Student Formula Project at Tohoku University

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Abstract

Student Formula Japan is a design competition organized by the Society of Automotive Engineers (SAE) of Japan. In this competition, which was inspired by Formula SAE in the USA, students organize a team themselves and manage all activities of producing a small formula-style racing car. The competition emphasizes not only running performance but also the car concept, design, cost, and all the aspects of the vehicle. In 2013, Tohoku University will take part in Student Formula Japan for the first time and enter the electric car class, which is due to be established. This report introduces Formula Student Japan and the Student Formula project at Tohoku University.

1. Introduction

Recently, the number of students is decreasing because of the falling birthrate. Moreover, young people are shying away from scientific fields drastically. Those trends might lead to the Japanese automobile industry losing its international competitive power and losing talented engineers in the future.

In the USA, it was noted that excellent engineers cannot be nurtured only in classrooms. Actually since 1981, SAE International has held Formula SAE as a practical student education program to provide opportunities for students to create objects. In this competition, students manage a team on their own to plan, design, produce and test a formula car. While creating their cars, students acquire widely diverse practical knowledge that is not limited to machinery and electronics. They also strive to increase performance, reduce costs, and improve their vehicle marketability. Leadership and teamwork among members is fostered with a strong sense of camaraderie. Therefore, this competition sharpens students' ability to identify and resolve problems on their own. They experience the magnificence and fun of manufacturing. Results show that a basis for nurturing human resources has been established through cooperation of industry, academia, and governmental offices.

In Japan, however, the curricula of engineering universities is currently lacking in practical, design/drawing elements, and other skills, thereby engineering a shortage of opportunities for object creation. Although solar car conventions and robot contests have been established as nationwide contests for object creation in Japan, no design contest has given full play to the special technologies obtained by students aiming at being active in automotive technology fields.

Under these circumstances, JSAE chose to hold the Student Formula Japan. Students can create an object independently, which enables them to deepen their understanding of technology, cultivate their practical abilities, and strive enthusiastically to achieve higher levels of accomplishment. The competition intends to aim at nurturing engineers who are rich in originality through an environment of object creation, in which they can learn the essence of object creation and the processes this entails, as well as experiencing team activities, and the difficulty, interest, and enjoyment of object creation.

In 2013, Tohoku University will take part in Student Formula Japan for the first time. It will enter the electric car class that is going to be established.

This report introduces the Student Formula project at Tohoku University. First, all events of the competition and their outline are shown. Second, we will write about the concept of student formula teams and show the composition, work and objectives for this year of the team from Tohoku University. Third, we describe the model and specifications of general student formula cars and the distinctive approaches at Tohoku University. Finally, we summarize this report.

2. Outline of competition

This competition emphasizes not only the running performance, but also the car concept and design, as well as costs and other vehicle aspects. The competition has three categories of evaluation: technical inspection, static events, and dynamic events. In the technical inspection, compliance with the safety and design requirements of the vehicle is tested. The static events consist of cost, presentation, and design events. The cost event is aimed at teaching competitors that budget and cost management are important factors that must be considered when manufacturing vehicles. The presentation event aims to assess the competitor's presentation skills. In the design event, an evaluation is conducted based on pre-submitted design materials and the vehicle itself. The dynamic events consist of acceleration, skidpad, autocross, endurance and fuel efficiency event. The acceleration event is a 0–75 m acceleration test. The skidpad event evaluates a performance of cornering on a figure-eight course. In the autocross event, competitors run one full lap of a roughly 950 m course that includes straights, bends, slaloms and chicanes. In the endurance event, competitors run 22 full laps of a roughly 1,000 m course which is similar to one of the skidpad. In addition, the car's fuel consumption is measured during the endurance event. Then the fuel efficiency event is conducted based on those data.

3. Team

The concept behind Student Formula is that a fictional manufacturing company has contracted a design team to develop a small Formula-style race car. Tohoku University Formula

Team, the Student Formula Japan team of Tohoku University, consists of technical teams and administrative teams. Technical teams are divided into a chassis group, a drivetrain group, and an education group for new students. Administrative teams advertise the team, manage resources, and raise funds for the program. The race team handles maintenance of all racecars, testing of various components, and training of the drivers. These activities promote careers and excellence in engineering because they cover all aspects of the automotive industry including research, design, manufacturing, test, development, marketing, management, and finance. This year, the Tohoku University Formula Team aims at winning the total performance award.

