Education of Design and Manufacture Using Hand-made Small-sized Electric Vehicles

Haruo Sakamoto [1], and Koji Amimoto [2]

[1] *Department of Intelligent Mechanical Systems Engineering, Kochi University of Technology, sakamoto.haruo@kochi-tech.ac.jp*
[2] *Department of Intelligent Mechanical Systems Engineering, Kochi University of Technology, 085202x@gs.kochi-tech.ac.jp*

Abstract

In the department of Intelligent Mechanical Systems Engineering, Kochi University of Technology, the synthesis lecture has been being carried out in 3rd and 4th years of the undergraduate program. In order to provide an active synthetic learning opportunity, self-learning environment is of great importance rather than just teaching-based classes. Project themes, therefore, are provided for each team in our laboratory, which belongs to the authors. In this report, the designing and manufacturing activity using small-sized electric vehicles is described. As well as the design, the manufacturing aspect is also considered to be of great importance for mechanical engineers. As a capstone learning course, two teams in our laboratory tried to design and manufacture. One is a hand-made small-sized electric automobile, and the other a hand-made electric motorcycle. Te former is suitably gentle for elderly drivers, and is the revised one from the vehicle made last year.

Keywords

small-sized electric vehicle, motor bike, 3D-CAD, engineering education

1. INTRODUCTION

The Kochi University of Technology was opened in April, 1997. The university has been trying to develop new engineering educational curricula such as first year seminars using real products [Sakamoto et al., 1999], experimental courses using vehicles [Sakamoto, 2001], computer assisted English education [Greene, 2000; Hunter, 2000], and so on. Among them, one of the authors thinks that the design education is of great importance, as Fargason [Fargason, 1995] mentioned that design is engineering synthesis.

In the previous paper [Sakamoto et al., 2003], two extracurricular (out of class and no credit) activities [Sakamoto, 2001; Sakamoto et al, 2001] in the following were reported. In November, 1997, the Kochi Eco-power Race, organized by Toyota Vista Kochi, was held in Kochi, and three teams in the 1st year grade joined the race. The second is the Electric Vehicle Rally. In August, 1998, the Shikoku Electric Vehicle Rally, organized by a committee of high school teachers and university faculty members, was conducted in Shikoku, the smallest main island of Japan. Three teams joined the race by converted electric vehicles.

As design practices, electric vehicles can be good targets to start. The synthesis education like design was then performed after the 3rd year grade, and the experiences gained by such extracurricular activities helped in their education. As for design education, 3D-CAD lecture has been considered, and design of manual winch was selected because the text [Technical Education Committee, 1991] teaches how to calculate and is though to give an appropriate time to draw. As for 3D-CAD software, three kinds are applied, ProEngineer, Solid Edge, and Solid Designer. Along with the design practices, electric vehicles have been designed and manufactured. The first is an electric automobile, which is the one revised from the previously manufactured [Sakamoto et al., 2003]. The other vehicle is a motorcycle powered by electric. Both cases include design and manufacture activities.

In the following, design education and design practices for electric vehicles are reported.

2. 3D-CAD DESIGN EDUCATION

In the 3rd year of the mechanical engineering department, advanced design education has been conducted. Table 1 shows the contents and procedure. Figures 1 shows the examples for practices, and Figure 2 shows the winch assembly. The procedure of the course is as follows. In the first three times, the instruction is given by a faculty member and teaching assistants. Students learn how 3D-CAD and 2D-CAD are performed with assisted exercises in class. In the following forth and fifth classes, they calculate the main sizes of each part.

