論文　**Original Paper**

Project Based Learning Education and Development Research through Production of Formula SAE® Car

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Abstract: The aim of the foundation of our Faculty of Engineering at Kokushikan University is to educate both creative and executively able engineers. Moreover, they can contribute to happiness of mankind and progress of culture and technology. The core education of our Faculty is creative engineering education by ''Manufacturing''. The remarkable example of this education is Formula Car Project challenged by Department of Mechanical Engineering and Applied Information Technology. Students decide by themselves the concept of Formula vehicle following the SAE Formula Regulation. This program is planned in order to bring up the ability of settling and solving the problems through teamwork. Kokushikan University carries out this as Project Based Learning (hereafter called ''PBL'') education. The distinctions of this education are as follows:

[1]　Our university has started PBL education program since 2002 Formula SAE® Competition. From the regulation, the team need to manufacture the new competition vehicle every year. The team takes out new subjects, and challenges new technology every year. All of the members can acquire the ability for the resolution of the problems occurred in the development process through the group activity. Moreover, they must design the vehicle in consideration of creativity, safety, high performance, light weight, endurance, low cost, styling by adopting various types of simulation methods.

[2]　This project is one of the practical educations, in which the members set up the new subjects and resolve them in recognition of the importance of teamwork. Both to continue this activity every year and to improve the skill are important factors in this PBL program.

[3]　Students, who join this program, can understand through the above-mentioned experience that manufacturing is fan and hard and they can improve their communication ability and international sense.

Keywords: Design, Manufacturing, Evaluation, Experiment, Numerical Analysis/Project Based Learning, Formula SAE®, Education, Gasoline Engine, Bench Test, CFD (Computational Fluid Dynamics), VES (Virtual Engine Simulation)

1. Introduction

The aim of the establishment of the Faculty of Engineering at Kokushikan University is to educate both creative and executively able engineers. Moreover, they can contribute to happiness of mankind and progress of culture and technology. The core education of the Faculty is creative engineering education by manufacturing generally on the base of the result of development research. The remarkable example of this education is a formula car program challenged by the Department of Mechanical Engineering and Applied Information Technology[1]-[3]. The students, who participated in this program, decided by themselves the concept of a formula-style racing car following 2005 Formula SAE® Rules[4]. They designed the car according to the concept and manufactured most accurately parts as many kinds of the parts as possible. Then, the individual parts including the commercially available parts were suitably fitted for assembly. The car was completely adjusted after finishing the assembly. Next, the students performed the shake-down test and the drivers were trained as much as possible for 2005 Formula SAE® Competition[5]-[12]. At the same time, they found out the problems to tackle during this process and solved each problem one by one. Besides, they had to confirm the durability of the manufactured car. Finally, the car was judged in a series of static and dynamic events including: technical inspection, cost, presentation, and engineering design, solo performance trials, and high performance track endurance by taking part in 2005 Formula SAE®

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Competition. This program is planned in order to bring up the ability of settling and solving the programs through teamwork. Kokushikan University carries out this as Project Based Learning education[1]-[3]. Some subjects in the formula car program have been taken up as graduation or master theses. Our university has started PBL education program since 2002 Formula SAE® Competition. In addition to the PBL education, the authors refer to the result of the development research connected with this practical education in this paper. The 2005 Formula SAE® Rules provide that a single circular restrictor must be placed in the intake system between the throttle and the engine in order to limit the power capability from the engine[13]-[17]. Therefore, the improvement of the intake system with the air restrictor is the most important factor for the engine of high performance[18]-[23]. Then, this paper refers mainly to the improvement of air flow inside of the air restrictor system, which can take the great effect on engine performance. Firstly, this paper refers to the determination of the dimension and the configuration of the throttle-air restrictor system by CFD analysis in order to increase the air flow. Secondly, this paper refers to the effect of the intake collector volume and the intake runner length on engine performance. Lastly, this paper refers to the effect of the secondary injection on engine performance.

2. PBL Education Program

2.1. System of PBL Education

This program has five important points, which are as follows;

[1] The students decide by themselves the concept of the formula car following Formula SAE® Rules. Moreover, this program takes into consideration that the students themselves bring up the ability of settling and solving the problems through teamwork.

[2] Some themes related to the formula car are taken up as graduation or master theses.

[3] The results of the theses are taken in the design and the production of the formula car. Moreover, the students make reports after solving the problems except the theses through teamwork.

[4] The system is built up so that not only the faculty professors' but also company technical experts' advices can be accepted.

[5] The students strengthen the connection among team members and work together mainly as students programs.

2.2. Method of PBL Education

The project team is divided into groups, that is, management group and design-manufacturing group. Moreover, each group has some subgroups. The design-manufacturing group is composed of four groups: power control, chassis, power train and manufacturing. Each subgroup posts a few students under the student in charge of the section. The jobs by younger ones are different from those by the elder ones. The team is organized so that the elder student can teach their acquired management and technology to the younger ones.

2.3. Design Processes of PBL Education

There are the three processes in the design stage. The students estimate the previously-made car in the first step of the design, and they extract the problems to tackle from this estimation. Then, the new concept, for the new car to be manufactured from then on, is decided. In deciding the concept, as much students' creativity as possible is tried to be incorporated. In the second step, the students decide the parts for the new car by estimating the existing parts and also fitting them to the prototype parts. Then, they confirm the total design of the new car. In the third step, the students estimate the vehicle performance by the simulations, that is, CAD, CFD, FEM, VES, etc., and calculate the weight and strength by computer. Moreover, they decide the final design by confirming the vehicle layout by solid 3D-CAD.

2.4. Manufacturing Target in PBL Education

In the manufacturing process, the policy of its manufacturing is both to improve the quality of the manufacturing parts and to observe the decided schedule strictly. In order to improve the quality, it is important to improve accuracy of the finishing and to make the touch perception of the finished parts fine. In order to observe the schedule strictly, it is necessary to decide the person in charge and besides to hold the regular meetings by all team members for grasping the present situation.

