

CREATIVITY DEVELOPMENT BY UTILIZING DIGITAL ENGINEERING

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1. Introduction

The Faculty of Engineering, Tohoku University, Japan is carrying out the Creativity Development Course (CDC) as one of the curriculum since 1996. This is a practice education and a training for a first grade (freshman) of under graduate course to experience an interest of research held with advices and instructions by the professors. To discover a problem and make a solution for it by oneself is required. Many experiences are gained to inspire a good idea and creativity through actual design and manufacturing. The greatest feature of this course is able to experience a delight realizing that own idea becomes an actual product at the first grade. There are many projects of CDC presented by each department of the faculty. The students can choose a project regardless of their belongings and can understand the necessity of engineering stands in the broad outlook at an initial stage of the education. The course of 80 projects was conducted in 2002 and 638 students took them. 106 projects are ongoing in 2003. In order to support the CDC, the facility Innovation Plaza was established in 2001. The Digital Prototype Lab which has the equipment for the practice education of a series of flow from idea, design, prototype, manufacture, inspection to evaluation utilizing newest digital engineering such as CAD, CAM and CAE effectively. The author is coordinating one project of the CDC using this equipment. This paper introduces the contents and the effect of the synectics and creativity engineering education of having utilized the digital engineering.

2. Contents of project for CDC

2.1 Subjects

The project "Digital design by 3D-CAD/CAE" has been managed as one of the CDC since 2001 (Figure 1). The following four subjects are given in this project. The attendance capacity is ten depending on the number of PC terminals because it is based on working with one terminal each. One professor (author) and two teaching assistants (graduate school students) are advising. Table 1 shows the equipment list of the Digital Prototype Lab.

Subject 1: Design and manufacture for a paper clip

To master the operation of CAD and Rapid Prototype (RP) equipment, a simple shape of product is modelled and manufactured by the RP equipment (Figure 2). The students sketch and measure the paper clip, then work with the 3D-CAD

Subject 2: Optimum design of a hook I

Lightening the hook, which shape likes L and maximum size is 50x16x20 mm shown in Figure 3, as much as possible by modifying the shape without decreasing its strength. The maximum thickness is



Figure 1. Digital Prototype Lab and scene of CRC

Table 1. Equipment list of Digital Prototype Lab

Hardware	PC terminals			
	-For practice		12	
	-For instructor		1	
	-For PC server, For RP equipment, For CAM software			1 each
	UPS			2
	A3 colour printer			1
	RP equipment FDM 2000, ABS Type (Strarasys, USA)			1
Software (All academic version)	3D-CAD SolidWorks		12	
	CAE	COSMOS/Works	12	
		COSMOS/Motion, Cosmos/M	1 each	
	CAM	Quick Slice (Strarasys, USA)	1	
		Craft Mill (Real Factory, Japan)	1	
	Report	MS-Office XP	10	



