Design, Manufacturing, Analysis, and Control for Small-sized Electric Vehicles with Renewable Energy

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Abstract
This report describes the design, manufacturing, analysis, and control activities students conducted for small sized electric vehicles. In 1997, the Kochi University of Technology opened. Since then, the students tried to design and manufacture the electric vehicles in the extra-curricula class and in the laboratory. Engineering education for mechanical engineering needs the practical design and manufacturing, since design and manufacturing is the key of engineering. We would like to report the 9 years activities in our laboratory since 1997. We started the production for joining the Kochi Eco-power Race in Kochi in 1997, and for joining the Shikoku Electric Vehicle Rally in Shikoku Island in 1998. Since then, the vehicles we produced are the one converted from a light weight conventional vehicle, two small-sized electric vehicles with four wheels, the one with three wheels, electric motorcycle, and electric tiller. Besides such activities of design and production, the stress analysis and control had been conducted.

For renewable energy utilization, we need to consider how to charge the batteries for electric vehicles. We might be able to use the fuel cell battery in the future. In order to charge the electricity for electric vehicles, we planned to use the self-powered electricity, which is produced by a wind-solar hybrid power system. The self-powered street light whose electricity is from wind and solar panel was installed in our university. The experiment had been conducted using the system, and the capability was studied.

Keywords
electric vehicle, 3D-CAD, renewable energy, self-powered street light

1. INTRODUCTION
The Kochi University of Technology 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, 1999; Hunter, 1999] 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.

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.

A power supply of battery for electric vehicles uses a self-powered street light. The self-powered street light is a power generation system with a solar panel and wind power wings. The wing type is the savonius type windmill whose characteristic is the power under a low wind velocity condition.

2. DESIGN AND MANUFACTURING OF SMALL-SIZED ELCECTRIC VEHICLE

2.1 Engineering aspects to be improved
The electric vehicle previously produced [Sakamoto, 2003] shown in Figure 1 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,

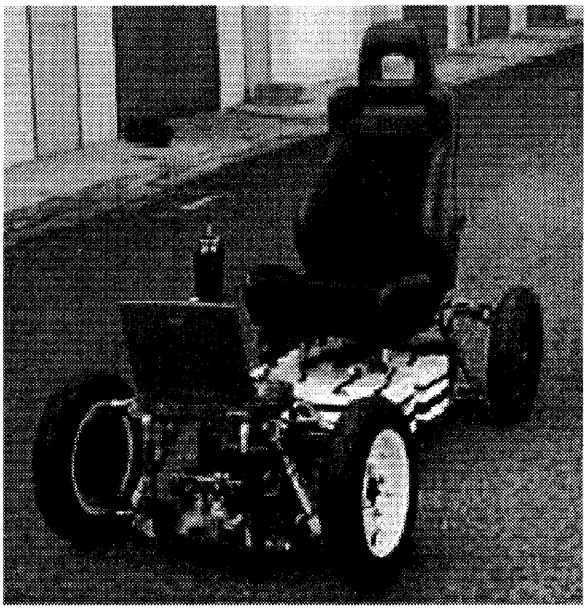

Fig. 1 Previously produced small-sized electric vehicle

(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

2.2 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 2. 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 1. This was decided from the viewpoint of handling, space for driving control, and lateral stability of the vehicle. This electric vehicle with the size can be carried by the truck in case of emergency or just transportation.

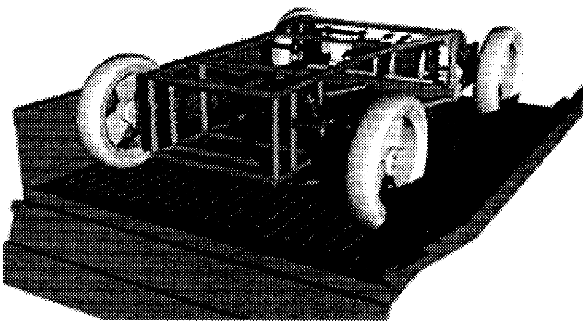

Fig. 2 Small-sized truck and the vehicle

As for suspensions, the ones for the previous vehicle shown in Figure 1 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 is shown in Figure 3. The stroke is longer, and stiffness is larger so that better riding quality is expected.

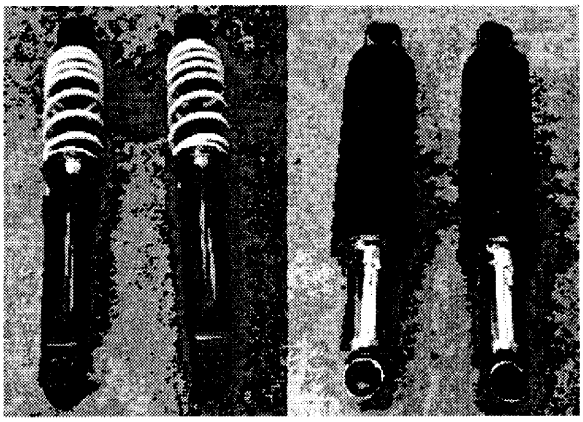

Fig. 3 Front (left) and rear (right) suspensions

2.3 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 1. 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 a motor abnormal protection system such as detection of excessive and extra low current, and protection of excessive heat.