4. Car

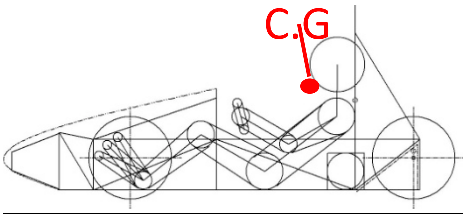
4.1. Specification of general student formula cars

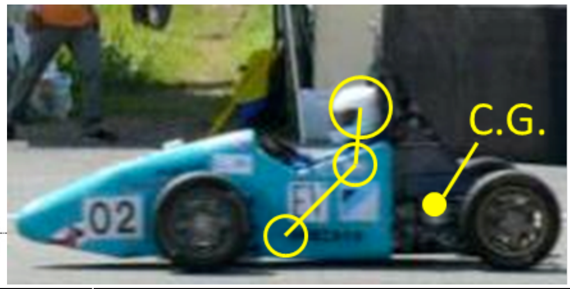
The prototype race car is to be evaluated for its potential as a production item. Because the target marketing group for the race car is the non-professional weekend autocross racer, the car must have excellent handling, braking and acceleration performance. The Student Formula Japan car weighs 150–200 kg with horsepower figures of 30–80 kW and a 0–100 km/h time in the 4–5 s range, lateral acceleration of up to 2.0 g and a 60 to 0 braking distance of about 35 m. However, dynamic performance alone is insufficient. The car must be affordable, easy to maintain, and reliable. In addition, ergonomics and aesthetics must be considered. Any team can achieve these requirements using large amounts of money, but the Formula SAE competition requires that the maximum cost of the car not be more than $25,000.

4.2. Our car

4.2.1. Concept

Our concept is to maximize the merits of electrification. The merits are as follows. First, because the battery can be placed near the center, good weight balance and mass concentration will be gained. Second, the electric motor requires no large space and the driving position can be put close to the center of gravity. Thereby, the design can realize unity of the car and driver. However, rival cars use a frame designed for an internal combustion car, so they cannot take full advantage of electric car capabilities. Therefore, we design a car tailored for the electric powertrain, which makes the most of electrification. The concept of our car TF13 is human-centric. In other words, it is an easy-to-use tool of human beings. Comparison of TF13 with the competitor is presented in Fig. 1. The important features of TF13 are its short wheelbase, short overhang, good weight balance, mass concentration, and the appropriate driving position. They will lead the car to have quick and neutral handling and good performance in the autocross and endurance event will be expected.





Frame	Steel	Frame	Steel
Body-work	GFRP	Body-work	CFRP
Overall Length	2450 mm	Overall Length	2815 mm
Wheelbase	1530 mm	Wheelbase	1600 mm
Track	Front: 1175 mm	Track	Front: 1150 mm
	Rear : 1175 mm		Rear : 1150 mm
Height	1050 mm	Height	1074 mm
Ground Clearance	37.5 mm	Ground Clearance	36 mm
Wheel	13 inch	Wheel	13 inch
Weight	270 kg	Weight	270 kg
Weight Dist.	50 : 50	Weight Dist.	30 : 70
Rated Power	12 kW	Rated Power	15 kW
Max. Power	30 kW	Max. Power	37 kW
Battery	Li-ion, 5.9 kWh, 84 V	Battery	Li-ion, 380 V
Suspension	Front: Pushrod	Suspension	Front: Pushrod
	Rear : Pushrod		Rear : Pullrod

Fig. 1 Comparison of TF13 with the competitor.

4.2.2. **Chassis**

The points on the designing chassis are manufacturability and human-centricity. Manufacturability is the most important point for the team which participates in the competition for the first time, as we are. To design a chassis that is easy to manufacture, we took the following approaches. First, we used steel pipes as the main structure. Unlike carbon fiber monocoque, steel spaceframe is inexpensive and workable. Furthermore, the steel spaceframe is repairable if the chassis get broken. These characteristics are suitable for fresh team like ours. Second, we designed the chassis to have as few welded points as possible. For example, the lowest frame of both the right and left side of the car are made of continuous pipes. It contributes to reduction of cost and improvement of accuracy. Human-centricity is our strongest theme. Our ways to realize human-centricity are as follows. First, we put heavy components such as batteries near the center from side view. It enables mass concentration and appropriate weight balance. Second, the driving position is put at the center of gravity of the car. Therefore, the driver will feel unity and controllability. Third, the frame is designed so that the toe variation is less than 0.001 degree on 1 G turn. Cornering force is generated by slip angles of tires and 1 degree rudder variation generates 1000 N cornering force. The toe decrease results from centrifugal force; it will cause understeering if the lateral body stiffness is insufficient. Therefore, to realize pure handling, we think much of lateral body stiffness. Figure 2 presents results of displacement analysis of 1 G turn using software: (SolidWorks 2010). From the displacement of each section, it is recognized that the toe variation is less than 0.001 deg on a 1 G turn.