Figure 2. Paper clip

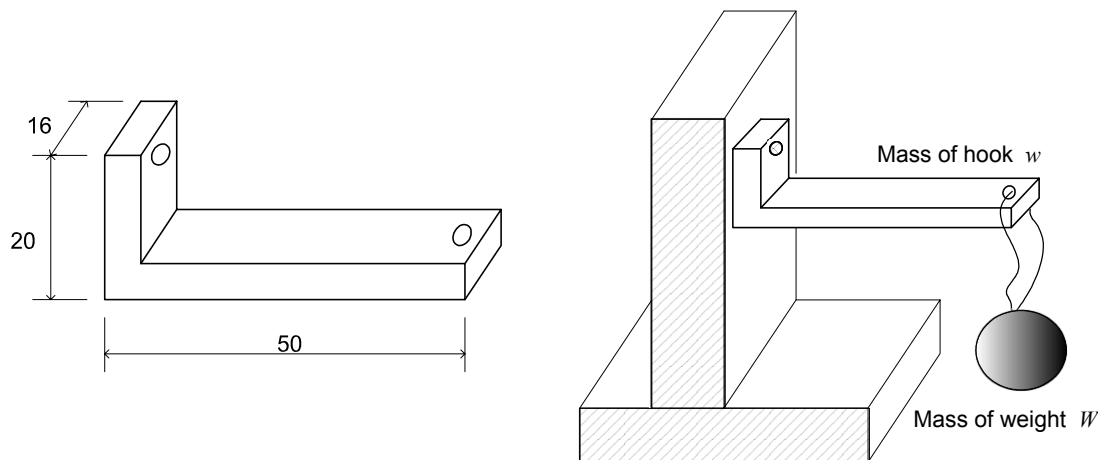


Figure 3. Original shape of hook for subject 2 and evaluation stand

set to 4 mm and the position of the whole for fixing the hook on a wall is free within the area of 16x20 left side. The hole for hanging a weight is adjusted at 45 mm apart from the wall. The shape of Figure 3 is the maximum and is assumed not to expand at all. The hook is modelled by 3D-CAD and analyzed by FEM. Then the designed hook is manufactured by the RP equipment actually and evaluated by the loading test (Figure 4). The hook is fixed with one specified screw on the test stand shown in Figure 3 and evaluated by hanging weights at its tip. The evaluation function is defined as $f = W / w$, where W is the mass of weight and w is the mass of hook. The mass of the weights when the hook is broken is recorded as a score. The masses of hook and weight are measured by a scale. The hook which gets large value of f is treated as excellent design. This regulation is explained at first, but there is no instruction how to design or analyze. The students must design the excellent hook by themselves.

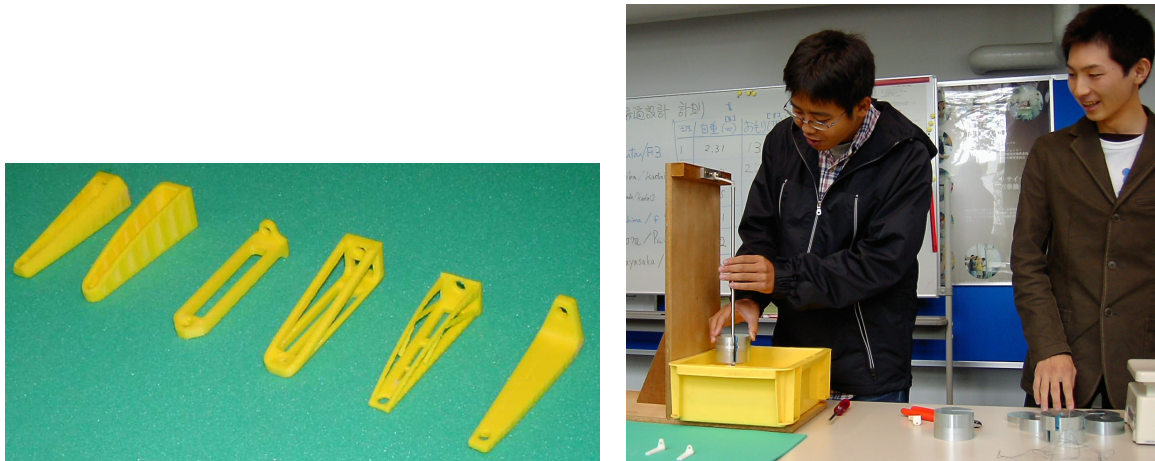


Figure 4. Designed hook products and scene of loading test

Subject 3: Optimum design of a hook II

The maximum modelling range is given by 65x16x20 mm. Designing new hook which increases above evaluation function f as much as possible within the allotted range. One hole for hanging the weights is required 60 mm apart from the wall. The hook must be fixed on the stand with one screw. The evaluation procedure is same to the subject 2. The freedom of the design has expanded greatly in comparison with the subject 2. This freedom inspires many good and funny ideas. The concept of optimum design is made to understand through the subjects 2 and 3.