2.5. Shake-Down Test in PBL Education

The students of this project must design and completely make their formula car within one year permitted by the rules. After making completely the formula car, the students must perform the shake-down test and train drivers as much as possible. At the same time, they must find out the problems to tackle during this process. When the problems occur, they must solve each problem one by one. Finally, they must confirm the durability of the manufactured car for taking part in 2005 Formula SAE® competition.

3. Formula SAE® Competition Objective

According to 2005 Formula SAE® Rules[4], the competition objective is as follows; The Formula SAE® Competition is for SAE student members to conceive, design, fabricate, and compete with small formula-style racing cars. The restrictions on the car frame and engine are limited so that the knowledge, creativity, and imagination of the students are challenged. The cars are built with a team effort over a period of about one year and are taken to the annual competition for judging and comparison with approximately 140 other vehicles from colleges and universities throughout the world. The end result is a great experience for young engineers in a meaningful engineering project as well as the opportunity of working in a dedicated team effort.

4. Concept of 2005 Formula Car and Design Condition

Figure 1 shows the concept for a 2005 small formula-

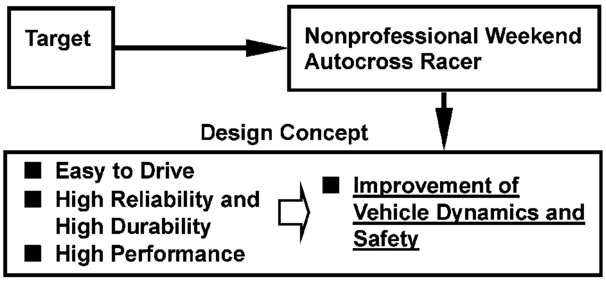


Fig. 1 Concept of KU–004 Formula Car

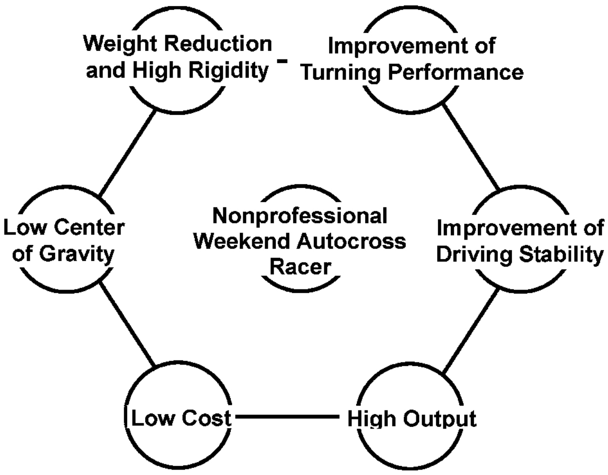


Fig. 2 Fundamental Conditions of Design

style racing car (hereafter called "2005 formula car" or "KU–004") of Kokushikan University. The concept for 2005 formula car was decided in full consideration of producing a small formula-style racing car for the nonprofessional weekend autocross racer. The design concept entailed the following factors. That is, being easy to drive, high reliability, high durability, and high performance. Based on the above-mentioned concept, the students designed and fabricated the car which placed emphasis on the improvement of vehicle dynamics and also safety. Figure 2 shows the fundamental conditions of the design. The design plan following the concept of a new prototype car are shown in this Figure. The design plan was composed of six subjects, that is, weight reduction and high rigidity, improvement of turning performance, improvement of driving stability, high output, low cost, low center of gravity. The students themselves who belonged to the formula car project found out the problems in the design stage which had to be solved, and they actually solved them through teamwork. The design stage for a new formula-style car was divided into three-step processes, as stated before. As for the control of design schedule, it was necessary for the students to make a mature plan, at first. Moreover, let them carry out project exactly on schedule. This is the very important point.

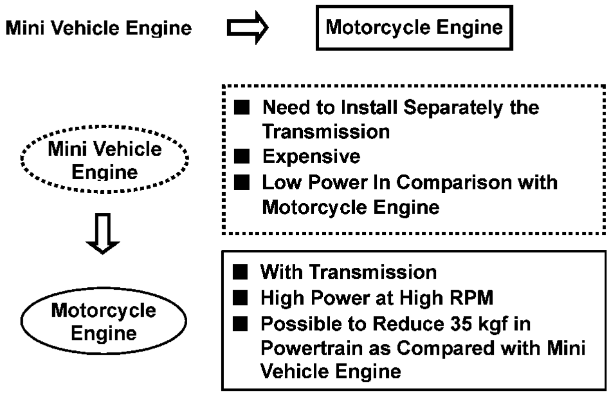


Fig. 3 Consideration of Engine and Transmission System

5. Selection of Engine in Accordance with Concept of Formula Car

The concept for the KU–004 formula car has been already decided in consideration of manufacturing a small formula-style racing car for the nonprofessional weekend autocross racer. So the design concepts was as follows;

[1] Being easy to drive,
[2] High reliability and high durability and
[3] High performance.

The formula car placed great emphasis on the improvement of vehicle dynamics and also safety. In order to satisfy these requirements, the engine of the formula car must have high power in the wide operating range and high torque in the low speed. The weight of rotating shaft system must be light besides. Figure 3 shows the comparison of the general features for the engine and transmission system between mini-sized motor vehicles (hereafter called "mini vehicle") and motorcycles. As this Figure shows, the mini vehicle engine needs equipping the transmission separately. Namely, that enhances the weight and the cost. And furthermore, its power is lower. On the other hand the motorcycle engine contains the transmission in itself, so the weight can be reduced. Moreover, the motorcycle engine has higher power and higher revolution. As the result of examining above-mentioned factors, the project team decided to equip a motorcycle engine for the KU–004 formula car in succession from the preceding year instead of the mini vehicle engines adopted previously.

