Tokai University Design Report
2007 Formula Student Car No.27

1. Abstract of our vehicle

The Formula SAE vehicles are divided into the steel pipe frame and CFRP Monocoque. However we feel most of them has similar style and their design is saturated. Therefore we design brand new style vehicle to shift Formula SAE next stage.

To design our Formula SAE race car, we attach importance to light weight, high comparable rigidity, low centre of gravity, uniform stress distribution, high torque at low and middle revolution speed and innovative high quality design. Aerodynamics and maximum horse power don't take high priority considering course layout and top speed restriction. Dynamic image of the vehicle is sharp cornering, little attitude variation, few roll changes, weak over steer and good traction.

2. A7N01 Aluminium twin tube frame

The strongest point of our vehicle is A7N01 aluminium twin tube frame. The structure has two large rectangular tubes located both side of the driver and it is inputted cornering force from the suspension arm in the top and bottom surfaces [Fig.4]. Aluminium collars are located inside of the tube to avoid crushing the tubes and the penetrating long bolts connect the upper and lower suspension arms.

For welded pipe frames, the welded points become weaker under the influence of welding heat and it makes chassis rigidity lower. Therefore, A7N01 which has a special characteristic is used for our frame to avoid this problem. The aluminum has great aging effect in normal temper and 1 month after welding, their strength recovers themselves 90%. More detail about the frame material is shown in our structural equivalency form.

To make the frame more compact and light, the vehicle has minus rear overhang and rear bulkhead is attached at end of the twin tube [Fig.5]. The weight of cutting bulkhead is only 1.5 kg and it is installed the rearward of rear suspension arms, toe control arm, rear bell crank, twin rear damper, rear stabilizer, L.S.D. case, main hoop bracing, engine mount, shift actuator jacking bar and silencer. When the bulkhead is cut off needless volume, firstly needed volume is leaved around each hole, secondly the ribs are arranged connecting tangently for the holes considering input force and direction.

The main hoop bracing is attached the rearward of bulkhead to get over 30 degrees between the main hoop and main hoop bracing, because of quite short rear frame. The bracing is crossed each other to get enough strength in case of lateral direction roll over.

3. Suspension system

3.1 Basic philosophies

Suspension geometry is considered that the tire treads must keep contacting suitable angle with ground any time, however suspension geometry is not able to satisfy all demands. In case of focusing chamber change of ground plane under the acceleration and deceleration, the equal and parallel link system is the best geometry, but the geometry is not good under cornering because of roll angle. Then in case of focusing it under the cornering, the suitable chamber change of ground plane is gotten to make negative chamber angle which is opposite angle with roll angle using unequal and non-parallel link. However the geometry is not good under acceleration and deceleration. Like this, suspension geometry is not finding perfect demand, finding satisfactory compromise.

Then a major factor of producing contrary demands are considered roll angle of the vehicle, therefore apposite chamber change of ground plane under all motion will be gotten to restrain the roll. Moreover to consider suspension geometry, tire specific character such a cornering force-slip angle curve is absolutely imperative but the data is not release. Accordingly, it will be hard to stay in ideal range if unknown tire move too much. As a result, the equal and parallel link system with hard stabilizer is picked up.

3.2 Rear upright

The arm mounts of rear upright have cantilever style which is same with frame side because of weight saving and compact design [Fig.6]. The M8 bolts mount suspension rod end and they are penetrate the M12 bolts which have M12 male and M8 female threads. Then the M12 are attached to the aluminium upright. It avoids snapped bolts leaving inside of the upright by accident. The female M12 of aluminium upright has ribs which are connected tangential with the upright bearing case to make uniform stress distribution. Consequently the upright has only 300 g weights.

In case of supporting axis, it is getting fewer play to detach two supporting point as wide as possible, therefore two bearings are shrunken fit both side of the upright. The rear upper arm have two parallel rod ends in frame side, so the initial camber angle is adjusted the threads. The camber change is also adjusted using shims at upright side of upper arm mount.

