Design Education to Develop Self-Directed and Innovative Engineers
- Short Technical Course to Enhance Design Capabilities -

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Abstract

"The Factory for Dreams and Ideas" (Yumekobo) offers varieties of short technical courses after classes in order to enhance students' technical competences and professional skills so that they can complete project activities within deadlines and achieve their goals. The authors offered a short technical course of fiber reinforced plastics (FRP) to members of Yumekobo projects with different academic background in order to enhance their design capabilities of FRP. We adopted measures to deal with differences in their knowledge and experience, as we did not impose prerequisites on their technical knowledge and experience of design of FRP structures. Consequently high satisfaction was obtained even though the contents of the course were advanced for them. In this paper, we first discuss strategies of Kanazawa Institute of Technology to develop self-directed and innovative engineers. And then we discuss the details of the short lecture of FRP, i.e. course objectives, learning materials, students' achievements, etc.

Keywords: engineering education, design capability, FRP, Yumekobo project, short technical course

1 Introduction

1.1 Engineering education at Kanazawa Institute of Technology

The world of today needs competent engineers who are able to demonstrate their professional technical competence. Professional technical competence integrates knowledge, understanding, skills, and values. According to Engineering Council of UK [1], the competence and commitment standard for incorporated engineers are:

A. Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.
B. Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate, maintain, decommission and re-cycle engineering processes, systems, services and products.
C. Provide technical and commercial management.
D. Demonstrate effective interpersonal skills.
E. Demonstrate a personal commitment to professional standards, recognizing obligations to society, the profession and the environment.

The formation process through which engineering professionals become competent generally involves a combination of formal education and further training and experience.

The educational goal of Kanazawa Institute of Technology (henceforth, KIT) is to develop self-directed and innovative engineers. Our strategy to achieve the goal is to combine engineering education and extracurricular activities. The reason why KIT considers extracurricular activities are important is that classes of regular curriculum are in session approximately 160 days a year. The remaining 205 days are vacations, holidays, Saturdays, and Sundays. Therefore, KIT established an innovative facility "The Factory for Dreams and Ideas" (henceforth, "Yumekobo, " which is the original Japanese name for the factory) so that students are able to spend the whole year including the remaining 205 days in a more productive and innovative way in its campus [2].

1.2 Project activity in Yumekobo

Yumekobo is designed and managed so that any students of KIT are able to convert their engineering ideas/dreams easily and safely into reality by designing and producing models/prototypes throughout the year. The mission of Yumekobo is to help students enhance students' motivation and creativity, and develop technical competence and professional skills through extracurricular hands-on activities.

Yumekobo has organized an innovative and creative students' project, "Yumekobo project", in order to accomplish its mission. The Yumekobo project is defined as a self-directed student project of extracurricular activities in a team. Yumekobo presently houses fifteen projects. More than 500 students are working vigorously on the projects, although they cannot get any credits for the projects. All of these projects are self-directed with minimal guidance from professors. One of the ultimate goals of the Yumekobo project is to participate in regional, national, and international competitions and win championships. In order to achieve the goal, students apply sophisticated and state-of-the-art technologies to their products.

Yumekobo projects recruit members with diverse characteristics (e.g., majors, special abilities and knowledge, age).

2 Technical Course in Design of FRP

Normal lectures offered by KIT are effective and instructive, but judging from their schedules, some of them are too late against demands for project activities. For example, a class of the mechanics of materials is offered to sophomore students majoring Mechanical Engineering. Therefore it is difficult for 1st grade students to understand fiber reinforced plastics (FRP) design using the mechanics of materials. Yumekobo project activities require technical competences and professional skills, such as machining process or structural designing theory, which are not included in the normal lectures. Therefore Yumekobo offers twenty short technical courses so that students will be able to enhance their technical competences and professional skills and to complete project activities within their deadlines and achieve their goals [3]. The short courses include operation of a machine center, project management, structural analysis, mechanical drawing, etc. Each course starts after classes. They are eager to attend the courses and try to enhance their technical competences and professional skills. Approximately 450 students take the courses each year.