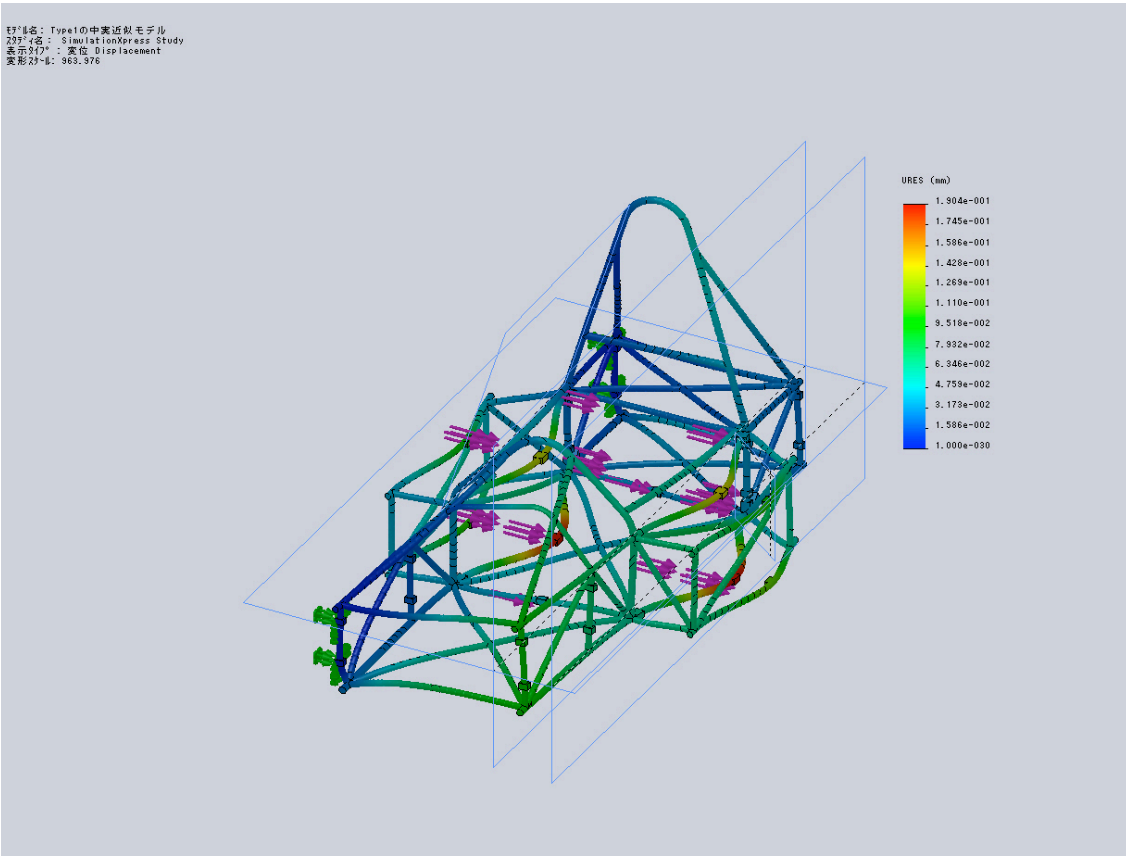


Fig. 2 Result of displacement analysis.

4.2.3. Drive train

As the chassis, the points on the designing drive train are manufacturability and human-centricity. Sufficient reduction is necessary for powerful acceleration, but we want to avoid having manufacturing and setting of the reducer complex. Therefore, the simple reducer with chain drive is adopted. Because generation of sufficient torque in a wide range of revolutions is one merit of the electric motor, we abolished the transmission to realize easy driving. The motor is chosen in reference to the power of the competitors with lightness and smallness paramount in thinking to reduce mass and inertia moment of the car and develop human-centricity. The battery specification is decided based on the running data of the competitors as well as the motor. On validation of selection of the battery and the motor, the performance curves are used. The maximum power of the battery and the running resistance on each running velocity is depicted in Fig. 3. The intersections of the graph indicate the maximum velocity on 3C continuous discharge, which is ensured by the manufacturer. From Fig. 3, it turns out that our car can do 106 km/h at maximum. Figure 4 is the travel performance curve. The driving force of the motor and the running resistance on each running velocity are shown. The driving force is calculated based on the rated output, the rated revolution and the maximum revolution. The intersections of the graph show the maximum velocity. From this figure, we infer that our car can do 90 km/h at minimum. For these discussions, it is considered that the performances of our motor and battery are not insufficient for the autocross or endurance course.