The batteries are the Lithium-ion ones by Ricel 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.

2.4 Frame configuration

Design and manufacture of the vehicle shown in Figure 1 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 4. Even with the modification by the added bar, the strength is still needed to modified.

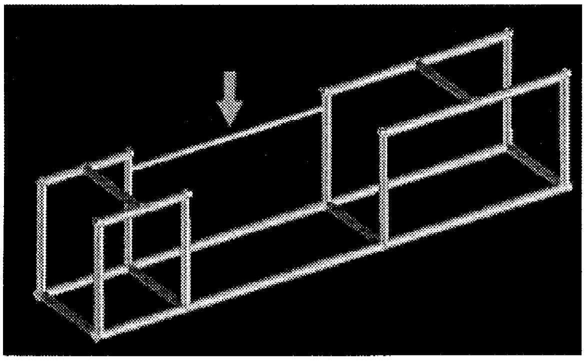

Fig. 4 Frame for previous vehicle in figure 5

(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.

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 5 and 6.

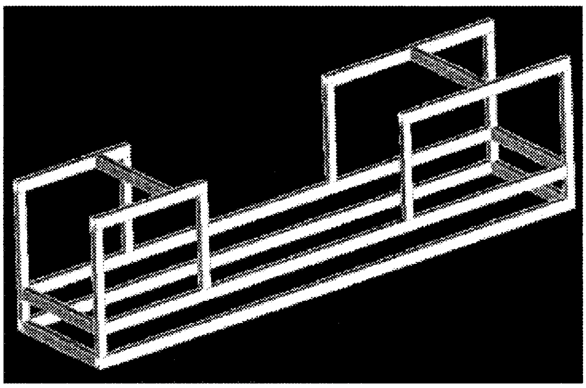

Fig. 5 Modified frame of double-deck

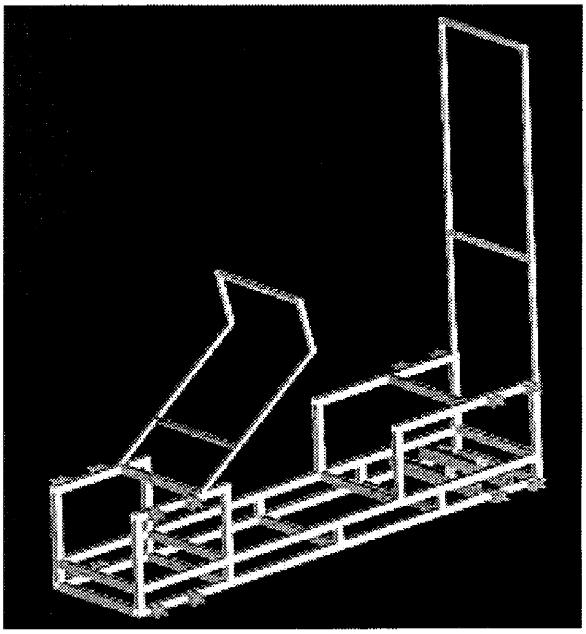

Fig. 6 Assembled frame construction

2.5 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 7. 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 8 shows the examples of analyzed results.

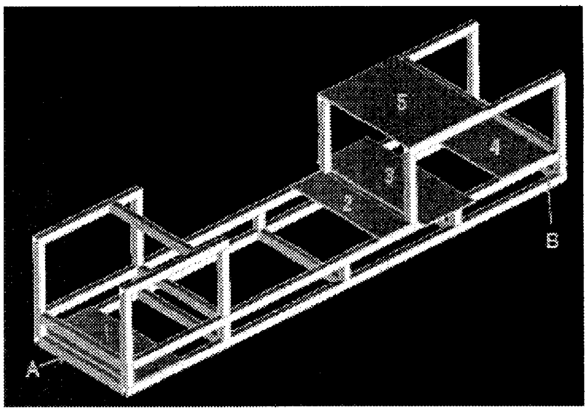

Fig. 7 Stress analysis (number designates force location)

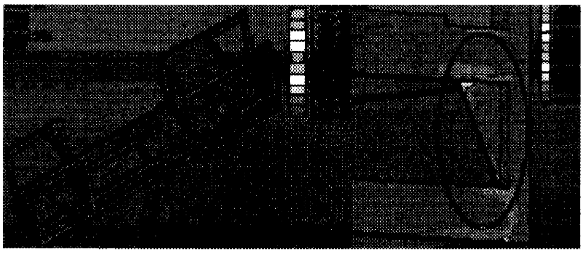

Fig. 8 Examples of stress analysis results

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

2.6 Manufacture of vehicle frame and assembly

The frame was assembled by welding. Figure 9 shows the appearance of the produced vehicle frame. Since the laboratory does not possess the welding tool, we asked a company near the university to manufacture. The frame weight is 2 kg lighter than the previous one shown in Figure 4, 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.

