DESIGN CONCEPTION ABILITY OF MECHANICAL ENGINEERS USING THREE-DIMENSIONAL COMPUTER-AIDED DESIGN (3D CAD)

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ABSTRACT: The process of forming an idea is commonly recognized by designers as the essence of design. There is no telling whether a design idea will be a success because it is still intangible at the time of design. Designers are constantly attempting to derive design solutions in as logical a manner as possible, although there are complexities and difficulties owing to the fact that demonstrating the significance and validity of an idea is impossible. In this paper, the following two items targeting mechanical engineers are discussed. 1) Example of training, its effectiveness, and standard design technology. 2) Designing skill using 3D CAD. In the future, we will examine the introduction of education based on hands-on experience and workshops on the assembly and disassembly of actual products, with the aim of further improving design concept formation abilities.

Keywords: Graphics Education, Design Engineering Theory, Three-Dimensional Design CAD, Basic and Practical Training Programs.

1. INTRODUCTION

Recently, product designers have been exposed to a flood of new information. Owing to this huge amount of information, it has become more difficult for them to select an appropriate topics and form new ideas for novel product designs. Moreover, engineering technology for developing, improving, and renovating various types of machinery and apparatus have been accumulated; however, no system of organizing experiences involving trial and error and acquired expertise has been established yet. Here, we discuss the importance and difficulties in forming new ideas in the design of novel devices. The process of forming an idea (expression, cogitation, or conceiving of an idea, or having inspiration) is commonly recognized by designers as the essence of design. There is no telling whether a design idea will be a success because it is still intangible at the time of design. Designers are constantly attempting to derive design solutions in as logical a manner as possible, although there are complexities and difficulties owing to the fact that demonstrating the significance and validity of an idea is impossible. Although it is impossible to predict the future accurately, designers are required to form ideas in their daily work as if they are able to do so. Our company provides basic and practical training programs for the purpose of improving design skills. In this paper, the following two items targeting mechanical engineers are discussed.

(1) Example of training, its effectiveness, and standard design technology.
(2) Designing skill using 3D CAD.

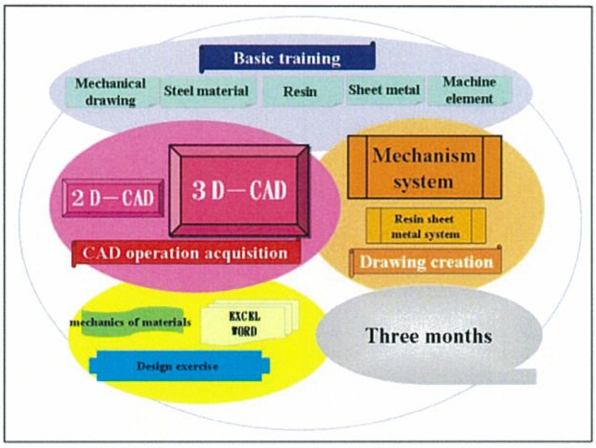
2. EXAMPLES OF TRAINING, ITS EFFECTIVENESS, AND STANDARD DESIGN TECHNIQUSE

2.1 Outline of basic training

The curriculum of specialized basic training is organized on the basis of customer surveys to accommodate customer needs and revised annually. The works of mechanical engineers are mainly classified into the following four types based on resin sheets, mechanisms, equipment, and analysis, although they are actually engaged in more varied types of work. Table 1 shows an outline of training given to new employees.

Basic training consists of classroom lectures on five subjects and instructions in 2-D and 3-D CAD operation. Applied training includes more practical design courses. The training period is approximately three months. By following this curriculum, new employees can acquire the main knowledge necessary for machine design and learn the procedures involved in developing a drawing and designing.

Table 1 : An outline of training given to new employees.



In this era when rationalization and numerical evaluation are emphasized, rapid and effective training is expected and people tend to evaluate the skills of trainees quantitatively. However, we do not consider that trainees who obtain high evaluation scores always have high levels of design skill. We cannot use a single criterion to evaluate trainees who have received training in different environments and thereby have different personalities and cultures.