3.3 Front upright

The front upright is different from frame and rear upright style, for the reason Ackerman geometry is adjusted using shims between the upright and arm mount blankets [Fig.7]. Then it is hard to cut needless volume from aluminium block because of structural design, therefore the upright is designed welded steel construction. Inside of the construction, the ribs are connected tangential with the spindle case considering each force flow. The upright has some adjustment mechanism at the initial camber angle, camber change, Ackerman geometry, king pin inclination and tread using shims.

3.4 Rear damper system

There are two options in the rear damper system which means mono damper and twin dampers systems [Twin-Fig.5, Mono-Fig.8]. The rear bell cranks are located near top of the rear bulkhead. The torsion bar of rear stabilizer is installed inside of the jack up bar which is located at the bottom of bulkhead, then the stabilizer shaft is connected the bell crank and torsion bar. The strength of the stabilizer is adjusted changing the moment of inertia of the torsion bar. In case of the twin dampers system, the dampers are attached to the bell crank and top surface of the bulkhead. In case of the mono damper system, the damper is attached to the bell cranks with quite hard stabilizer. Each rear suspension system has progressive geometry.

3.5 Front mono damper system

There is different from the rear mono damper system. The front one is longitudinal mounted mono damper system which mechanism is referred to DALLARA F305 [Fig.9]. The rotation axis of Front bell crank is attached to the blankets which are welded to the front hoop bracing. The front push rods are connected to the blanket which are located both ends of the bell crank.

In case of the same forces inputted both front tires such as braking in a going straight state, going through a difference in level, it is just rotated around the axis. However in case of the different forces inputted each front tires such as cornering, braking with turning, the bell crank try to make both front tires the same movements. The bell crank in itself has stabilizer mechanism and it restrict to the roll angle of the vehicle. The strength of restrict ion is adjusted changing materials of collar.

4. Power train

4.1 Engine

From specific characteristic of the track, compact and light weight single cylinder engine is loaded with our vehicle. It is used as an engine of Yamaha's enduro motorcycle called WR450. The engine has only 30kg weight, 5 titanium valves, 5 speed and dry sump system. Originally, maximum horsepower is 44.1 kW (60.0PS) at 9000 rpm and maximum torque is 52.9N･m (5.4kgf･m) at 6500 rpm.

The engine has only carburetion fuel delivery system, it is not good at Formula SAE because of the rule restricts location of the throttle. In case of the throttle located upstream of the restrictor, it couldn't deliver enough fuel-air mixture to the combustion chamber, as a result the horsepower is down over 3000 rpm. To improve such a problem, we change fuel delivery system into fuel injection system using Haltech E6X which change amount of fuel consumption and its angle.

Then high revolution speed is restricted by the restrictor, low cams are installed to shift revolution speed of maximum horsepower and torque to lower range.

If the engine is mounted transversal, it is hard to secure enough space for intake and exhaust systems. There is the seat in the engine intake direction and there is the rear

damper system in the exhaust outlet direction. Therefore the engine is mounted longitude to expand the possibility of intake and exhaust designs [Fig.1]. Then too much work angle is caused to the propeller shaft just changing direction of the engine, therefore the engine is tilted until the work angle becomes zero. Of course it has serious problem in the delivery system of engine oil, so the oil strainer is modified. The rear bulkhead is tilted same angle of the engine and the engine mount bolts penetrate the bulkhead.

4.2 Intake system

In our calculation, air speed of the smallest area of restrictor reaches sonic velocity over 6000 rpm, therefore the restrictor has long diffuser to restrain pressure loss and the air box is installed to make influence of the restrictor weak. The volume of air box is 2500 cc which is 5.5th times of the engine displacement. Then the restrictor is installed inside of the air box to get enough volume and to keep compact style. The suction pipe length is influential with output, therefore it is adjusted to change some parts. The restrictor and air funnels are made form CFRP to make light weight and high strength.

4.3 Limited Slip Differential

The L.S.D. is attached to the rear bulkhead. It is used for Suzuki's ATV called LT-A700XK5 and torque bias ratio is 3.7, gear reduction ratio is 3.

