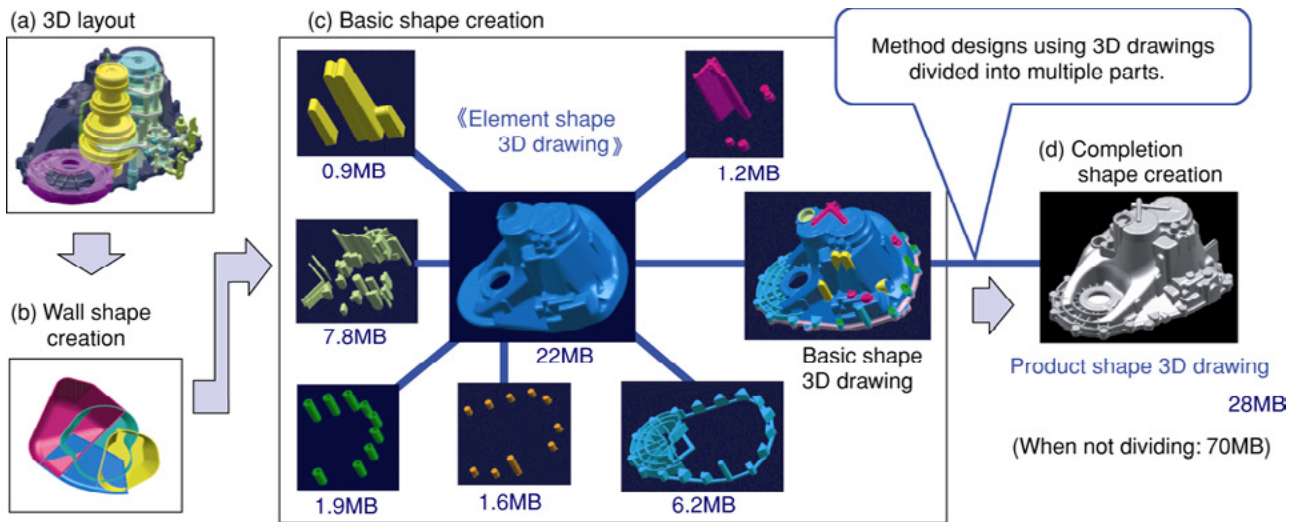


Fig. 11 From the 3D layout to the 3D drawing method

- (a) 3D layout:
A 3D layout of the transmission case was made based on the basic specifications.
- (b) Creating wall shape:
Using the 3D layout, the wall shape was created by indicating the wall thickness, considering clearances from inner components. (a 'shell' functionality was developed).
- (c) Creating the basic shape:
Bosses and other features were added to the wall shape, then, unnecessary portions were removed, and a 3D drawing of the basic shape was made (a 'trim' functionality was developed).
- (d) Creating the final shape:
Corner radii (fillets) were added to the basic shape to complete design of the product.

4.3. Development and Application of 3D CAD Functionalities

4.3.1. Development of 3D CAD functionalities offering easy creation of uniform thickness wall

The new 3D CAD functionalities described below were

developed for creating the 3D drawings from the 3D layouts. The functionalities are described in Fig. 12.

(1) 'Shell' function

A clearance is defined from the outer shape of internal components. Then, the wall thickness is indicated, instantly creating a wall shape with a uniform thickness.

(2) 'Trim' function

Unnecessary portions of bosses added to a wall are selected and deleted.

These 3D CAD functionalities were requested to a software maker and developed in a joint effort; a method and system for turning 3D layouts into 3D drawings and for the easy creation of uniform thickness walls were established.

4.3.2. Reduction in 3D CAD calculation processing time by division of drawings

In order to reduce the amount of 3D drawing data and thereby reduce calculation processing time, each drawing was divided into multiple, independent 3D drawings. The advantage offered by this division function is explained below with reference to Fig. 11. When a 3D drawing occupying 70 MB was divided into seven element- shape 3D drawings and a product-shape 3D drawing, the total data size was reduced to 28 MB. As a result, the load on the computer posed by calculation processing was relieved; as shown in