Table 1 Contents and procedure of design education

No.1	Guidance of the lecture and explanation of simple 3D-CAD example
No.2	Exercises of three 3D-CAD examples and one 3D-CAD homework
No.3	Explanation of winch, assembly file list, bird's eye view sketch
No.4,5	Calculation for determining size, measurement, and configuration
No.6	Flame and flame assembly
No.7,8	Midway axle and assembly
No.9,10	Wind drum and assembly
No.11,12	Handle parts and assembly
No.13,14	Brake parts and assembly
No.15	Others and whole assembly

Fig. 1 Examples for practice

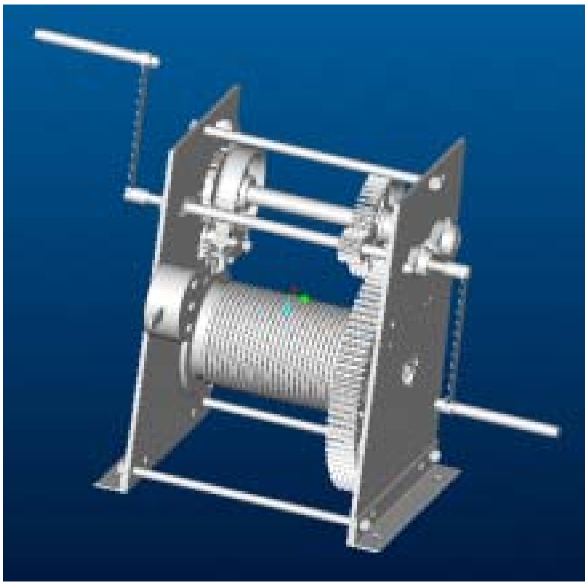

Fig. 2 Assembly of winch

Since the preparation for design is provided by the first five classes, they start to design following the text. The design conditions of weight to raise the goods and length to pull up are given individually for each student.

The components designed are frame related, midway shaft related, wind drum related, handle related, and brake related parts, and totally 34 parts need to be designed. Figure 2 is the assembled winch and it contains all parts. Among 80 students who originally joined in the course, 54 students accomplished the course. They calculated and made their drawings. The rate of accomplished students, therefore, is 74 %, which seems lower than the other design courses in the other universities [Creative Design Education Committee, 1998]. The improvement should be considered. However, we think 3D-CAD including assembly drawings would not be so popular in Japan.

As the course summary, the followings are concluded.

(1) As simple design exercise, the manual winch is proposed, and the seminar-like design course was performed for the manual winch. The 3D-CAD design practice was conducted.
(2) The total 3D-CAD assembly design succeeded.
(3) However, the average time per student for the course was 4 hours per one time. The course in class per one time is 90 mins (1.5 hours). They needed to overwork by themselves in out of class. One student needed totally 100 hours for 15 times. This should be considered. More appropriate way to teach or learn will be examined.

As is mentioned above, 3D-CAD education has been conducted, and the potentiality for design and manufacture of electric vehicles seems to be enough to proceed.

3. DESIGN AND MANUFACTURE OF SMALL-SIZED ELCECTRIC AUTOMOBILE

3.1 Engineering aspects to be improved

The electric vehicle produced in 2002 [Sakamoto et al., 2003] shown in Figure 3 was not able to run as smoothly as was aimed for the previously designed and manufactured vehicle. Although the weight and other remaining technical issues need to be improved, some items remained as they were. Those are the double-wish bone suspension type, motor, driving controller and unit, and speed controller. Items to be considered this time are as follows,

(1) Light-weight frame
(2) Frame design for easy getting on and off
(3) Improvement of riding comfort and brake performance
(4) Easy driving and control

Fig. 3 Previously produced small-sized electric vehicle

3.2 Vehicle size, suspension, and driving control

The vehicle size was determined from small-sized trucks used in Japan (The size limitation is 2,500 mm length, 1,200 mm width, and 1,600 mm height) as is shown in Figure 4. The determined size is 1,700 mm length, 1,100 mm width, and 1,600 mm height, and the size is larger than the one shown in Figure 3. This was decided from the viewpoint of handling, space for driving control, and

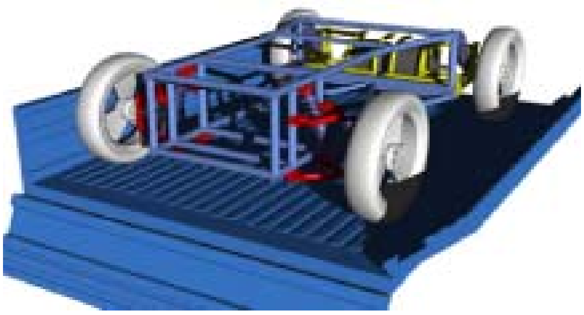

Fig. 4 Small-sized truck and the vehicle

lateral stability of the vehicle. This electric vehicle with the size can be carried by the truck in case of emergency or just transportation.