2.2 Example of specialized training and its effectiveness

To evaluate the performance of trainees who have received the basic training, we carry out tests on the contents of classroom lectures and require trainees to score at least 70%. In the test of drawing, the scores for information missing in the drawing, namely, missing shapes, dimensions, and finish marks, are deducted from the maximum possible score, and trainees who score at least 70% pass the test. However, to pass the course, trainees are required to submit a corrected perfect drawing. Unexpectedly, however, some trainees who pass the test on machine drawing with a high score ask basic questions on other aspects of design.

The most frequently asked questions concern machine drawing, followed by questions on calculation exercises, CAD operation, and molding methods. The following questions on machine drawing are frequently asked. (1) How are the dimensions of resin sheet products and mechanical parts determined? Trainees do not understand whether the dimensions are determined? from the center of the product/part or from a reference plane, and they do not know their proper use. (2) How are fit tolerance and surface roughness calculated and used properly? There is no answer that can satisfy all requirements for tolerance because it depends on the experience of individual designers, the standards of each company, and the practices at the design and manufacturing sites. (3) Where is the reference plane and how is a cross-sectional view drawn? (4) What do the numbers assigned to mechanical parts in the table of a drawing mean? Are the parts listed in order of assembly?

2.3 Fundamental knowledge for design

1. Culture of design

In discussing when and how the culture of manufacturing is acquired, the concept of interest is considered important; for example, one is interested in various phenomena and in unraveling their mechanism. In addition, the cycle of having an interest, finding a new fact, and experiencing the resulting satisfaction is thought to be a soft power that guides the inquiring mind when pursuing the essence of a phenomenon. When seeing a bolt, one may want to remove it. When seeing a machine, one may want to disassemble it. The possession of such simple impulses is one of the most essential capabilities in the initial stage of becoming a design engineer.

2. Fundamental knowledge for design

Fundamental engineering knowledge, a flexible imagination, and creativity are needed to foster excellent design engineers.

One of the problems that trainees encounter when they have just started designing concerns matters requiring the experience and sense of balance that are common sense to designers, but which trainee designers do not possess.

In addition, when given a drawing assignment, trainees try to draw a clear and accurate drawing using a scale, which takes a long time. However, the most important purpose of drawing is to enable the manufacture of a product. Therefore, it is necessary to quickly draw an accurate picture with the minimum necessary information even when it is drawn freehand. In practical scenarios, engineers must always be aware of manufacturing deadlines, operation hours, and cost. Considering these factors, an instructor in change of training demonstrates drawing so that trainees can acquire a sense of cost by observing the speed of the instructor's operation.

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

3. Handover of techniques

We consider the following daily actions to be the ideal way of passing down techniques. People who experience the excitement of design through their work share their experiences with the younger generation. Young engineers persevere in improving their skills with the assistance of senior engineers until they fully realize the appeal of design. Through the integration of practical experience and enterprising sense, traditional techniques are passed down from generation to generation.

The continuous passing down of such intangible techniques obtained through experience is considered to be indispensable for developing our company, which specializes in design techniques. However, as a result of outsourcing, in the flow of daily business we may miss the roles of individual designers in exhibiting their skills, the stock of design-related information, which is part of the assets of our company, and passing down of such information to the next generation, although individual engineers can cultivate 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, our company has tackled this issue and has established a practical system for achieving it.

3. DESIGN SKILL USING 3D CAD

3.1 3D CAD system

3D CAD design systems have been developed and are increasingly applied to mechanical engineering and other practical fields. In 3D CAD, the designer's 3D image of an object is defined as a virtual 3D object in a computer. Design information is managed as 3D digital information in an integrated fashion, and this information can be revised in arbitrary directions. Most 3D CAD systems include an interface that comprises three views, i.e., a front view, a top view, and a side view, and the inputting and editing of any of these views are handled as standardized operations applied to the 3D design information, which is uniformly managed. Also, design data can be used for computer-aided engineering (CAE) and computer-aided manufacturing (CAM) because of their format as 3D digital information, and therefore, a consistent system from design to manufacturing can be realized.