6. Features of Newly Adopted Engine and its Vehicle

Formula SAE® Rules provide that the engine used to power the car must be four-stroke piston engine with a displacement not exceeding 610 cc per cycle. The engine can be modified within the restrictions of the rules. The air for the engine must be pass through a single air intake restrictor. The project students decided to adopt the motorcycle engine in due consideration of the rules besides. Table 1 shows the specifications of the newly adopted PC37E engine with natural aspiration as compared with the previ-

Table 1 Main Engine Specifications

Item \ Year	Base Engine	2002 (KU-001)	2003 (KU-002)	2004 (KU-003)	2005 (KU-004)
Engine	K6A, Natural Aspiration	K6A, Turbocharger	K6A, Turbocharger	PC37E, Natural Aspiration	PC37E, Natural Aspiration
Type	4-Cycle, Gasoline	4-Cycle, Gasoline	4-Cycle, Gasoline	4-Cycle, Gasoline	4-Cycle, Gasoline
Number of Cylinders	In Line, 3 Cylinders	In Line, 3 Cylinders	In Line, 3 Cylinders	In Line, 4 Cylinders	In Line, 4 Cylinders
Valve Train System	DOHC Chain Drive IN: 2, EX: 2	DOHC Chain Drive IN: 2, EX: 2	DOHC Chain Drive IN: 2, EX: 2	DOHC Chain Drive IN: 2, EX: 2	DOHC Chain Drive IN: 2, EX: 2
Bore and Stroke mm	68.0×60.4	68.0×60.4	68.0×60.4	67.0×42.5	67.0×42.5
Compression Ratio	8.6	8.6	8.6	12.0	12.0
Displacement cc	608	608	608	599	599
Maximum Power kW/r/min	32.3/6000	42.3/6000	46.4/8000	47.9/10000	54.0/10000
Maximum Torque Nm/r/min	43.1/3500	67.4/6000	71.8/6500	47.5/9000	53.2/9500

Table 2 Ratios of Weight to Power and to Torque for Mini Vehicle and Motorcycle Engines

Engine	Ratio of Weight to Power kgf/kW	Ratio of Weight to Torque kgf/Nm
Mini Vehicle Engine (Natural Aspiration)	7.65	4.94
Motorcycle Engine (Natural Aspiration)	4.74	4.67

ously adopted K6A engine. The K6A engine, the PC37E engine is the previously adopted mini vehicle engine, the newly adopted motorcycle engine, respectively. The motorcycle engine has higher maximum power and lighter weight in comparison with the mini vehicle engines. Table 2 shows the comparison between the mini vehicle and the motorcycle engine in the rations of weight to power and to torque. Both the ratios values of the motorcycle engine are smaller than those of the mini vehicle engine. The power train of the motorcycle decreases its weight by 35 kgf as compared with that of the mini vehicle in the natural aspiration engine. As the weight and the rotational inertia moment of the KU-004 car with the motorcycle engine could be made lighter and smaller, respectively, the acceleration performance could be improved. And further, the load distribution ratio could be brought to 48:52. As the center of gravity became lower and could nearly arrange in the center of the vehicle besides, the dynamic characteristic can be improved.

7. Improvement of Engine Performance by Further Intake System with Air Restrictor

The 2005 Formula SAE® Rules provide that a single circular restrictor must be placed in the intake system between the throttle and the engine in order to limit the power capability from the engine[24]-[32]. And further, the engine airflow must pass through the restrictor. The maximum restrictor diameter of gasoline fueled cars is 20.0 mm. The circular restricting cross section may not be movable or flexible in any way. Therefore the improvement of the intake system with the air restrictor is the most important factor for the engine of high performance. The students of the project team set the problems. That is, what type of engine performance with the air restrictor is the best for the nonprofessional weekend autocross racers. One of the solutions for this problem is to design the power of the engine to be as high as possible in the wide operating range and also the torque of the engine to be as flat as possible within the engine revolutions used most frequently and at the same time to be as high as possible in the low speed range. The high technology for the intake and exhaust system of the engines contributes greatly to the improvement of charging efficiency and thermal efficiency which can satisfy the demand. This paper refers to the improvement of air flow inside of air restrictor system, which can take the great effect on engine performance. Figure 4 illustrates the air intake system with removal of the intake port by solid 3D-CAD. As was stated previously, a single circular air restrictor must be placed in the intake system between the throttle and the engine in order to limit the power capability from the engine. The main factor of the improvement of the engine performance is charging efficiency and thermal efficiency. The thermal efficiency makes very little difference among engines, but the charging efficiency takes an infinite variety of the performance. The charging efficiency can be determined by the specifications of the intake and exhaust including the valve timing. This chapter refers mainly to the improvement of the air flow for the intake system with the air restrictor.