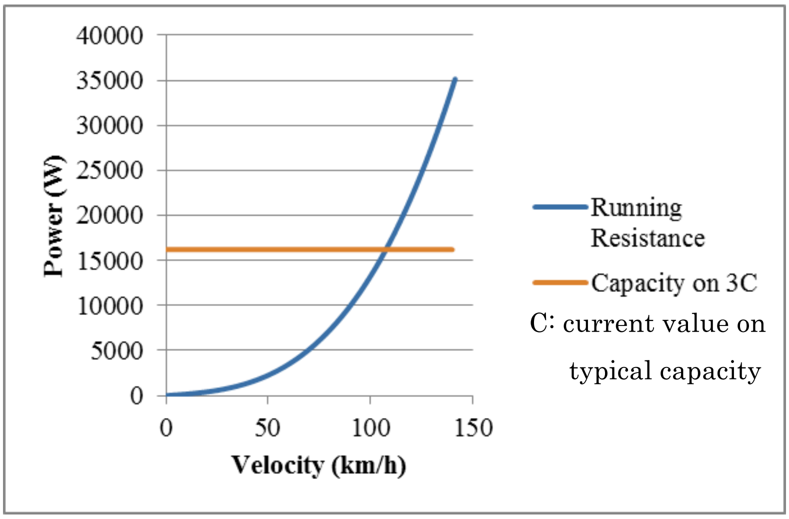


Fig. 3 Battery performance and the running resistance.

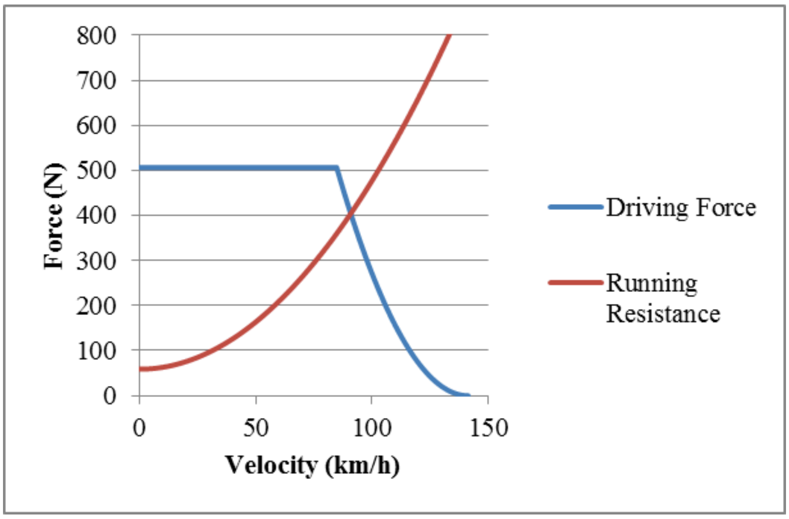


Fig. 4 Travel performance curve.

5. Summary

In this report, we introduced formula Student Japan and Tohoku University Formula Team. Formula Student Japan is a design competition sponsored by SAE of Japan to develop excellent engineers through practical experience. Students set up and manage a team. Then they plan, design, and produce a formula car independently to win the competition. In this competition, not only running performance but also the concept, design, cost, and all aspects are evaluated. In 2013, Tohoku University will take part in Student Formula Japan for the first time and enter the electric car class which is going to be established. Tohoku University consists of technical teams and administrative teams. We operate to win the total performance award. The prototype race car is to be evaluated for its potential use as a production item. The target marketing group of the race car is the amateur weekend autocross racer. We initiated the concept of human-centric for our racecar. It has many special features that include its short wheelbase, short overhang, appropriate weight balance, mass concentration, and driving position close to the center of gravity. These are expected to realize quick and neutral handling and to provide good performance in autocross and endurance events.

References

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