As for suspensions, the ones for the previous vehicle shown in Figure 3 are those for motored bicycles. Because of the weight in the rear side, the suspensions were in an almost punctured state. For the modified design, the rear suspensions for 400 cc gasoline-powered motorcycle are used, which are shown in Figure 5. Their stroke is longer, and stiffness is larger so that better riding quality is expected.

Fig. 5 Front (left) and rear (right) suspensions

3.3 Motor, controller, and batteries

The other parts such as the double-wish bone suspension type, motor, driving controller and unit, and speed controller are the same as those of the previous vehicle in Figure 3. As for the motor, the authors selected to be the one for solar energy motored direct motor made by Tsushima Electric Company. The characteristics are light weight, high torque, and high efficiency by high performance permanent magnets, high endurance, and high start-up response.

The speed controller is also used by Tsushima Electric Company. The voltage range that can be controlled is set to be larger. The controller takes into consideration of energy saving by PMW control and function of energy efficiency. The controller is also equipped with motor protection, detection of excessive and extra low current, and protection of excessive heat.

The batteries are the Lithium-ion ones by LitCEL Company, subsidiary of Mitsubishi Chemical Company. The voltage per one battery is 14.8 V, the weight is 6.5 kg, and the capacity is 33Ah.

3.4 Frame configuration

Design and manufacture of the vehicle shown in Figure 3 clarified the issues to be improved. The items are as follows,

(1) The strength is not enough, because the design was stressed on easy getting on-off. A bar component was added as is shown in Figure 6. Even with the modification by the added bar, the strength is still needed to modified.

(2) Due to the distance between frames of front and rear, the vehicle was hard to drive. The seat height was low for driving, and hard to drive.

(3) It was found that the method of joystick applied in the previous vehicle was not easy for driving, especially for elderly drivers. Although the idea from handle to joystick was raised considering easy driving even for weak power elderly drivers, the actual driving way was hard, and it needed practice. Moreover, the joystick driving was not simple as was aimed.

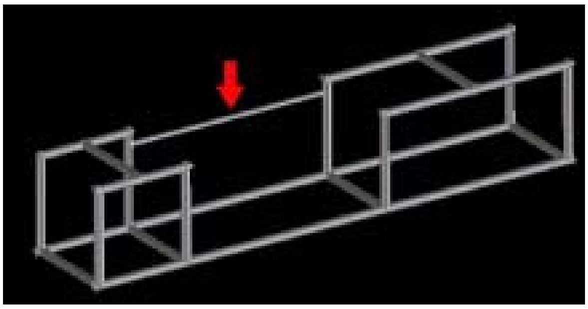

Fig. 6 Frame for previous vehicle in Figure 5

For the design modification, the followings were considered.

(1) Frame of double-deck construction was proposed.

(2) The pipe was changed from round for the previous design to square this time. Stronger, stable and easy welding design was aimed.

(3) The distance to be between front and rear positions was studied. The seat height was also examined, and the handle position was investigated by gathering the data of handle height and position of hands for easy driving. The data was those from 14 students in our laboratory, and the location was decided by using the data.

The final configurations of the frame and frame assembly are shown in Figures 7 and Figure 8.