7.1. Determination of Dimension and Configuration of Throttle-Air Restrictor System

The throttle available in the market was used until last

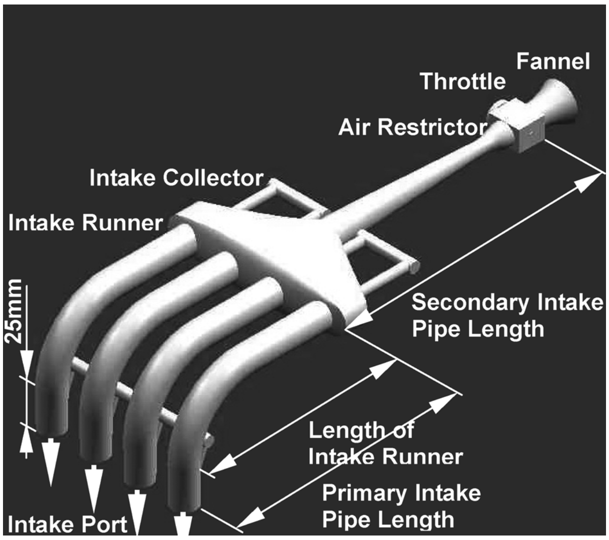


Fig. 4 Air Intake System with Removal of Intake Port by Solid 3D-CAD

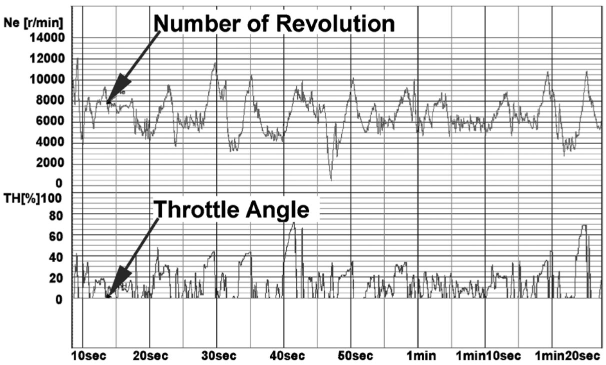


Fig. 5 Relationship between Throttle Angle and Number of Revolutions obtained by Data Logger on Running Speed in Autocross Course

year, so the dimensions of the throttle side were unilaterally determined. In this study, the configuration of the throttle was designed in full consideration of the air restrictor, so the freedom of the air restrictor design increased in order to gain more air flow. The butterfly valve was adopted as the throttle valve, because the response was fast on the partial load which was widely used on the Autocross Course as shown in Figure 5. The diameter of the valve was determined by the computational result of the air flow from the throttle to the air restrictor system: that is ϕ 35 mm. The inclination angle of the diffuser was 3 degree, which was determined by our previous study. Figure 6 shows the throttle body by solid 3D-CAD. The throttle weight was 221 gf. The weight of the newly-designed throttle was reduced by more 60% in comparison with the throttle available in the market. Figure 7 illustrates the drawing of the throttle-air restrictor system. The dimensions shown in this drawing has been already determined by our previous study except the dimensions of L, R1 and R2. The static pressure of the throttle-air restrictor system

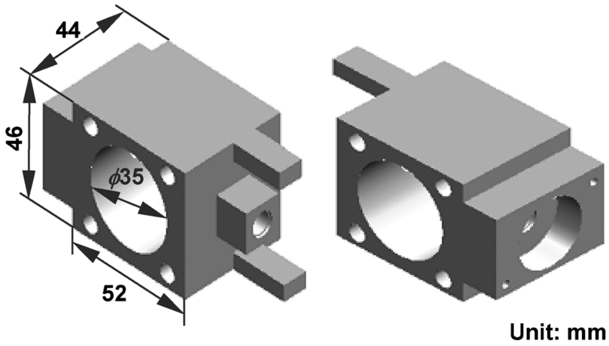


Fig. 6 Throttle Body by Solid 3D-CAD (KU–0004 Formula Car)

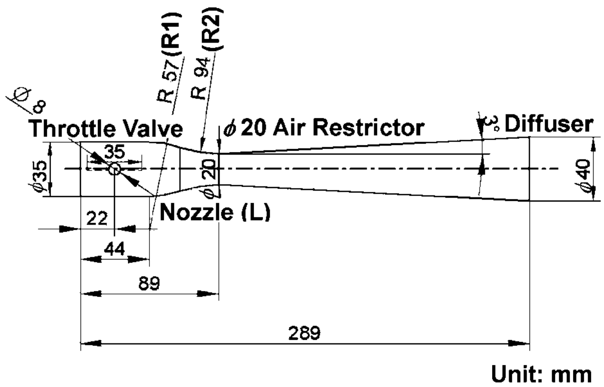


Fig. 7 Throttle and Air Restrictor System

was analyzed by CFD (Computational Fluid Dynamics) in order to increase the air flow[34]-[36]. The software of the analysis is Fluent version 6.0.2.0. Table 3 shows the computational conditions. Table 4 shows the values of parameters R1, R2 and L adopted in the competition. Figure 8 shows the contours diagram of static pressure of type 04 in the wide open throttle. Figure 9 shows the contours diagram of static pressure of type 04 in the throttle angle of 45 degree. The minimum values of the pressure difference between the inlet and the outlet of the throttle-air restrictor system are type 04, 06 on the condition of the wide open throttle (WOT) and type 04 on the condition of the throttle angle obtained by 45 degree. Judging from the results of the analysis, the dimensions of type 04 are the best values in all combinations. Therefore, the dimensions of type 04 was adopted as those of the throttle-air restrictor system. Figure10 illustrates the comparison of the engine performance curves between the last year throttle-air restrictor system (KU–003) and with the newly-designed system (KU–004). The performance tests were carried out on the same experimental conditions (temperature: 283.5 K, atmospheric pressure: 1003.8 hPa, relative humidity: 45%)[33]. The brake torque of the newly-designed system is improved in the wide range of the engine speed. Besides, the brake power is improved in the high range of the engine speed.

Table 3 Computational Conditions

Inlet Computational Conditions	Velocity in Inlet
Inlet Velocity	30 m/s
Inlet Gaude Pressure	0 Pa
Outlet Computational Condition	Out Flow

Table 4 Dimensional Changes of Venturi

Type	L	R1	R2
01	20	19	10
02	30	48	13
03	40	27	94
04	45	57	94
05	60	156	60
06	70	230	66

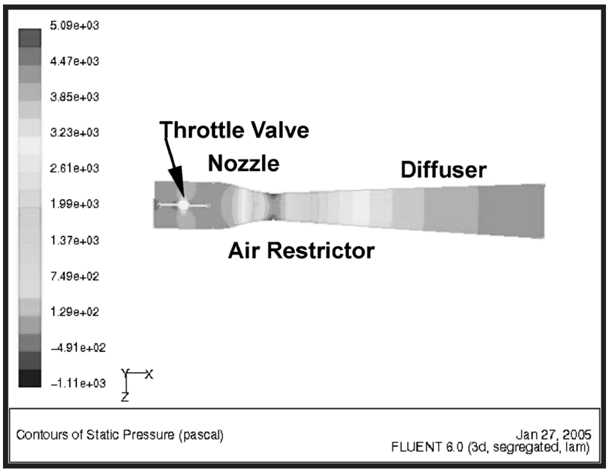


Fig. 8 Contours Diagram of Static Pressure in Wide Open Throttle (Type 04)

7.2. Effect of Intake Collector Volume and Intake Runner Length on Engine Performance

The intake collector can equally distribute the air flow to each cylinder. The shape illustrated in Figure 4 was adopted by the research of our group[37]-[40].