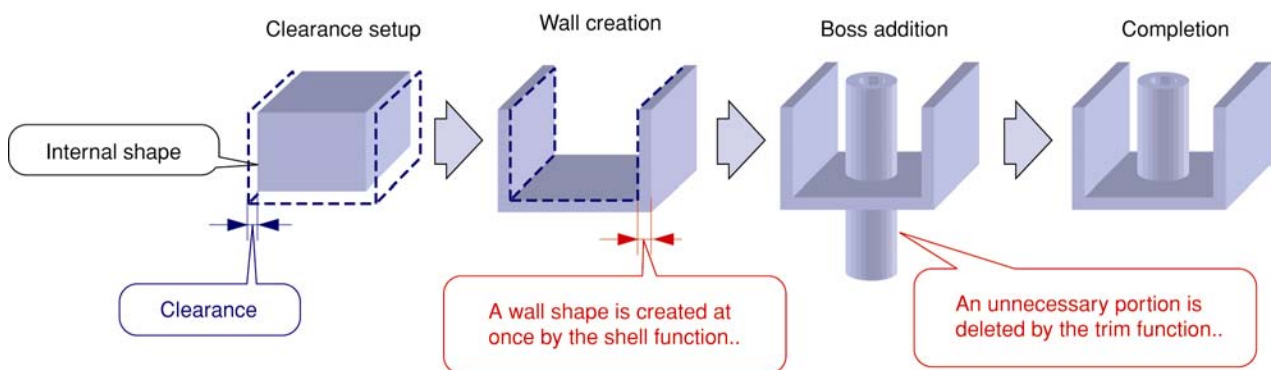


Fig. 12 Shell function and trim function

Fig. 13, calculation processing time was cut from 54% of the total design time to 10%.

4.3.3. Improvement of automatic functionalities to create 2D drawings from 3D drawings

It became necessary to expand 3D CAD function to improve efficiency of creation of 2D drawings. As shown in Fig. 14, the software included automatic functions to create a 2D view from a 3D drawing and to create sectional views, but these functions were somewhat prone to the errors shown in Fig. 15; one line was duplicated, while another is only partially shown. Authors and a 3D CAD software maker cooperated in correcting the errors for these functions, resulting in correctly working functions and a greatly reduced labor time for creating the 2D drawings from the 3D drawings.

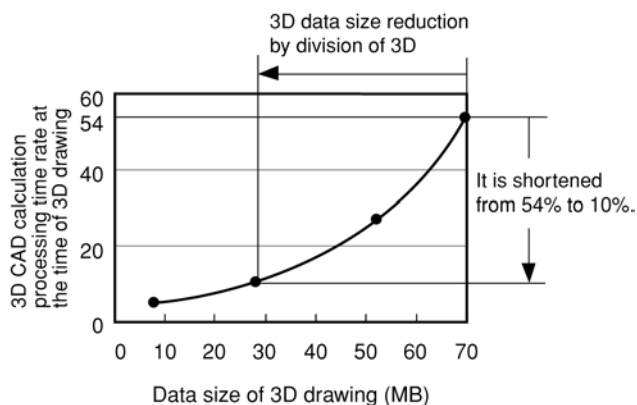


Fig. 13 The shortening effect on 3D CAD calculation processing time

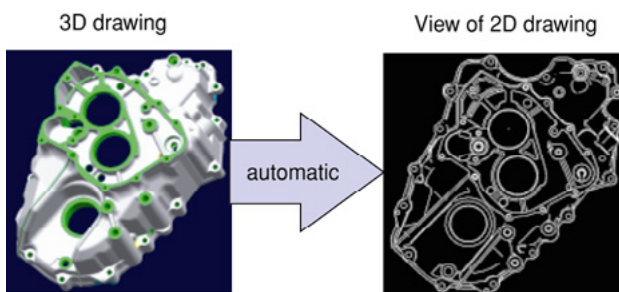


Fig. 14 Automatic drawing of 2D view

4.4. Obtaining Information of Production's Specification at the Layout Stage

As shown in Fig. 10, the development process was revised, with moving forward the specification adjustment

meeting between the Design and Manufacturing departments, to enable publication of information of production's specification during the layout stage. This enabled the Design and Manufacturing departments to cooperate in the following issues:

- (1) Specification adjustment meeting between Design and Manufacturing should be held with already-completed 3D layouts.
- (2) Listing of production's specification action items that should be arranged.
- (3) Standardize those items in (2) which can be standardized and apply them in the Design stage before the specification adjustment meeting.
- (4) Train all technical staff in charge of production's specification to operate 3D CAD software.
- (5) Installing 3D CAD in all departments in charge of examinations over production's specifications.