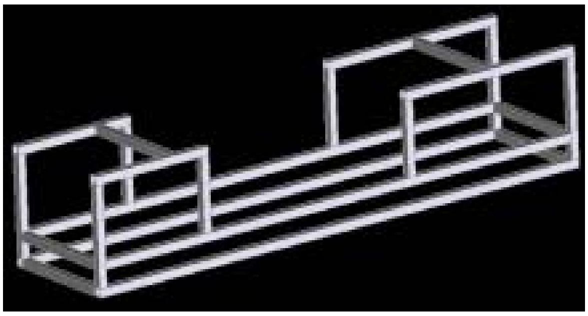

Fig. 7 Modified frame of double-deck

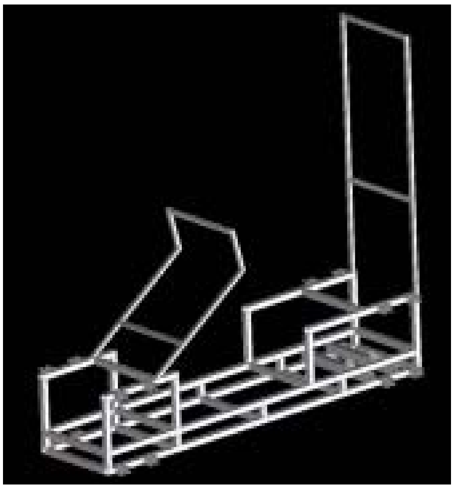

Fig. 8 Assembled frame construction

3.5 Stress analysis of frame

The stress analysis was performed using ProMechanica, which is a software associated with ProEngineer. The weight of batteries, motor and differential gear, and passenger was estimated about 160 kg. The forces from the weight, then, was distributed as 200 N for 1, 200 N for 2, 300 N for 3, 200 N for 4, and 1,000 N for 5 as in Figure 9. The dynamic component from the weight was only 0.21g, which seems to be small. The dynamic component needs to be re-considered. From this assumed force assumption, the obtained stress result was the maximum static stress of 180 MPa. The values of tensile and yield strength are 450 MPa and 230 MPa for the material of SS400. The safety factors for tensile and yield are 2.5 and 1.3. These results by calculation are not accurate and need to be considered in the very near future. Regarding the fatigue safety factor, the dynamic load was considered in the load condition. Figure 10 shows the examples of analyzed results.

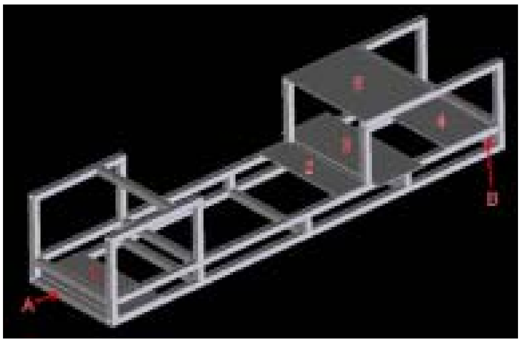

Fig. 9 Stress analysis (number designates force location)

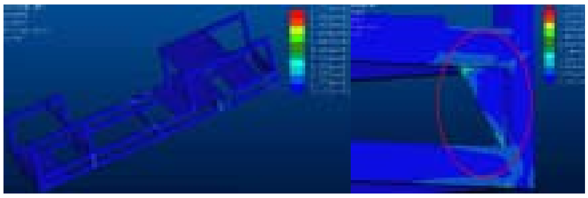

Fig. 10 Examples of stress analysis results

The load condition applied for the analysis this time was decided from the viewpoint of mainly light weight. Although more marginal design is desirable from the viewpoint of safety factor in design, the weight is a primary concern in case of electric vehicle. The analytical result also needs to be confirmed by experiment after manufacture.

3.6 Manufacture of vehicle frame and assembly

The frame was assembled by welding. Figure 11 shows the appearance of the produced vehicle frame. Since

Fig. 11 Welded frame assembly

Fig. 12 Vehicle modified from Figure 3

the laboratory does not possess the welding tool, at the moment of manufacture we asked a company near the university to manufacture. Figure 12 shows how the vehicle looks like, because we did not finish the assembly of every parts and components. The vehicle in Figure 12 is the modified one from the previous vehicle shown in Figure 3. The vehicle will be expected to be accomplished in early June, 2004.