[1] Effect of Intake Collector Volume on Brake Torque

The brake torque was experimentally investigated on the condition that the volume of the intake collector was 1.5 Litter (hereafter called ''L''), 2.0 L, 3.0 L, respectively. The length of the intake runner was selected among 200 mm, 275 mm and 350 mm. Figure 11 (a), (b), (c) illustrates the brake torque characteristics on condition of the intake collector volume change at the constant intake runner length of 200 mm, 275 mm, 300 mm, respectively. The volume change of the intake collector scarcely effects on the brake torque within the experimental conditions. The collector volume 2.0 L has almost a maximum in brake torque, but the response is slow on the low range of the engine speed because of the lower inner pressure of the collector. In the case of the collector volume 1.5 L, the response is fast and also the brake torque keep nearly high in comparison with the other volume. Therefore, the volume of the intake collector was determined to be 1.5 L.

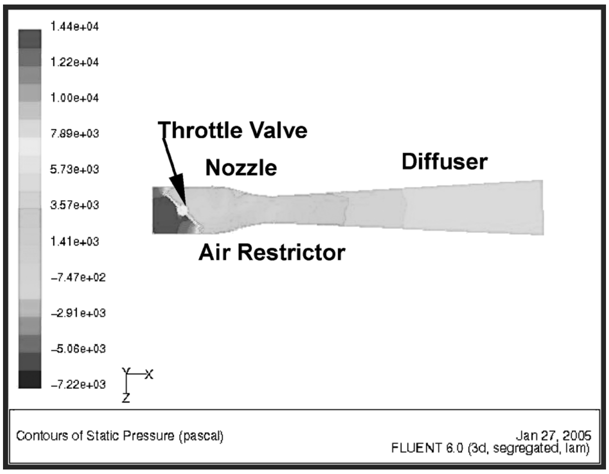


Fig. 9 Contours Diagram of Static Pressure in Throttle Valve Angle of 45 deg (Type 04)

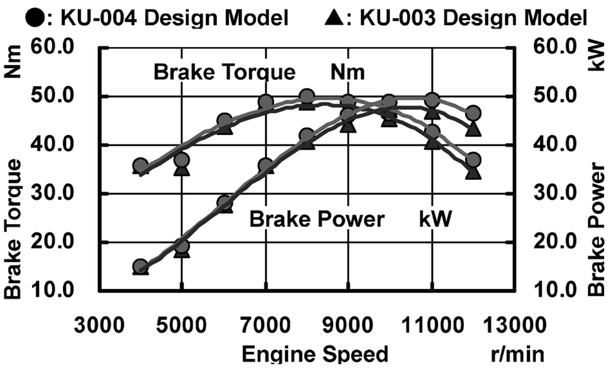


Fig. 10 Comparison of Engine Performance between KU-003 and KU-004 Design Model

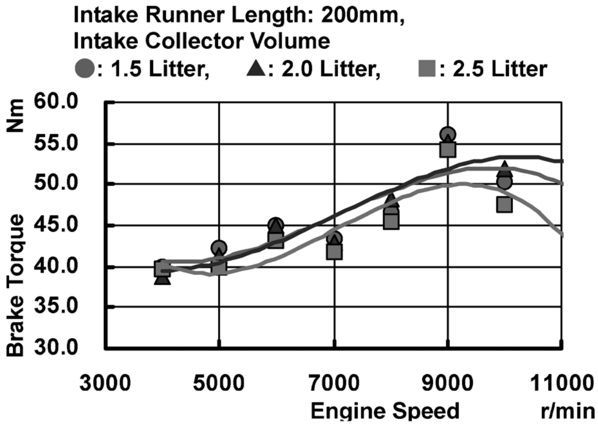
[2] Effect of Intake Runner Length on Brake Torque

Figure 12(a), (b), (c) illustrates the brake torque characteristics on condition of the intake runner length change at the constant intake collector volume. From Figure12, it is shown that the brake torque is greatly influenced by the length of the intake runner. The acceleration and the deceleration occurs frequently on the range of 7000 r/min on the driving conditions (refer to Figure 5). The engine needs as high torque as possible on the range of 7000 r/min, so the length of the intake runner was selected to be 350 mm.

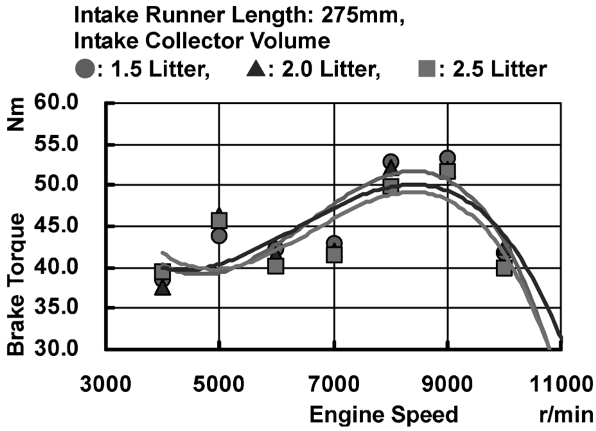
7.3. Effect of Secondary Injection on Engine Performance