The authors offered a new short course on designing and manufacturing of FRP in 2012 because opportunities to use FRP as the structural materials have been increasing in several Yumekobo projects, e.g. human-powered airplane project and fuel efficient car project.

FRP is characterized by anisotropic properties, which depends on the fiber orientation angles, and lamination, which consists of multiple thin ply with different fiber orientation. Thus, it is necessary to consider both the thin plate theory and the laminate theory. If FRP products are designed neglecting above-mentioned properties, they will experience geometrical and mechanical problems such as warpage and cracks caused by thermal residual stress [4]. The mechanical properties of FRP laminate can be predicted by the laminate theory. Therefore students are required to possess basic mathematical knowledge including tensor calculation, as well as the mechanics of materials [5].

28 engineering students attended this course. However, as shown in **Fig. 1**, their academic years were varied from freshmen to juniors. Besides, students' departments were also varied as follows: Mechanical Engineering, Aeronautics, Robotics, and Electronics, Information and Communication Engineering. Some of them did not take the mechanics of materials course, which is essential for the design of FRP. Therefore we designed the course so as to overcome the problem that some of them did not have enough technical knowledge for the design of FRP. The details of the course will be discussed in the next chapter.

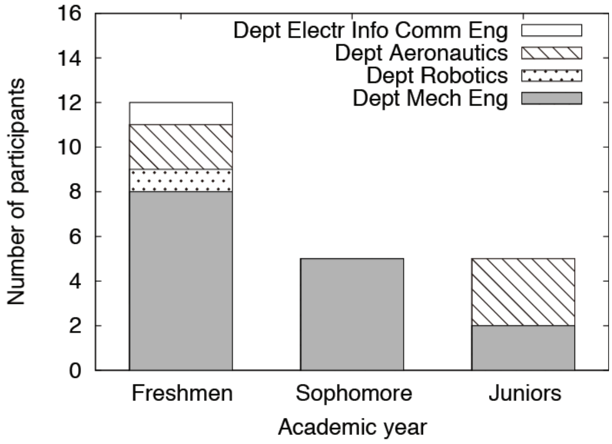

Fig. 1 Academic year and division of students participated in technical course in design of FRP

3 Details of FRP Course

3.1 Contents of FRP course

The contents of technical course are shown in **Table 1** The course is a 90 minute contact, three day course. First we taught the basic concepts of the mechanics of material, for example the concept of stress and strain, the relationship between them, and bending moment, before teaching the theory of FRP design. The basic concept of tensor calculation was explained as the calculation of simultaneous equation.

Table 1 Contents of lecture course.

Day 1 Introduction of FRP and Rule of Mixture ・What is FRP? ・Schematic image of design of FRP structures ・Basic knowledge for learning of design theory of FRP ・Rule of Mixture
Day 2 Laminate Theory ・Relationship between stress and strain in a thin layer ・Relationship between stress and strain in a laminate
Day 3 Evaluation and molding methods of FRP ・Evaluation methods of mechanical properties of FRPs and their constituent materials ・Molding methods of FRP

We taught the introduction of FRP, and gave students the general idea of the design of FRP, as shown in **Fig. 2**. Next, we taught the design theory, especially the Rule of Mixture and the Laminate Theory. Intermittently, we had time to touch actual FRP samples, such as laminates of glass or carbon fiber reinforced plastics (GFRP or CFRP, respectively), sandwich panels, or their constituent materials (fibers, resins or prepregs). This approach intended to give students visual information, better idea and clear relationship between the contents of lectures and the actual materials they treated. Finally, we explained how to make such FRP structures as much as possible. **Figure 3** shows photos of the classroom lecture and display of FRP samples.