Subject 4: Optimum shape of a mouse or a remote controller

Manufacturing a mouse or a remote controller, which fits to the operator's hand. Because this subject has no quantitative evaluation function like the hook's case, it is required to design the optimal shape by one's sensitivity, tactile impression, appearance and so on. The maximum modelling range of the mouse and the remote controller are given by 95x145x50 mm and 60x100x25 mm, respectively. Two buttons and a wheel for scroll for the mouse, and four buttons for the remote controller are provided as the specification. The procedure of this subject is as follows:

1. The idea is sketched on a paper and the feature of product is written by sentences.
Two plans are required to make.
2. Choice of better plan and making a clay model
3. Modelling by 3D-CAD referring the clay model and colouring to improve a reality, then printing by a printer
4. Manufacturing the product by the RP equipment

The purpose of this subject is to realize own image to an actual shape.

2.2 Schedule

The CDC assigns 2 hours per week and 15 times (1 semester) for the first grade (freshman). Both every week's course (regular) and intensive course for several days (special) were carried out to compare the proficiency of training. I found that the latter is more efficient. Because the CAD/CAE operation skill is improved day after day in the intensive course, the students become well to use the CAD/CAE as the tool and the projects are achieved smoothly and effectively. The following intensive course of 6 days (for approximately 50 hours) was executed in 2003.

1st day: Introductory; the purpose of course and an introduction of digital engineering

Practice of 3D-CAD (tutorial text "first step" is used)

Subject 1; The students sketch the shape of actual product "paper clip" and measure, then draw by 3D-CAD.

Practice of FEM software (tutorial text is used, static analysis only) and CAM software for the RP equipment.

Manufacturing of the paper clip by the RP equipment for all members (night)

More practice of 3D-CAD (additional functions)

2nd day: Explanation of the subject 2 and design of a hook, which are tackled in two-person pair (5 teams) aiming a collaboration design.

Explanation of the subject 4 and design work, Members are divided half for the mouse and the remote controller (individual work)

Manufacturing the hooks by the RP equipment (5 pieces, night)

3rd day: Evaluation for the subject 2 (competition style)

Explanation of the subject 3 and design (member alternation)

Continuation work for the subject 4

Manufacturing the hooks by the RP equipment (5 pieces, night)

4th day: Evaluation for the subject 3 (1st trial, competition style)

Examination of problems and determination of the policy for improved design. Then another hook is designed.

Completion of the subject 4

5th day: Virtual contest for the subject 3 (Discussion and expectation of the order)

Evaluation for the subject 3 (2nd trial for the improved product, real contest)

Explanation of how to make a report

Design Review for the subject 4

Preparation for presentation

6th day: Presentation, report making, questionnaires and closing

The optimum shape is made by repeating modify of the shape by 3D-CAD and analysis by FEM in subjects 2 and 3. Because the goal is clear and simple, the students can tackle with the subject keeping high motivation. The concept of optimum design is well understood from taking the routine twice in the subject 3. They get enough experiences of "try and error". It is nothing to say that the struggle at second trial by the team which got low f value in the first trial. I felt the basis of making good product exists in this subject. Moreover, the process, which is called a virtual contest, of expecting the value of evaluation function f that is the order for five-entry hooks before actual loading test by the examination of FEM result and observation of actual hooks is added. This process is helpful to understand the objectives of the subject by observing and criticizing the design result of other teams or making device for restraint and load conditions in common to compare each other. They examined the criterion by themselves and the expected orders by 2 teams are shown respectively before the real contest. The final contest on 5th day is so exciting. The estimated and actual orders are matched well than I expected. All 5 teams succeeded to improve the value of evaluation function. The result of examination was presented by the student at the final day. The example of design for subject 3 is shown in Figure 5.

In the subject 4, the processes "write on a paper" and "making a clay model" were added for the training of realizing the own image to the actual shape. The students operate 3D-CAD for the first time at this project and acquired the minimum functions of 3D-CAD. If they draw their images directly by using the 3D-CAD, the idea should spring up originally is dispirited by the restriction of the CAD

drawing skill. A good work with the originality was invented by adding the processes such as paper and clay. In addition, the evaluation session like a Design Review (DR) executed on the production site was tried to explain the concept of the work by oneself, to criticize each other and to mark them (Figure 6). The effort to tell others own idea as well as possible is observed by taking the competition style evaluations.