[1] Effect of Intake Temperature on Engine Performance

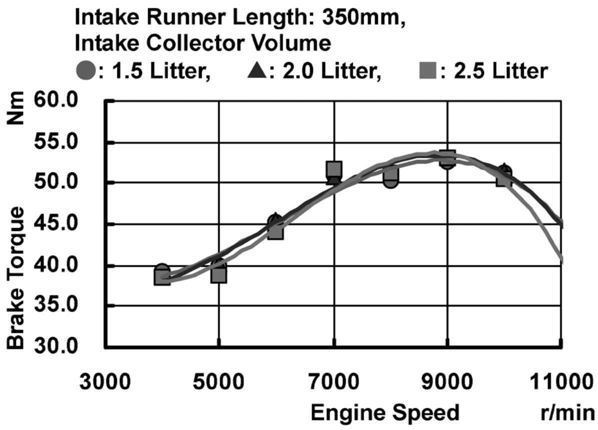
The ambient temperature of the intake inlet can be controlled by the heater. Figure 13 shows the effect of the in-



(a) Constant Length: (200 mm)

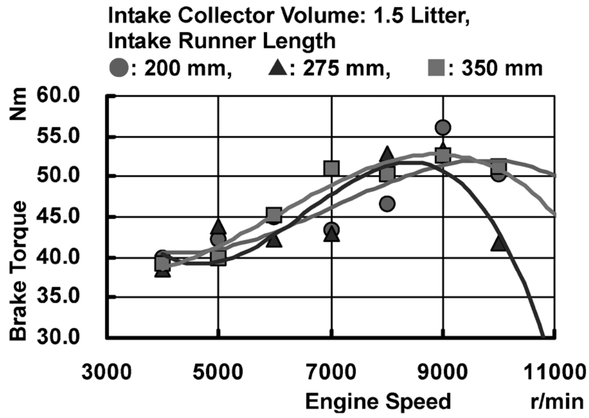


(b) Constant Length: (275 mm)

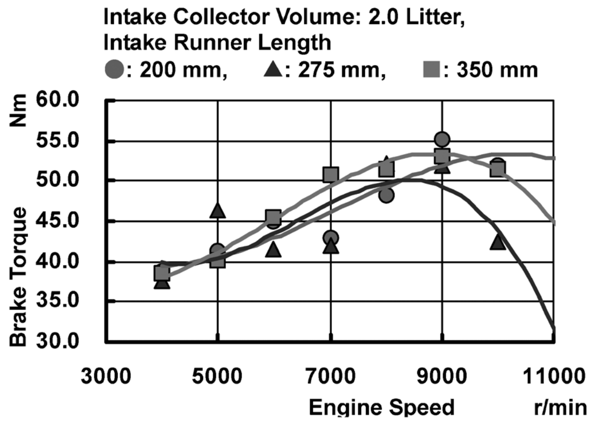


(c) Constant Length: (350 mm)

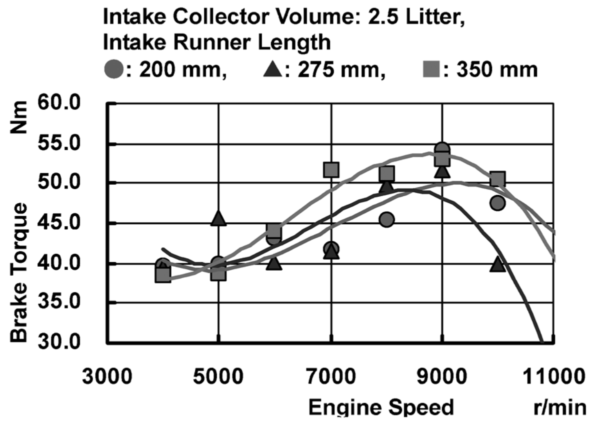
Fig. 11 Brake Torque Characteristics on Condition of Intake Collector Volume Change at Constant Intake Runner Length



(a) Constant Volume: (1.5 Litter)



(b) Constant Volume: (2.0 Litter)



(c) Constant Volume: (2.5 Litter)

Fig. 12 Brake Torque Characteristics on Condition of Intake Runner Length Change at Constant Intake Collector Volume

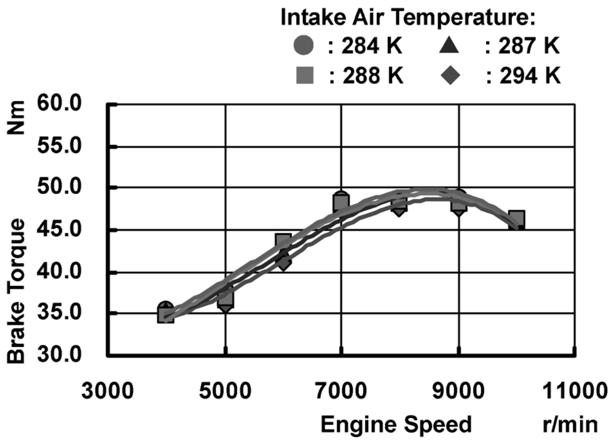


Fig. 13 Relationship between Brake Torque and Engine Speed (Change of Intake Air Temperature at Intermediate Point of the Intake Runner)

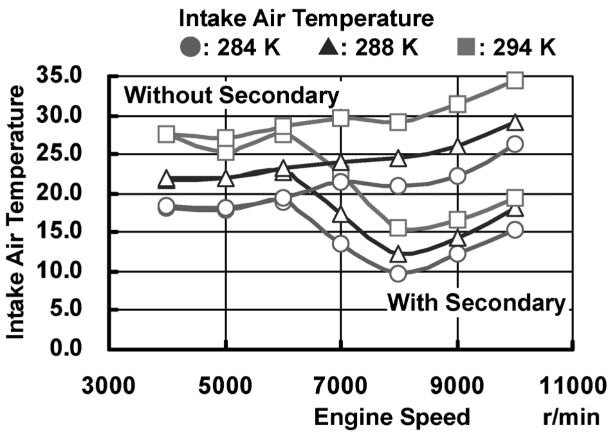


Fig. 15 Intake Air Temperature Change at Intermediate Point of Intake Runner (With, Without Secondary Injector)

