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Essence and Effective Use of Three-Dimensional (3D) Machine Design

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Abstract

Although the capability for which a company asks a design technique person is various and the degree of expectation (ability requirement) changes with a time, the request to the three-dimensional design capability to include the improvement in the quality of a design and the viewpoint of increase in efficiency to three-dimensional-CAD practical use capability in the near future from the present age is large. In this study, we examine the essential knowledge of general mechanical engineering required for three-dimensional (3D) machine design and discuss the skill improvement of machine designers through the acquisition of a shape modeling technique using 3D computer-aided design (CAD) (design = determination of a shape = determination of blurred parts and their appropriate shapes). We also examine and analyze the actual design processes and discuss particular cases with practical training methods.

Keywords : mechanical engineering, three-dimensional (3D) machine design, computer-aided design, actual design processes, practical training methods

1. Introduction

3D CAD has been established as a standard; however, a significant change is experienced at the actual design sites.

The change is a result of the insufficient recognition of the fact that the ability required for designing is different from that required for drawing. Conventionally, drawing carried out by hand using the JIS drawing method has been mainly performed, and the drawing ability required to convey the design intent is significant for designers.

Even two-dimensional CAD, only the drawing that has been carried out by hand is replaced by the computer; therefore, the work related to drawing while imaging the orthographic projection (projection method) is essentially similar to that required for hand drawing. Improvement of design efficiency by the practical application of 3D designing has been promoted. This holds true for designers with extensive work experience. For designers with insufficient experience, it is considered that the purpose and concept of 3D CAD have not yet been established.

It is necessary for companies to continuously create innovative and original products that cannot be copied by third parties in order to survive in the 21st century, in which high-quality and rapidly producible products are desired. The most important task in realizing this is strategic training to produce truly experienced design engineers.

To effectively carry out three-dimensional (3D) machine design using 3D computer-aided design (CAD), it is necessary to understand the features of CAD and make full use of its functions.

We provided training for new employees with degrees in mechanical engineering so that they could acquire essential knowledge of machine design, offered courses on 3D machine design using practical design tasks, and obtained the desired learning results.

2. Design Occupanies at Artner Co., LTD and Outline of Training System

Figure 1 shows the outline of design roles at Artner Co., Ltd.

Designers who are highly motivated, can work independently, and can produce original and creative designs are required. Three -dimensional computer-aided design is a mere method for verifying designs, and we must consider how design specifications should be quantified to realize the design target and what is essential for the realization of the design target. Moreover, it is also important to feel the joys and pains of designing by working continuously on designs.

Figure 2 shows the results of the questionnaire on training completed by employees of the company and its customers.

3. 3D CAD and Design Methods

Although 3D CAD is used in designing, 3D CAD appears to require a longer time than the conventionally used 2D CAD. The use of 3D CAD certainly reduces the drawing time compared with the use of drawing machines and eases the design process. However, it is difficult to clarify whether the designing time can be markedly reduced using 3D CAD.

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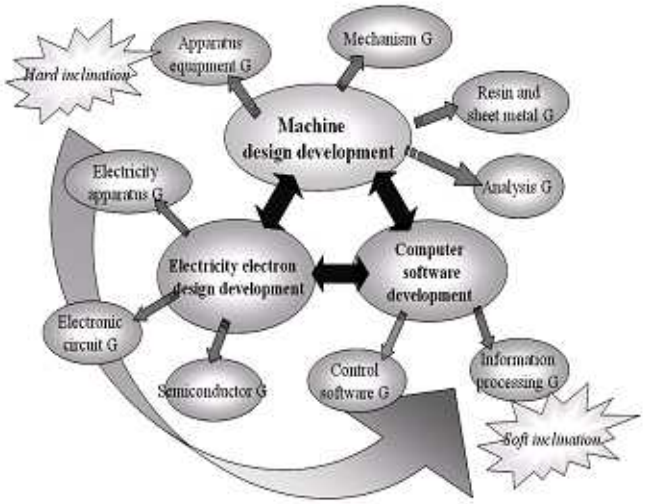

Fig.1 Outline of design roles at Artner Co., Ltd.