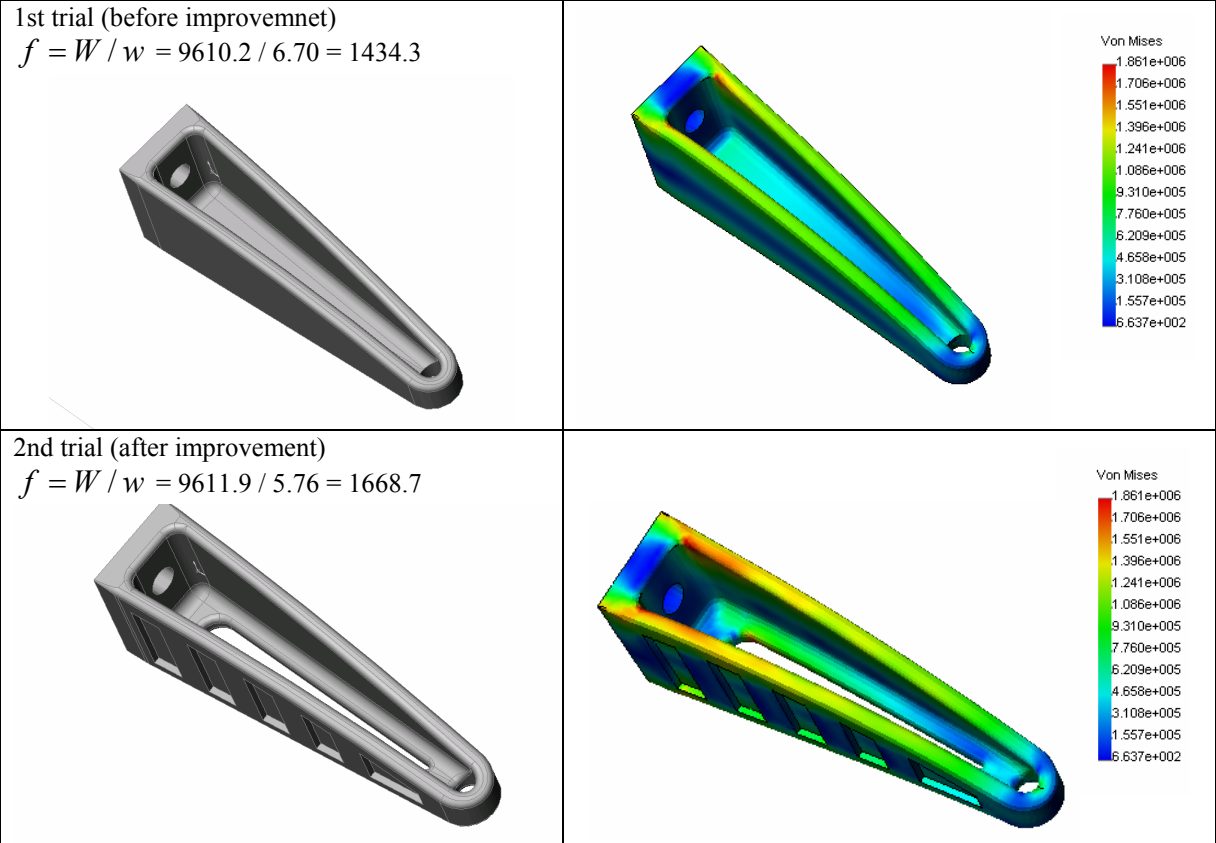


Figure 5. Example of hook product for subject 3

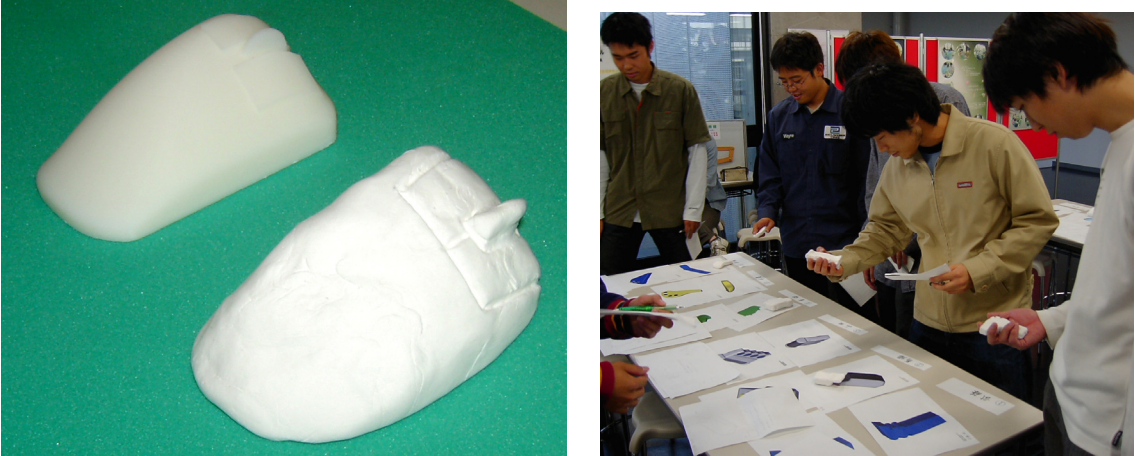


Figure 6. Designed mouse (RP; upper and clay; lower products) and scene of Design Review for subject 4

3. Effects of digital engineering

The participants of CDC have taken neither machine design, engineering graphics nor mechanics of material courses since they are first grade students. Even if they don't know the concept of the bending of beam or the concentration of stress, visualization by CAE software makes possible to understand them intuitively. Moreover, the hands-on experience that actual product designed by oneself is broken actually helps to understand the effective use of a simulation and the importance of giving restraint and load conditions appropriately. These are considered as the good motivation to learn above courses taking at second and third grades.