As a result of these measures, although it was necessary to review the layouts for products whose shapes would be affected by information of production's specification, they obtained drawing corrections after layout preparation, including those necessary to reconcile 2D drawings with 3D drawings (see Figs. 4, 10). The advance examinations in the Design department over production's specifications also contributed to reducing the labor time on the layouts.

4.5. Increasing Efficiency of Manufacturing Department by Revising the Development Process

Owing to revision of the Development process from Design through Manufacturing, it has taken a firm hold to create 3D drawings in the Design department. As a result, labor time for creating drawing in the Manufacturing department was reduced. Furthermore, labor time spent on consultations in Manufacturing was reduced as well since the standardized production's specifications were examined in advance in the Design department.

4.6. Establishment of 3D Drawing Forms

3D drawing forms were established as a part of the institution of 3D design methods. Transmission case drawings require specifications from its manufacturing methods to indicate on material shape and to machining dimensions. Since 3D CAD has no functions to indicate machining dimensions, tolerances, geometric tolerances, or finish instructions, in 3D drawing, it was decided to indicate these on the 2D drawings. As shown in Fig. 16, drawing forms which combines 2D drawing and 3D drawing with material shape definition were established, designated as "3D drawing + 2D drawing" (see Table 1). The labor time for preparation of 2D drawings in the "3D drawing + 2D drawing" was reduced by the time it had previously taken to write the instructions for the shape of the material.

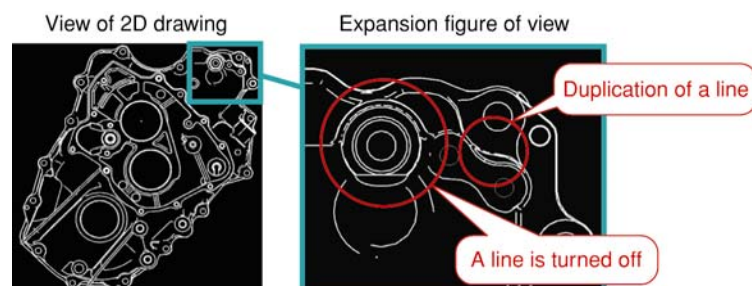


Fig. 15 Shortcomings in function of automatic 2D drawing

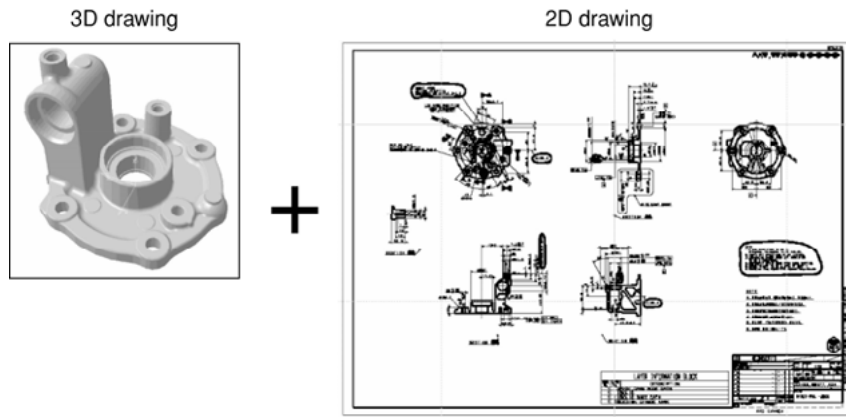


Fig. 16 3D drawing + 2D drawing

Table 1 Drawing rule of “3D drawing + 2D drawing”

Item	3D drawing + 2D drawing		Conventional 2D drawing
	3D drawing	2D drawing	
Material surface dimension	○		○
Machine work dimension		○	○
Tolerance, Geometrical tolerance		○	○
Finish specification		○	○
NOTE	Material, Heat treatment, Pressure leakage standard, hardness, etc..	○	○

4.7. Summary of Methods for Reducing 3D Design Time

The following methods were established for reducing the design time in 3D design:

- (1) The process shown in Fig. 17, where 3D drawings are made from 3D layouts; then, 2D drawings are automatically made from 3D drawings.
- (2) Functions to create 3D drawings from 3D layouts and to easily create wall with uniform thickness (shell and trim functions).
- (3) Division of 3D drawings in order to reduce their data size, shortening the calculation processing time for 3D

CAD.