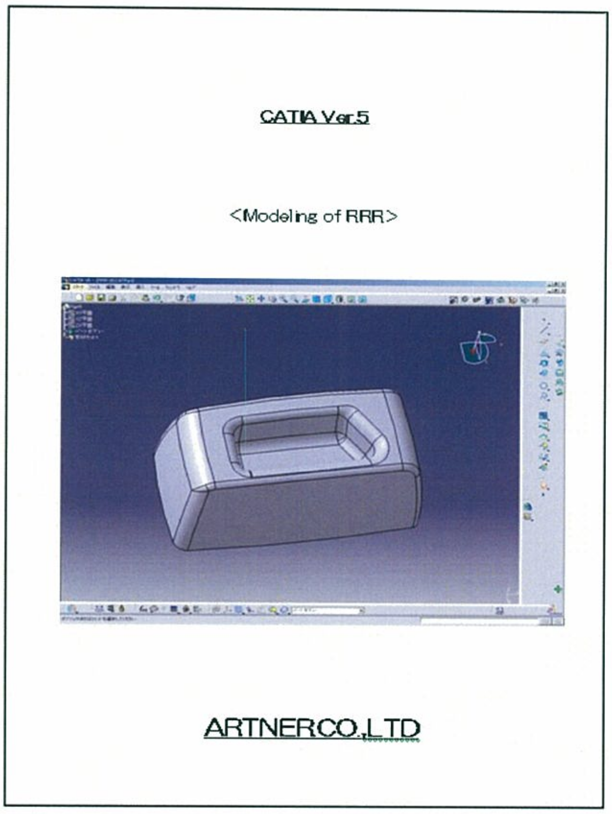
3.2 Operation procedure

Figures 1-5 show an example of an operation procedure.

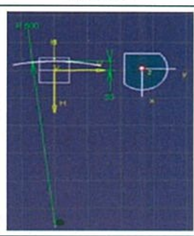
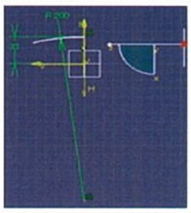
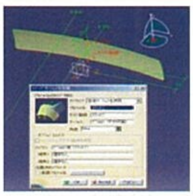
3.3 Fostering of imagination using punch drawing

1. Realization of ideas imitating the shape and motion of animals

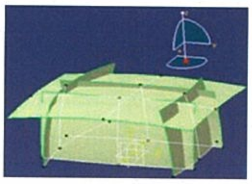
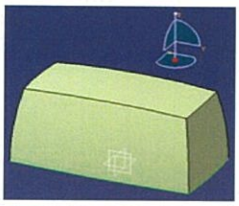
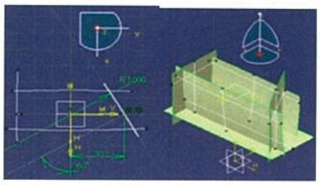
In the repair and inspection of giant plant facilities, such as power plants, the target sites include many narrow spaces and those with



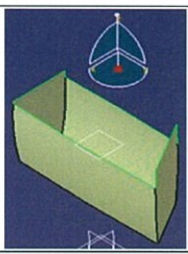
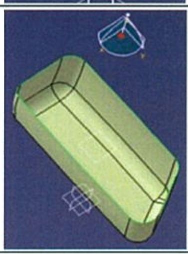
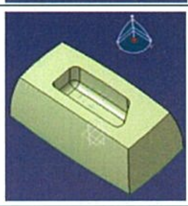
Figures 1:

Work	Screen	Command	Bench
1.The profile to make the surface is sketched.			
2.The guide curve to do the profile in the sweep is sketched.			
3.The sweep surface is done by Using sketches 1 and 2.			

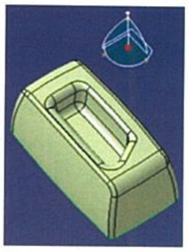
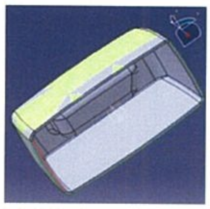
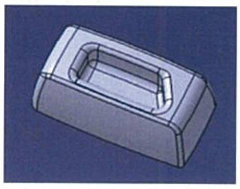
Figures 2:

Work	Screen	Command	Bench
4.It keeps similar and the surface on four another sides is made.			
5 The surface is trimmed.			
6.Five inside surfaces are made just like outside of.			