5. Cockpit component & body work

The accelerator and brake pedals are attached to rearward of the front bulkhead and location of the pedals are adjusted with the shims. The brake master cylinders are located under the driver's thigh. A brake bias bar is attached the master cylinders and brake bias is changed by the exclusive wire located left side of the cockpit. The proportioning valve is located at left side of the bottom surface to change the rear brakes character.

The steering wheel is made from CFRP and the clutch paddles are located right and left of behind it. The shift buttons are also located on behind the steering wheel. When driver cut the clutch, the paddles touch the buttons and then engine transmission is changed by the shift actuator. The Shift actuator is attached to the left side of lower rear bulkhead and it changes the transmission obeying the shift button. A digital monitor is attached to the steering wheel and it has the tachometer, thermometer, oil pressure meter, voltmeter, warning light and shift indicator.

The body work is made from aluminium plate and it is considered aero dynamics. Bottom of the forward body is inducer shape and bottom of the rearward body and the end of the side pontoons are diffuser shape. The front body work is designed low and the front mono damper is seen through the clear shield.

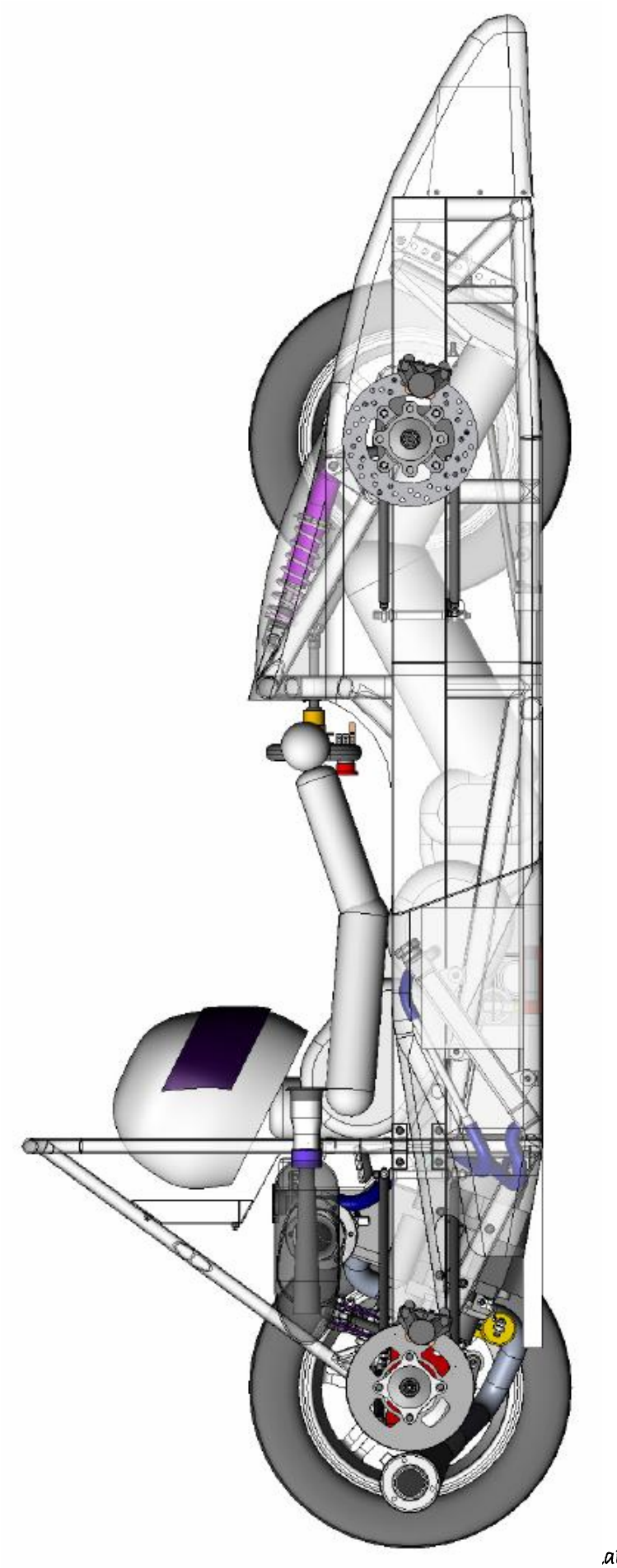


Fig. 1 Side view

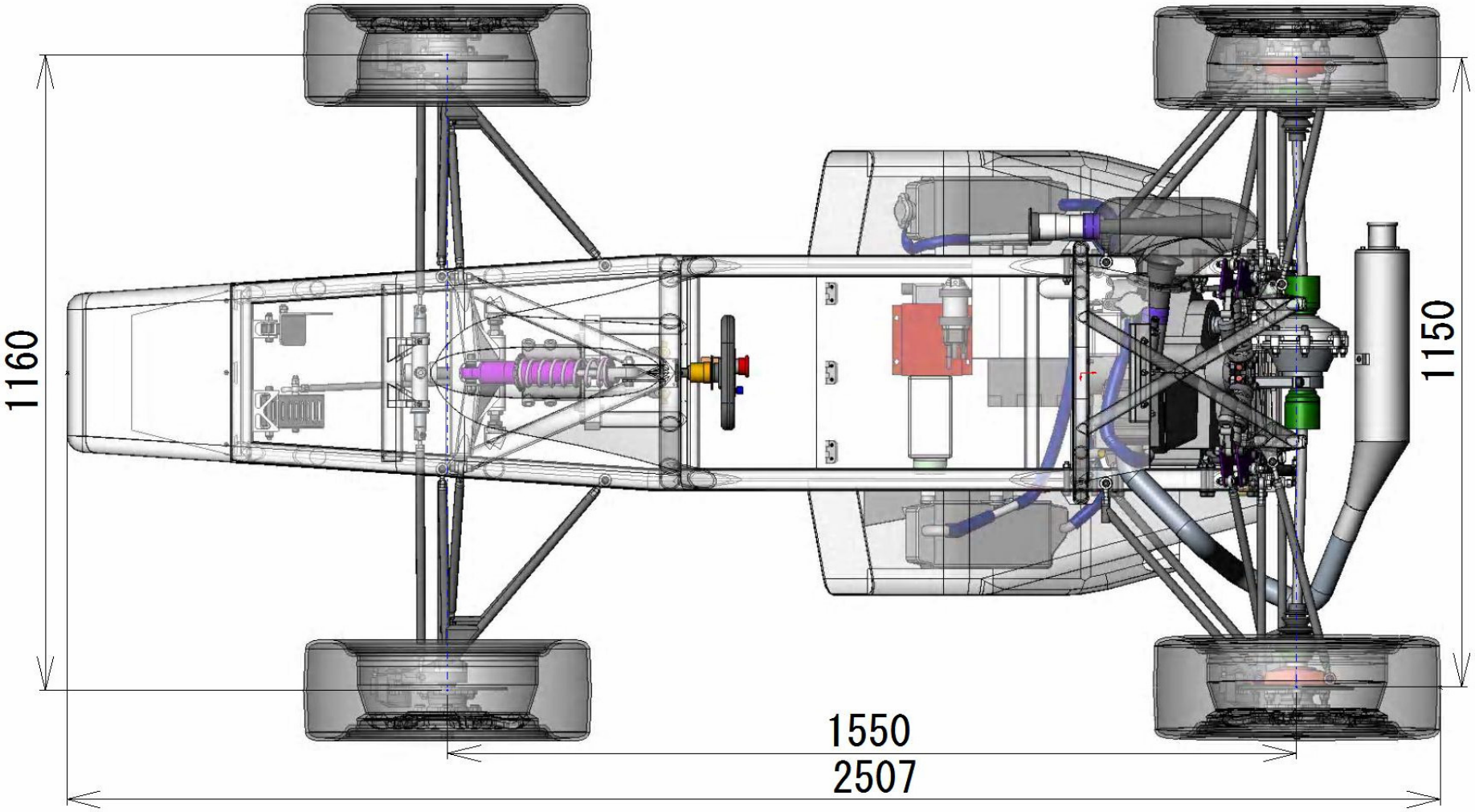


Fig.2 Top view

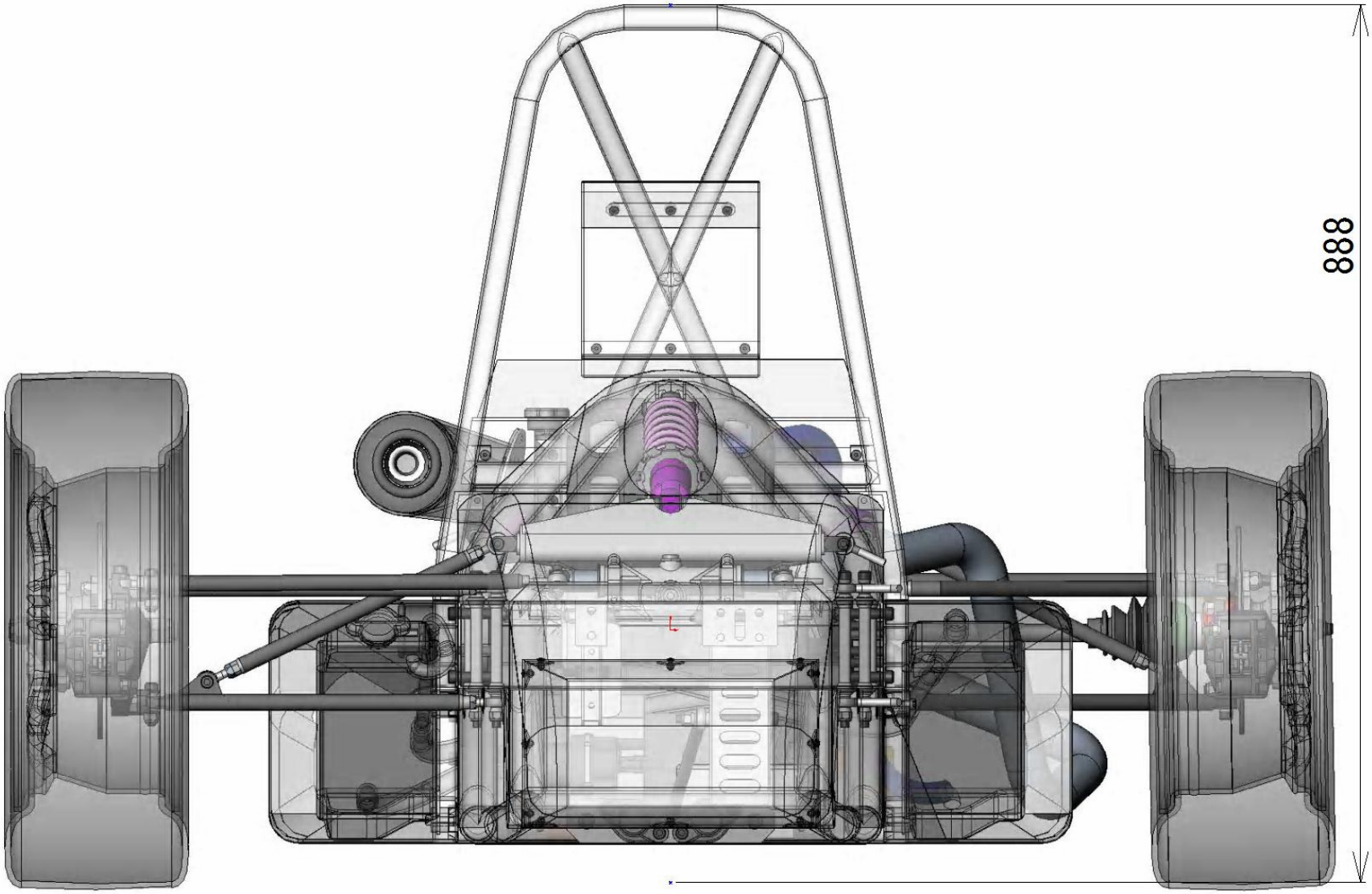


Fig.3 Front view
(left:R suspension right:F suspension)