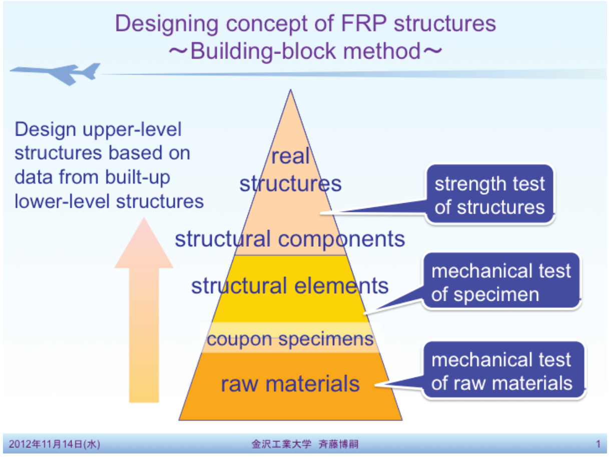

Fig. 2 A schematic image of design of FRP structures

(a) Classroom lecture

(b) Display of FRP samples

Fig. 3 Aspects of technical course in design of FRP

Generally speaking engineering learning requires practical training in addition to a classroom lecture. If possible, such theory should be converted to some kind of tools for actual use such as a computer program. Moreover, it is desirable that students make such program by themselves. However, as we mentioned above, the academic backgrounds of students were various in our course, and it was necessary that almost all students could understand a program language and formulate a computer program. Therefore, we employed Microsoft Excel, with which all students can perform at least a certain level of calculation, as the programming tool. The programming was divided into several steps, and students completed stepwise module programs at the end of each step. Here, we prepared the Excel file formats for the module programming as shown in **Fig. 4**. Basic information, such as where the constituent material properties should be input or where students should input formula, was written in the format files already.

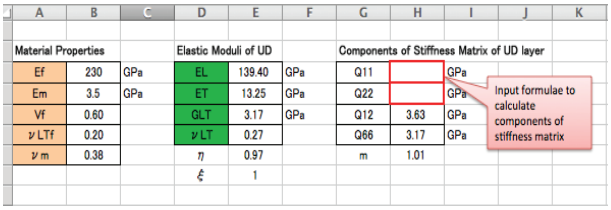

Fig. 4 Example of module program

The flow of the programming is shown in **Fig. 5**. Each step refers to the previous results, and finally students complete a program of "the Laminate Theory" [5, 6] by themselves. The first step was to understand "the Rule of Mixture" [5], which can obtain the elastic moduli and Poisson's ratio of unidirectional FRP from the mechanical properties of constituent materials. At the next step, stiffness matrix of unidirectional FRP thin layer was obtained. Then, the program calculated a stiffness matrix of an arbitrary oriented layer in general condition under bending and twisting loads. At the last step, a laminate stiffness matrix and its engineering moduli were obtained.

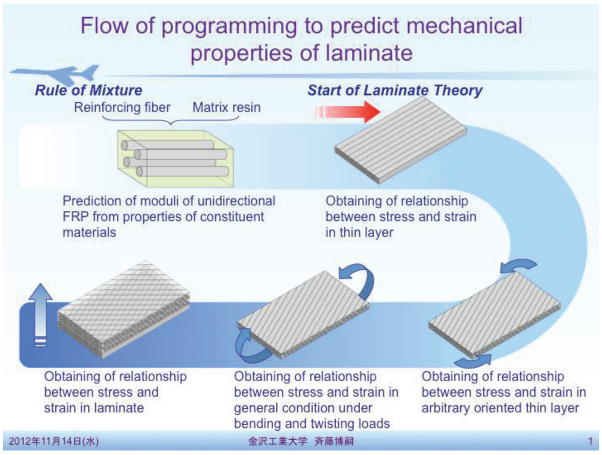

Fig. 5 Flow of programming from Rule of Mixture to Laminate Theory

After students made a program by themselves at each step, we gave them a list of material properties to verify their programs and confirmed that the programs are correct. We gave them about 15 to 20 minutes to complete a program. After self-verification, we showed a correct program. In the explanation of the correct program, we lectured and also made students try to understand, for example, how the mechanical properties vary depending on the fiber orientation angles. **Figure 6** shows one example of such approaches. This figure shows the relationship between fiber orientation angle and some components of the stiffness matrix of unidirectional FRP thin layer.