Figures 3:

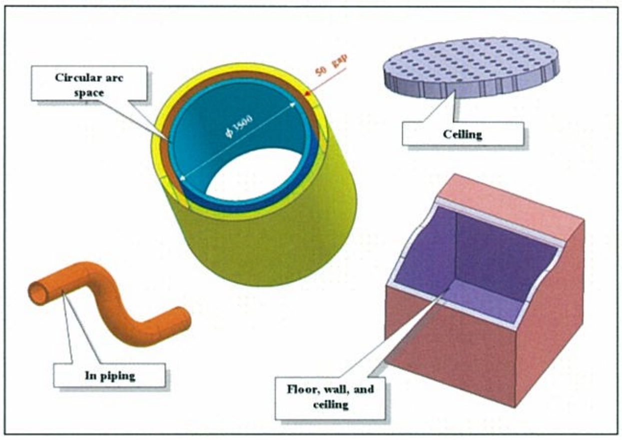
Work	Screen	Command	Bench
7.The surface is trimmed.			
8.Fillet is operated.			
9.It trims by an outside, inside surface.			

Figures 4:

Work	Screen	Command	Bench
10.Fillet is operated.			
11.The thickness is put in the surface.			
12. The surface is made non-display and it completes it.			

Figures 5:

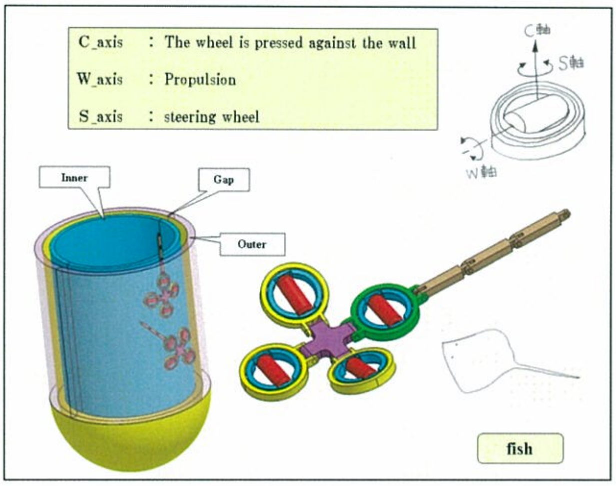
limited access. In the case of designing robots used to carry out work in such spaces, it is difficult to install mechanisms that can achieve the necessary functions on the basis of general design concepts. Radical ideas and the imitation of the shape and motion of natural objects are sometimes used in design. Here, we introduce design methods based on this idea along with some actual examples used in design (Figures 6).



Figures 6:

2. Access to target site (Figures 7)

Inspections are carried out to ensure the safety of a target site by evaluating the strength and state of the site. There is no need to manufacture expensive apparatus for sites that humans can access; however, construction sites frequently include places inaccessible to humans in terms of safety, for example, the inside of winding pipes, in the water in a pool, wall surfaces, ceilings, and narrow curved spaces.



Figures 7:

3. Design requirements of apparatus

The requirements of apparatus discussed in this study are as follows.

① The apparatus can enter a target narrow space with limited access.

② The necessary functions can be installed in the apparatus while retaining its ability to enter the target space.

③ The apparatus has satisfactory robustness as well as functionality.

4. Design starting from imaging a shape

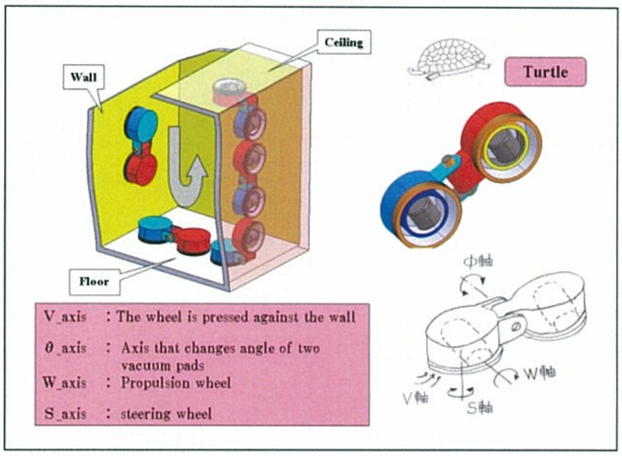
If the target site is a wide space, the shape of the apparatus can be determined without the need for a strong awareness of the dimensions of each component, and the apparatus can then be assembled. However, if the target site is narrow, another method of determining the size, shape, and image of the apparatus using information on the target of inspection and then incorporating the necessary functions in the apparatus may be necessary.