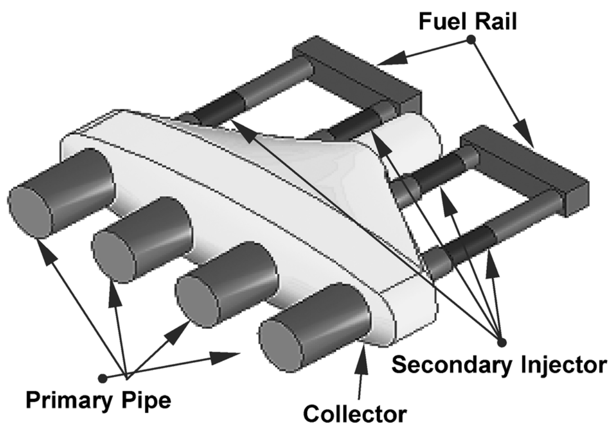


Fig. 14 Schematic Diagram of Secondary Injector

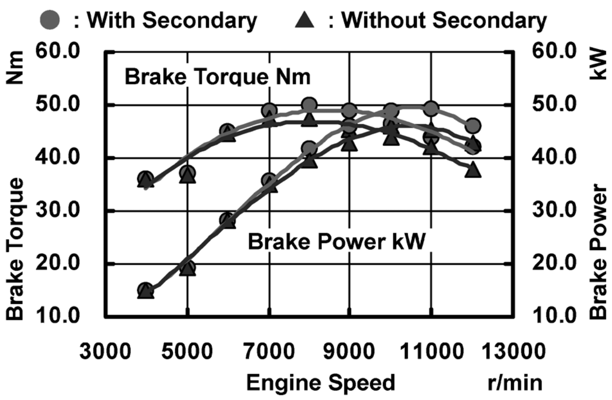


Fig. 16 Comparison of Engine Performance Curves between Intake System with and without Secondary Injector

take air temperature at the intermediate point of the intake runner on the brake torque. The brake torque at the low temperature becomes lightly larger than that at the high temperature.

[2] Effect of Secondary Injection on Engine Performance

In this section, the effect of the secondary injection on the engine performance is investigated from experimental viewpoint[33]. Figure 14 shows the schematic diagram of the secondary injectors. The fuel is injected at the back part of the collector by the secondary injectors in order to decease the intake air temperature. The secondary injectors are controlled by the ECU (Engine Control Unit). The engine control unit system fulfills the intended function over 5500 r/min. Figure 15 shows the intake air temperature change at the intermediate point of the intake runner. The temperatures change greatly over 5500 r/min by fulfilling the intended function. Figure 16 illustrates the comparison of the brake torque and the brake power between with and without the secondary injections. The brake torque and the brake power with the secondary injectors increase over 5500 r/min. The values of the maximum torque and power are 49.2 Nm and 50.0 kW, respectively. The values of the maximum brake torque and power increase 7.0% and 8.0% respectively.

8. KU–004 Formula Car and it's Shake-Down Test

Figure 17 shows solid 3D-CAD drawing of the KU–004 formula car without cowling. Table 5 shows the main specifications and the photo of the manufactured KU–004 formula car. The ratio of the front to rear weight is in the ratio of 48:52 by adopting the motorcycle engine. The vehicle size and the gross vehicle weight could be reduced, also. The students of this project had to design and fabricate the formula car within one year permitted by the regulations. They had to perform the shake-down test and the drivers had to be trained as much as possible for 2005 Formula SAE® Competition. At the same time, they had to find out the problems to tackle during this process. As the problems occurred, they had to solve each problem one by one. Finally, they confirmed as the durability of the manufactured vehicle. Figure 18 shows the performance curves of the KU–004 engine. This performance curves could be obtained from adjusting thoroughly the fuel con-

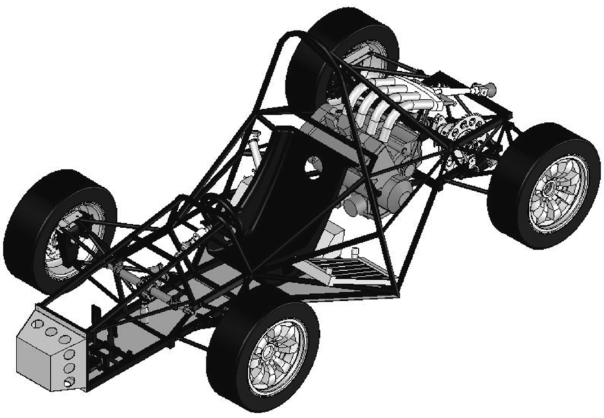


Fig. 17 KU–004 Formula Car without Cowling by Solid 3D-CAD

Table 5 Main Specification of KU-004 Formula Car

Items	KU-004 (2005)
Vehicle Type and Photo	
Overall Dimension	2820 mm · 1346 mm · 1128 mm
Wheel Base Length	1650 mm
Tread F/R	1200 mm/1200 mm
Tire Wheel Size	20.0×6.0–13 inch
Ground Clearance	50 mm
Weight	250 kgf
Load Distribution Ratio	48 : 52
Frame Type	Space Frame (STKM12A)
Engine Type	PC37E (HONDA CBR600RR)
Total Displacement Volume	599 cc
Supercharging Type	Naturally Aspiration
Maximum Power	54.5 kW/10000 r/min
Maximum Torque	53.2 Nm/9000 r/min
Transmission	I Pattern 6 speed Geartrain
Suspension	Non-Paralled, A-Arm, Pull Rod
Brake	Outboard 2-Piston
Bodywork	GFRP-Cowling

trol computer system. Brake power, brake torque has been increased by 14.1%, 10.4%, respectively. The KU–004 engine is further improved in performance as compared with the KU–003 engine.