- (4) High-efficiency 2D drawing method using automatic creation function from 3D drawings.
- (5) Obtaining production's specification information at the layout stage (revising the development process).
- (6) Establishment of drawing forms for 3D drawings.

The labor time for the works involved in creation of design drawings with the newly created 3D design method takes about 1/4 the time required in creation of 3D drawings and about 1/3 the time required in layout and 2D drawings compared to the 3D design trial program. As a result, as shown in Fig. 18, the design time with 3D design method is reduced less than that of the 2D design method, which was our goal.

5. Summary

The primary factor of increasing design time during the 3D design trial was the simplistic creation of 3D drawings after 2D design. In order to solve this issue, the transmission design method was fundamentally revised and the following procedure was established for application of 3D media throughout the design course:

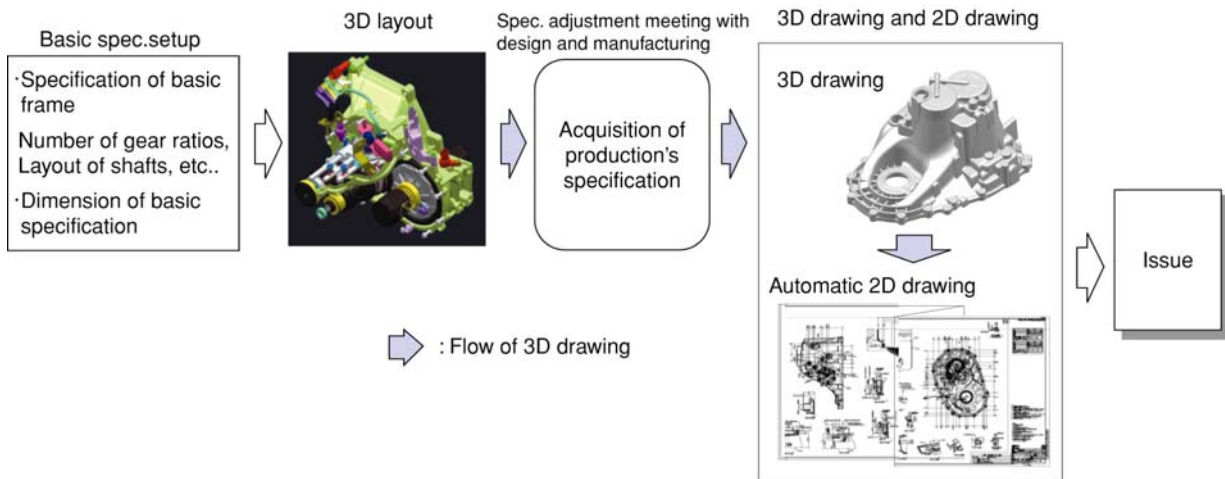


Fig. 17 Design method for transmission by 3D media

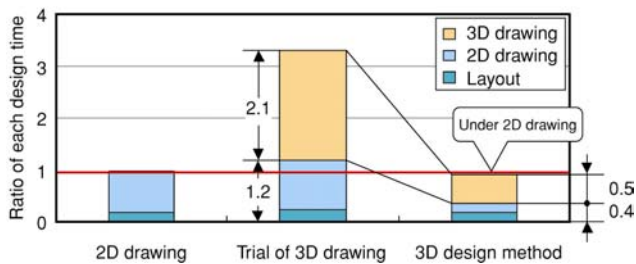


Fig. 18 Effect of the 3D design method

- (1) A design process of creating 3D drawings from 3D layouts.
- (2) Development of 3D CAD functions for establishing the design process.
- (3) Establishment of 3D drawing forms.

The design time under the newly established 3D design method requires less time than that under the 2D design method. A large improvement in design efficiency was realized.

In addition, due to the changeover to a 3D design development process, the work of creation of 3D drawings, which used to be done by the Manufacturing department, has been passed back to the Design department, without labor cost. This has resulted in a highly efficient development system, from Design through Manufacturing.

The authors extend their deepest appreciation to Dassault Systemes, which added and upgraded the 3D CAD functionalities necessary to create this new 3D media-based design method.

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