In an extreme case, an apparatus may be designed by imitating the shape and motion of animals in nature. Concretely, an apparatus to be used in narrow spaces is restricted in its shape and therefore must be thin and long or flat. Animals naturally having such a shape have reasonable strength and excellent balance. Therefore, the shape and motion of animals in nature are very helpful in design.

5. Installation of functions in a limited space in apparatus

When incorporating the necessary functions in a limited space of an apparatus, a designer cannot proceed if he considers that the design requires robustness as an essential property. The priority is given to installing the mechanisms providing the necessary functions. If this is not prioritized, the design of the apparatus is difficult, and the construction may become impossible. For example, for a thin design space, the dimensions of all components can be reduced by 0.1 mm and the balance of each component included in the apparatus can be evaluated. This process can be repeated until all the components can be packed in the apparatus. In an extreme case, a 0.3-mm-thick gear may be manufactured. For components with insufficient strength, materials are changed. If the strength is still insufficient even after changing the materials, the initial design specifications are changed to make the construction of the apparatus possible.

6. What is imaged (Figures 8) ?
When designing the apparatus used in narrow and curved spaces, a ray (fish) can be imaged. Let us consider that a ray enters a space between two curved walls and moves up and down between the walls. To realize this motion, the apparatus must include double axes with four driving wheels, each of which has an S-axis to provide a steering function, and a C-axis to allow it to be extended in the space. In addition, four probes are connected by a hinge along the direction of curvature of the space, realizing some flexibility of motion.
Such a ray-shaped apparatus is a unique example of design; good machines are generally said to have a good design. Namely, high-quality machines have a simple efficient structure and rational well-balanced functions.



Figures 8:

In other words, such a machine is a mimic of natural objects. In the design method of imitating the shape and motion of natural objects, it is important to focus on their rationality, observe them daily, and keep them in mind by drawing sketches, from the viewpoint that modeling is the origin of design. This will add greater delight to the design operation.

3.4 Prospective 3D CAD design

When designing apparatus using conventional design methods, components that can achieve a predetermined performance are selected and assembled. This is because it is difficult to evaluate whether or not each component, which is individually designed, can ensure the necessary performance when combined with other components. However, evaluating the performance of a design target has become easy in many cases owing to advances in CAD/CAE techniques.
If the performance required for a design target is only given as a design condition, designers can design the object by trial-and-error analysis using a computer. The application of CAD/CAE to design may greatly change the conventional concept of design, and the establishment of a design process in which the use of computers is assumed will be required to promote the advanced usage of computers in future machine design.
There are various requirements in design, such as the reduction of the dependence of design quality on the expertise of the designer, the prevention of the recurrence of failure in products, and the improvement of design quality by arranging information so that designers can rapidly find necessary information. Design departments have a large amount of various types of technical information, e.g., design techniques related to previously designed products and techniques related to the tests and experiments needed for product design. It is necessary to develop a system that can smoothly provide and effectively use the information needed by designers, particularly that related to design methods.

4. CONCLUSIONS

The training of new designers and the efficient usage of design techniques in companies have a complicated relationship with various factors, such as the training system used to realize, systemize, and develop intangible techniques, as well as company policy and workers' motivation.

The process of passing down techniques from generation to generation and its accumulation as 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 lend an ear to and encourage junior engineers. This attitude must be at the heart of an ideal technical support system.

In the future, we plan to provide opportunities for younger engineers to play an active role by introducing both group education and one-on-one support, to promote teaching as an opportunity for their own training. Furthermore, we will emphasize face-to-face training as a valuable opportunity for fostering human resources, and work toward the education and handover of design techniques.

REFERENCES

[1] Shigeo Hirano and Sozo Sekiguchi: Creative Production Process & Manufacture, Science, Published by Corona, 2007.

[2] Institute of Practical methodology of design technology: Practical methodology of design technology, Science, Published by Aiwa, 2005.

[3] Sozo Sekiguchi at all,:The Development of Design Education Materials for Design Engineering Cultivating, Proc.5th JCCGE, 2005.

[4] Sozo Sekiguchi at all,:A study with regard to way of advancing of 3 dimension machine designs: Proc.12th ICGG,2006.

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