Figure 7 shows a computer program completed by students. This program can calculate the stiffness matrix and the moduli of tensile, shear, bending, etc. of FRP symmetric laminates under the condition of any fiber orientation angles and layer thicknesses.

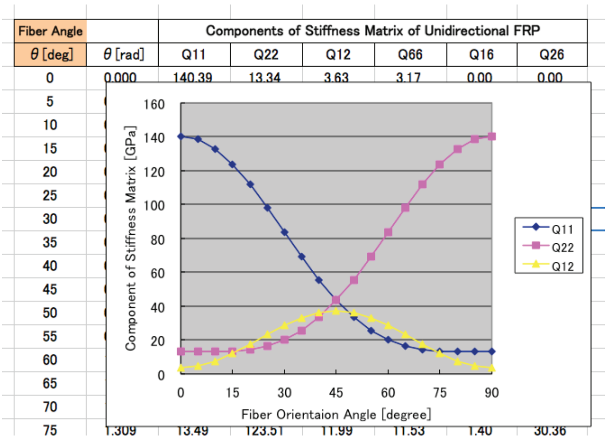

Fig. 6 Relationship between fiber orientation angle and some components of stiffness matrix of unidirectional FRP thin layer

3.2 Benefits for students

The aim of this course, at least the output for students, is to give them a tool to estimate the mechanical behavior of FRP. The programs, which students made by themselves through this course, enables them to predict mechanical properties of FRP laminates. The mechanical properties can be directly used to calculate mechanical behavior of FRP structures in finite element analysis. This is a big advantage for students who design and manufacture FRP structures such as airplanes or cars.

In addition, to learn usage of MS Excel for actual purpose is also important aspect of this course. In regular curriculum, students utilize a part of the function of MS Excel, e.g. drawing a graph or making a simple calculation. They don't know the potential capabilities of MS Excel until they use it for engineering problem solving.

However, on top of everything, it is most important to make students feel familiarity with designing through the course. Much of them familiar with FRP, whereas they feel that designing of FRP is very difficult. Especially they tend to avoid to treat or to consider orthotropic property of FRP. Therefore, we think it is meaningful to give them an opportunity to remove such obstacles.

4 Students' Achievements of Educational Objectives

Students who attended the course were given two post-course questionnaires to complete. The first question was designed to ask motive(s) for attending the course:

What is your motive(s) to participate in this course? Select all that apply.

a. Be able to design FRP structure
b. Be able to analyze FRP structures
c. Be able to utilize for project activities
d. Recommended by faculty members or seniors
e. other

Figure 8 shows feedback from students who participated in the course. Their motives for attending the course were to design and analyze FRP structures, and to utilize learning results for their project activities. All students decided to participate on their own judgments. Their motives for the course were definite.

The second questions were to determine if students thought the course was a valuable contribution to their project activities. The questionnaire was administered by having students indicate their responses to questions using the following numerical scale:

1 = Disagree strongly
2 = Disagree
3 = Disagree a little
4 = Agree a little
5 = Agree
6 = Agree strongly

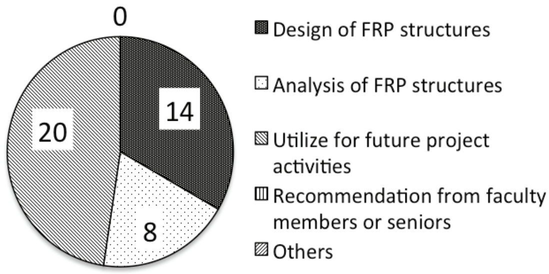

Fig. 8 Result of questionnaire regarding motive of participants

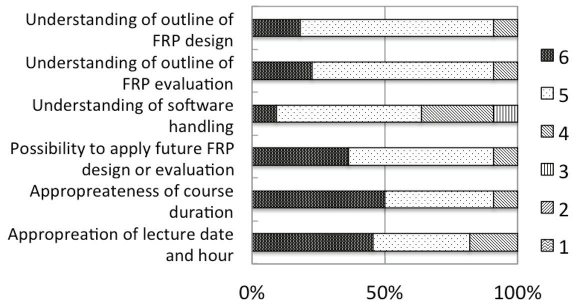

Fig. 9 Result of questionnaire regarding level of understanding and satisfaction of course