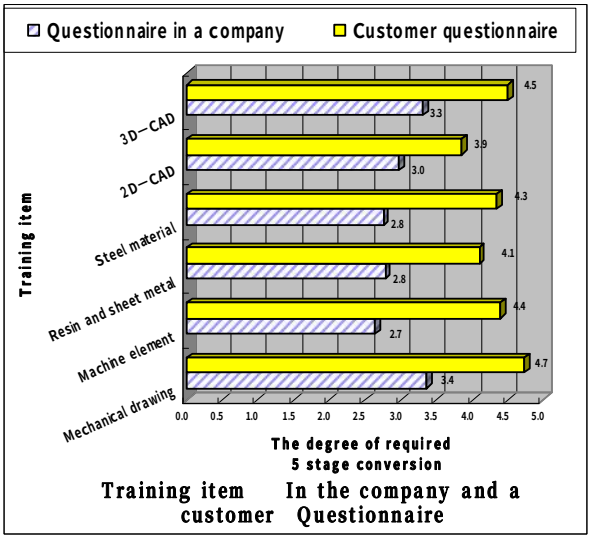

Fig.2 Company and its customers

3.1 Difficulties in 3D CAD

In general, complexities of 3D CAD operation and modeling appear to make 3D machine design difficult. However, even if these problems were overcome, designers would next find that the design process involved in the 3D machine design itself is difficult.

Here, we discuss whether the operation of 3D CAD and modeling are difficult and whether the process of 3D machine design is difficult.

(1) Such difficulties depend on whether 3D CAD is used only for modeling or used also for improving the efficiency of machine design.
(2) If 3D CAD is used only for modeling, it requires a longer time than 2D CAD and there are many items to learn. Hence, the designing time is not expected to decrease.
(3) Difficulties also greatly depends on the capabilities of individual designers. Rapid progress is observed for designers who have conventionally used 2D CAD and are eager to identify problems and improve their own work using 3D CAD and those who are familiar with the process of manufacturing machine parts.

3.2 Purpose of using 3D CAD

There are two reasons behind the apprehension that designers encounter when attempting to carry out 3D machine design for the first time.

(1) Difficulties attributable to CAD operation and modeling
(2) Uncertainty in how to proceed with machine design even after modeling is completed

When only modeling is focused on, designers draw a sketch of a product on the basis of a three-view drawing, then construct a 3D model. This is based on the assumption that cross-sectional shapes of the product have already been visualized in the brain. Therefore, the designers are only required to model the product following the visualized shapes using 3D CAD.

Everyone is likely to follow such procedure immediately after undergoing the CAD operation training. However, designers may sit stumped in front of the CAD display, not knowing how to proceed when trying to design the parts of mechanical structures. Thus, the design of a product starts by visualizing its cross-sectional shapes.

Modeling a 3D shape at the beginning of visualization is equal to converting the imagined shape into 3D data. Whether a part is complicated or not, the same basic design procedure of visualizing unclear parts and modeling only the clear parts is followed. Namely, once essential design techniques have been mastered, designers can carry out machine design even though they cannot model complicated shapes.

4. Examination of Essential Knowledge for 3D Machine Design

In discussing when and how understanding of the culture of manufacturing is acquired, the concept of interest is considered important; for example, one may be interested in various phenomena and in clarifying their mechanisms. In addition, the cycle of having an interest, finding a new fact, and experiencing the resulting satisfaction is thought to be a psychological power that guides the inquiring mind when pursuing the essence of a phenomenon. On seeing a bolt, one may want to remove it. On seeing a machine, one may want to disassemble it. The possession of such simple

impulses is one of the most essential qualities in the initial stage of becoming a design engineer.

Essential engineering knowledge, a flexible imagination, and creativity are characteristics of excellent design engineers. One of the problems that trainees encounter when they have just started designing is related to matters requiring the experience and sense of balance that come naturally to experienced designers, but which trainee designers do not possess.

Thus, there are many issues that cannot be determined from design standards or from theoretical calculations during the machine design process. Instructors try to give simple answers to questions on such issues by using examples. If trainees say "I see," they are considered to have absorbed a new concept related to the matter.

4.1 Capability of reading drawings

Recently, it has been reported that some young designers are unable to read drawings. Artner Co., Ltd. has also received comments from our customers that young designers have a low skill in reading drawings. Therefore, we shortened the technical training program by 5% and introduced a task to develop freehand drawing. In this task, trainees must imagine a shape and carry out 3D modeling in the brain. We are trying to help trainees clarify the unclear parts of drawings and to read pictures and drawings by providing a program of tasks at which trainees are yet unskilled.

4.2 Standpoint of machine design

It is necessary to develop the skills of inventing and designing unknown objects, exploring methods of their manufacture, and realizing the design into actual objects. In other words, designers should draw a sketch that expresses the design details and structure of a product in the initial stage of design. They should improve the sketch by constantly considering the customers' demands and exploring ways to meet them. This is the standpoint of design, and the process until the completion of the sketch can be considered to account for 60% of the entire design process.

4.3 Handover of techniques

The continuous passing down of intangible techniques obtained through experience is considered to be indispensable for developing our company, which specializes in design technologies.