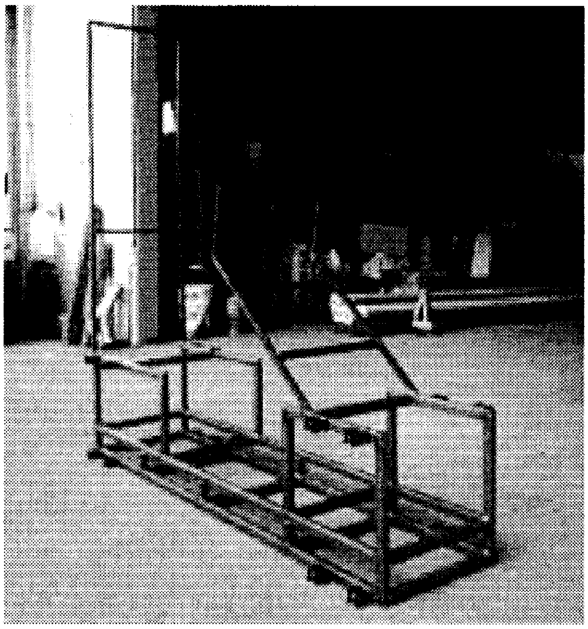

Fig. 9 Welded frame assembly

2.7 Running test using the produced electric vehicle

The Electric Vehicle was completed by assembling. Figure 10 is the finished Electric Vehicle. As a result of the running tests, the running velocity was not so high and was under 30km/h. However, the velocity was the design aim. It remains that there is an automatic control issue.

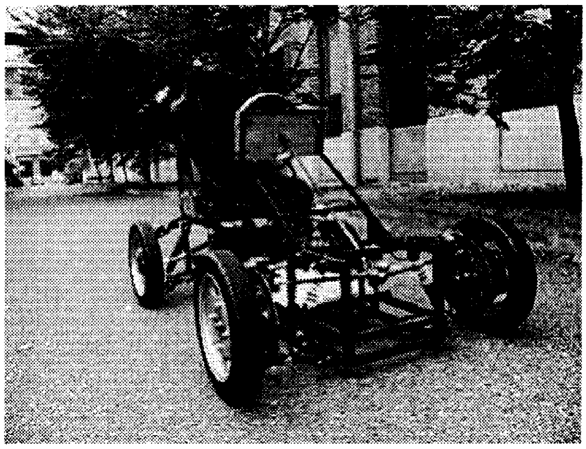

Fig. 10 Manufactured hand-made electric vehicle

3. BATTERY CHARGE WITH RENEWABLE ENERGY

3.1 Battery charge method

FFor renewable energy utilization, we need to consider how to charge the batteries for electric vehicles. We might be able to use the fuel cell battery in the future. In order to charge the electricity for electric vehicles, we planned to use the self-powered electricity, which is produced by a wind-solar hybrid power system. The self-powered street light whose electricity is from wind and solar panel was installed in our university. The experiment had been conducted using the system, and the capability was studied.

3.2 Self-powered street light

Large-scale wind power generators have been being installed in recent years in many countries. Compared to the large ones, the efficiency of small-sized wind power generators is not sufficient at this moment. However, it is required to provide more economical and efficient small-sized generators from the viewpoint of earth ecology and global warming. We have researched the efficient power generators for especially small sized ones [Sakamoto, et al, 2003]. In 1998, we started a project to study how to obtain and spread local clean energy in a local area such as our prefecture, Kochi.

The idea is to use a special power generator with Nd-Fe-B permanent magnets and coreless coil. In general, steel material is winded by copper wire as electric magnets, which are cored coil. However, cored coil causes to pull each other with permanent magnet as rotational parts inside the generator. The pulling force is called cogging torque. If coil is without the steel (coreless), the cogging torque will be zero, and it causes easy rotation. Easy rotation means the one even when wind velocity is small like in the town area, not in the mountainous area. We developed the coreless coil generator, and the power generator with savonius wings as shown in Figure 11. The commercial use started in 2001. Today 50 units of savonius wind power generators are used in Kochi. Figure 11 shows the self-powered street light (left), power generating system (right).

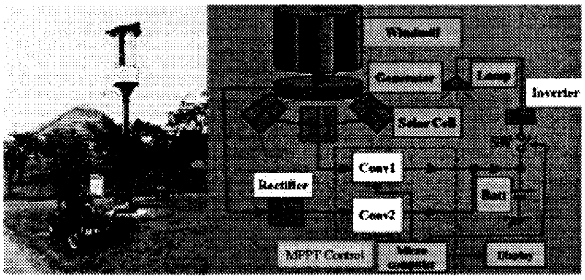

Fig. 11 Self-powered street light (left), power generating system (right)

4. CONCLUDING REMARKS

A hand-made small-sized electric vehicle 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 that 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.

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