Figure 9 shows students' achievements of educational objectives and evaluation of the course. Almost all students could understand how to design and evaluate FRP structures. They were confident to utilize their learning results to project activities. They were satisfied with hours of instruction and its schedule. Approximately half of them found programming of FRP structures were not easy. This is because the computer programs made by students were composed of modules and the flow of calculation was a little complicated by referring to the previous calculation. Some students found tensor calculations included in the program difficult to understand. One of the students answered an open-ended text question “The contents of the course were pretty difficult.”

We were impressed that almost all students attained high satisfaction even though the contents of the course were advanced for some of them. We considered that their deep satisfaction is caused by their high motivation to learn in order to complete their projects successfully. One of the students answered an open-ended text question “I could calculate easily the strength of FRP structures by the spreadsheet program of Microsoft Excel developed in the course. This experience made me feel the design and evaluation of FRP familiar.” It can be concluded that the spreadsheet program was effective as students are familiar with Microsoft Excel.

5 Concluding remarks

The authors offered a short technical course of FRP to members of Yumekobo projects in order to enhance their design capabilities of FRP, because opportunities to use FRP as the structural materials have been increasing in several Yumekobo projects. As we did not impose prerequisites on their technical knowledge and design of FRP structures, their academic years were varied from 1st to 3rd grades, and some of them did not take the mechanics of materials course, which is essential for the design of FRP. Therefore we designed the course so as to overcome the problem of different academic background.

Important information obtained in this study is as follows:

1. Students’ motives for attending the course were to design and analyze FRP structures, and to utilize learning results for their project activities. Their motives for the course were definite.
2. All students decided to participate on their own judgments.
3. Almost all students could understand how to design and evaluate FRP structures. They are confident to utilize their learning results to project activities.
4. They were satisfied with hours of instruction and its schedule.

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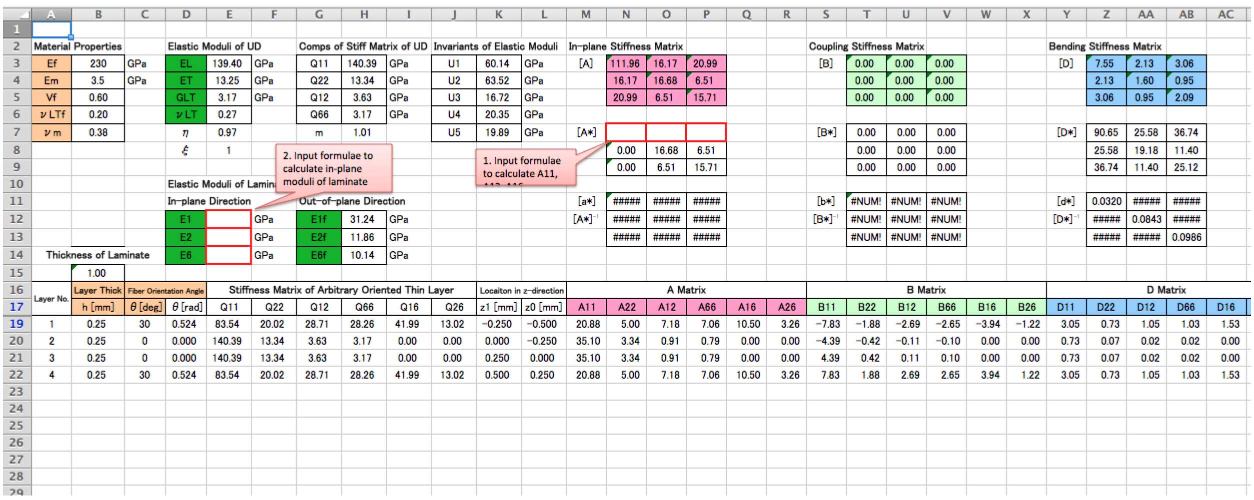

Fig. 7 Program of Laminate Theory completed by students