However, because of the current outsourcing trend, in the flow of daily business, the skills of individual designers are not shared and the fountain of such design-related information, which would be a great asset to our company, may be lost and not passed down to the next generation, although individual engineers may cultivate their skills in their own division.

Therefore, it is necessary to establish a sustainable management system that enables the positive and intensive collection of design-related information. Since around 1997, Artner has tackled this issue and has established a practical plan for achieving the system.

5. Cases with Practical Training Methods

In the workplaces of automobile and home electric appliance divisions to which trainees are assigned, the design of parts is generally carried out using 3D CAD.

Therefore, we established a design environment in which the mechanical training sheets developed by us can be effectively used and the interference and operation of designed parts can be checked by 3D CAD assembly.

5.1 Improving spatial recognition ability

The spatial recognition ability of some recent young designers is low, although they have reasonable skill in 3D CAD operation. To increase spatial recognition ability, we provide training on hand drawing on A4 paper every morning during the training period as follows.

(1) Visualize a machine part and draw two 3D views of the part freehand in the margin.
(2) Draw a 2D view freehand by the third angle projection method on the basis of the above 3D views.
(3) Draw a 3D view freehand on the basis of the above 2D view.
(4) Develop parts drawings on the basis of a 2D exploded view.

5.2 Presenting design examples of ambiguous parts

(1) In actual design, customers' demands are frequently satisfied by determining appropriate shapes of parts. Therefore, we present examples of ingenious designs of shapes and instruct trainees to use them for reference.
(2) During the 3D design of machines, the shapes of ambiguous parts must be determined by the designers themselves to progress with the design process. We clearly specify the key factors of shapes that satisfy the design conditions and also present actual design examples of determining shapes to improve the trainees' design skills.

5.3 Design techniques and know-how

Practical training in which trainees can see, touch, and realize actual objects is necessary. To this end, we provide

training with our original materials, such as mechanical training sheets and a library of machine components.

Not only virtual but also actual objects are used to understand their properties, such as weight, smoothness, hardness, motion, and structure. In addition, practical training using know-how required on site enables the fostering of human resources with immediate adaptability.

3D CAD is merely one of the technical means of creating shapes. To accomplish smooth 3D machine design, all of the following steps should be taken in order.

(1) Learn the minimum necessary CAD commands for design.
(2) Learn the procedure for 3D modeling.
(3) Design an object in a style similar to that established for 2D CAD design.
(4) Examine a design style that can make the best use of the 3D CAD functions with a minimal level of knowledge.
(5) Use 3D CAD in practice.
(6) After gaining experience in the use of 3D CAD, devise a way of designing that improves the production efficiency using the CAD functions.

The key to 3D CAD design is to efficiently carry out steps (1)-(5).

5.4 Results of computer-aided engineering (CAE) depend on experience and sense.

Because there are many varied design targets, it is difficult to ensure the quality of analysis results unless a modeling technique is standardized to some extent. Moreover, at present, there is an evident difference between designers in their design quality depending on their skill, even when the same tool is used. This can be regarded as a problem of training. In other words, designers are required not only to learn how to use CAE but also to have the ability to make decisions in order to accurately examine the behavior of objects, which is supported by experience and a feeling for design (which can be gained by experiments and theoretical consideration).

6. Establishment of Business Processes Suitable for 3D Design

The process of passing down techniques from generation to generation and the accumulation of permanent information cannot be completed within a single section of a company. Designers and engineers should support each other in their work, and senior engineers should listen to and encourage junior engineers. Such cooperation forms the heart of an ideal technical support system.

3D design is expected to become increasingly popular in the future. To maximize the effects of 3D design, it is necessary to establish business processes suitable for 3D design and to train designers.

Furthermore, although we begin using 3D CAD, two-dimensional drawings are still necessary. The drawing tasks such as inputting attribute information still remain. The work of producing orthographic projection can be carried out using 3D CAD; however, the work that is dependent on the designer's qualifications, such as functional and effective designing, should be carried out and structured by designers according to their judgment.

7. Conclusions

One of the reasons behind the slow spread of 3D CAD is the temporary decrease in the pace of designing, because many parts are reused during machine designing and this requires a huge amount of paper drawings. However, with the strengthening of the competitiveness of Japanese manufacturing businesses in the international market, competition has increased; therefore, the strengthening of overseas production sites, the shortening of product life cycles, and the production of various products in small lots have been carried out. Because Japan came to play the main role in planning and designing, Japanese companies inevitably started to use 3D CAD.

Design, which is the origin of all industries, is a world of devising and creating, in which new styles and the innovation of techniques are constantly demanded. Constant effort and diligent study are needed for designers to create designs that can appropriately meet the demands of the present age.

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