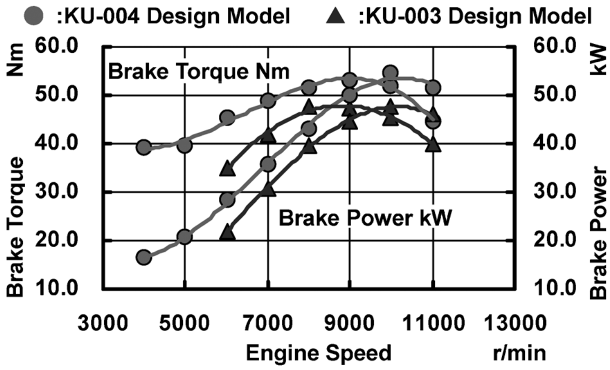


Fig. 18 Performance Curves of KU–004 Engine on Optimum Tune Conditions

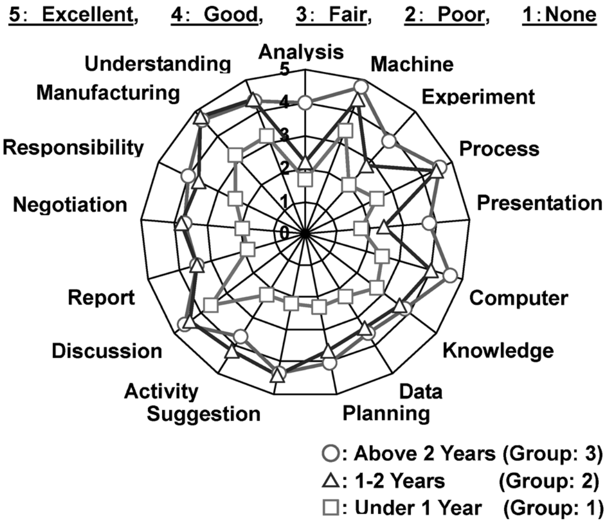


Fig. 19 Result of PBL Education Questionnaire

9. Effect and Advantage of PBL Education Program

9.1. Result of PBL Education Questionnaire

In Figure 19, PBL project students' feelings of achievement, namely, extant of good result, acquirements of technical knowledge and skill, are assessed by five-stage level about 17 items and are shown in circular graph. The students are divided into three groups consisted of under one year (named group 1), above one year under two years (named group 2) and above two years (named group 3) by means of activity term. Out of the questionnaire result, the students both group 2 and group 3 have nearly the same achievement feeling except for a few items. Especially, both of them have enough achievement feeling as for ''manufacturing'' using machine tools. However, the students under two years who didn't engage in real vehicle development felt less achieved because they didn't analyze nor experiment according to their own ideas. The group 1 students' achievement feeling is, as a whole, lower than other two groups. The reason is that the group 1 students did their work not by themselves but under the leadership and the instruction of their senior students. In order to give them the accomplishment feeling, the students must be given the environment where they have their own jobs in charge and carry out their own ideas and thoughts.

9.2. Effect and Advantage of PBL Education by Producing SAE Formula Car

The effect and the advantage of our PBL Education are as follows;

[1] Because of the regulations, the newly built car must be manufactured every year. Therefore, new design and manufacture problems to be solved must be set every year. The student must always challenge new technology. Without any enforcement they can acquire the ability both to establish the subjects and to solve the problems which occurred in the process of development through their group work.

[2] The students who joined this educational program could go through with the precious experience mentioned before. Therefore, they can realize both fun and hardship of manufacturing and besides can acquire both communication ability and international sense.

[3] In the process of designing and manufacturing the formula car,

(I) Creativity is fostered by repeating the new experiences through which the students can search out possibility in the activity of each group.

(II) This education is the precious experience through which the students can be given many chances to apply their knowledge of the special field to the real experience of manufacturing.

[4] We can say that this PBL education can be practical education to learn the importance of teamwork. This education must be done every year continuously. Moreover, it is important to raise students' skill-level every year.

[5] In the international competition piling up various experiences make it possible both to enrich their international senses and to improve their English ability. Through exchanges with the foreign teams, they can get many friends from abroad.

[6] As the other effect except for the above-mentioned ones, 39% of the freshmen knew this PBL education program before entrance and 80% of the freshmen was interested in this program.

10. Conclusions

The authors refer to the PBL education system by the formula car program and its effect, and also the result of the development research connected with this practical education. Their results are as follows:

[1] Our university has started PBL education program since 2002 Formula SAE® Competition. From the rules, the team need manufacture the new competition car every year. The team takes out new subjects, and challenges new technology every year. All of the members can acquire the ability for the resolution of the problems occurred in the development process through the group activity. Moreover, they must design the vehicle in consideration of creativity, safety, high performance, light weight, endurance, low cost, styling by adopting various types of simulation methods.

[2] This project is one of the practical educations, in which the members set up the new subjects and resolve them in recognition of the importance of teamwork. Both to continue this activity every year and to improve the skill are important factors in this PBL program.

[3] The students, who join this program, can understand, through the above-mentioned experience, that manufacturing is fan and hard and they can improve their communication ability and international sense.

[4] The suitable configuration and its dimension of the throttle-air restrictor system were determined from the computational result of CFD (Fluent version 6.0.2.0) in full consideration of the diameter (ϕ 20 mm) of the air restrictor.

[5] As the experimental result of the effect of the intake collector volume and the runner length on engine performance, the volume of the intake collector effects scarcely and the length of the intake runner influences largely on the engine performance within the experimental conditions.

[6] The engine performance is greatly influence by the intake temperature and the secondary injection over 5500 r/min on fulfilling the intended function of the ECU.

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