The frame weight is 2 kg lighter than the previous one shown in Figure 6, and it is considered that 2 kg is good result, since we enlarged the size of the vehicle. The vehicle is expected to be stronger and easy for getting on-off by the double-deck construction.

4. DESIGN AND MANUFACTURE OF ELECTRIC MOTORCYCLE

Electric motorcycle has been studied as a capstone project for 4th grade undergraduate as well as the small-sized electric automobile in the previous chapter. In this report, brief explanation of design and manufacture is given, because this report intends education and not development. The detail will be reported in the next chance.

4.1 Design of electric motorcycle

The size of the motorcycle was decided in the same manner of the electric automobile. The electric motorcycle needs to be transported, when batteries are gone or an emergency accident happens. The idea is the same, and small-sized trucks are to be considered to carry. Therefore, the size should be within 1,900 mm length and 1,200 mm width. The size was decided to be similar to a gasoline-powered bicycle. 3D-CAD using ProEngineer was studied for the planned motorcycle, and Figure 13 shows the image by 3D-CAD. The stress analysis was conducted by ProMechanica.

Fig. 13 3D-CAD of hand-made electric motorcycle

4.2 Manufacture of electric motorcycle

After the design was finished, the motorcycle was manufactured. The welding equipment was ready to use this time in our laboratory, and the motorcycle was produced mainly by welding. Figure 14 shows the appearance of the motorcycle produced. The maximum speed aimed was 25 km/h, and the one obtained by running testing was 23 km/h. Considering the rolling friction between tire and road and other factor, the value should be satisfactory.

Fig. 14 Manufactured hand-made electric motorcycle

5. DISSCUSION AND CONCLUSION

As undergraduate capstone projects of design and manufacturing, two teams in our laboratory challenged to design and manufacture a hand-made small-sized electric automobile and an electric motorcycle.

5.1 Design education by 3D-CAD of winch

Students learned how to design using 3D-CAD software, mainly ProEngineer and Solid Designer. The course includes how to assemble, and they are able to make 3D-CAD even in a form of assembly. Solid form like ProEngineer or Solid Designer enables students to perform the stress analysis using solid forms. In the projects, there introduced 3D-CAD and stress analysis that the students conducted. The design exercise like winch is thought to be a good design target.

5.2 Design and manufacture project of electric automobile

A hand-made small-sized electric automobile was completed, although many technical issues still need to be solved.

(1) As a project, the team considered their theme and target. The faculty supported this project from the viewpoint of funding and suggestions. The team completed the vehicle by themselves.

(2) The project theme aimed at manufacturing as well as design. In the design process, computer graphics were effective for group discussions. Although the design detail was not sufficient for manufacturing due to students inexperience in design, the team obtained experience on how to produce a product from

their own drawings. Students learned how the design for manufacturing is difficult by comparing to the experienced engineers in the company which we asked the manufacturing.

(3) In this project, the students had a chance to study 3D-CAD, stress analysis, and manufacture. This is the aim for the faculty to let students to learn synthetic engineering by themselves as well as basic engineering courses like mathematics, physics, strength of material, and so on.

5.3 Design and manufacture project of electric motorcycle

One of the students in our laboratory, Mr Taku Fukui, who goes abroad for study in 2004, selected the capstone project for his graduation theme in 2003, The project is a small-sized electric motorcycle. Although the detail of the project will be reported in the next chance, the work included 3D-CAD, stress analysis, and manufacture. The manufacture was conducted by himself by using the welding equipment. Since the category of the vehicle is in gasoline-powered bicycles, the maximum velocity should be below 30 km/h. The aimed maximum velocity was 25 km/h, and the actual maximum velocity obtained was 23 km/h.

The project contained 3D-CAD and manufacture, and is thought to be a good example for engineering education

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