This program works well and utilizes the feature of the digital engineering. When developing a similar project, I recommend checking three viewpoints and their relationship as shown in Figure 7. This concept includes “Theory and Knowledge”, “Analysis Tool” and “Observation of Physical Phenomenon”. Though each element is independent severally, it is required to play the roll to support understanding other two elements. In case of subjects 2 and 3 above three elements are expressed as “mechanics of material”, “FEM” and “loading test”, and the purpose is achieved by those synergy effects. Learning the operation of commercial analysis tool only is not enough to develop a creativity. Constructing the program by keeping this concept leads efficient results.

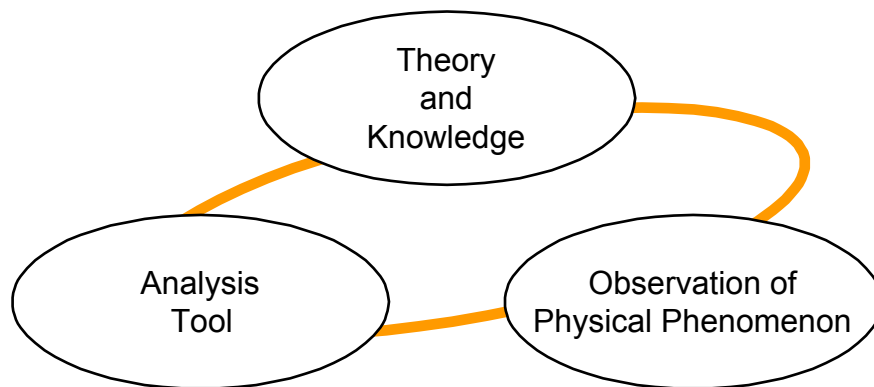


Figure 7. Development effective program

4. Summary

The educational program effective for creativity development utilizing the digital engineering was developed. Design education for the first grade student who has not received specialized engineering education is possible by devising the program.

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