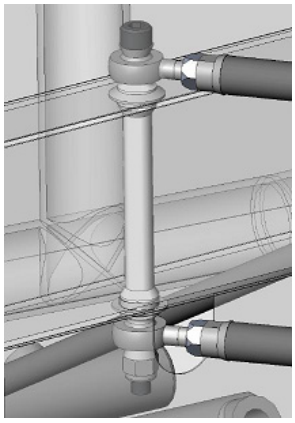
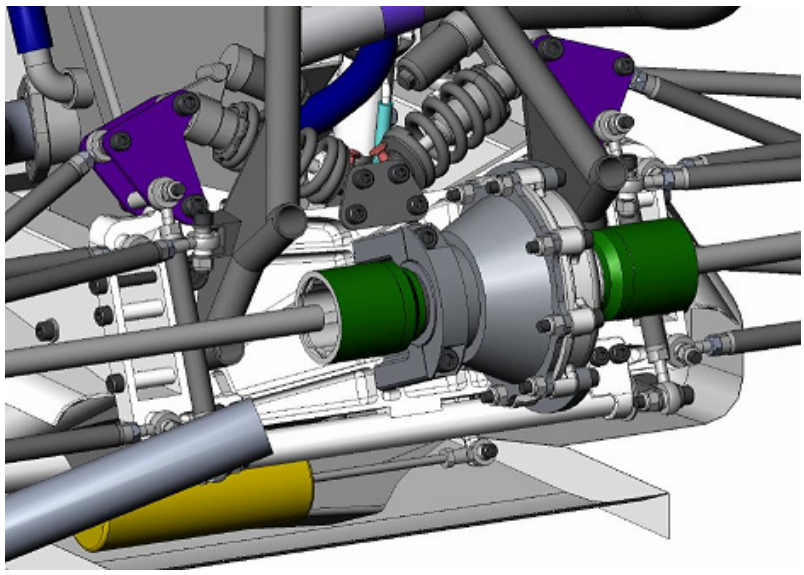


Fig.4 collar



Fig, 5 Rear section

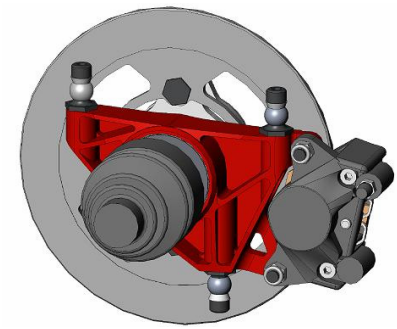


Fig.6 R upright

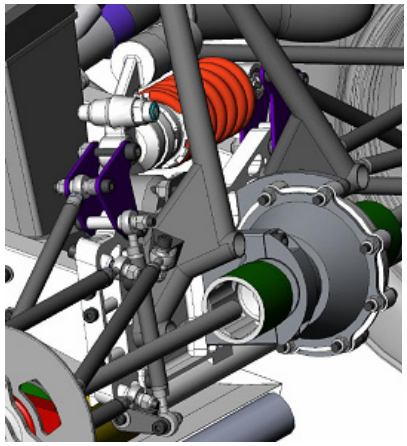


Fig.8 R mono

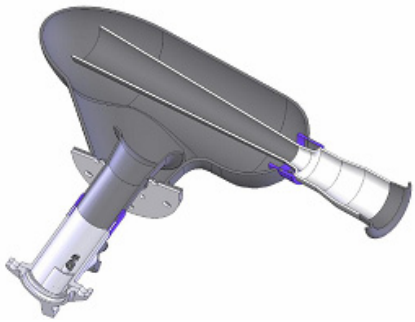


Fig.10 Air box

Fig.7 F upright

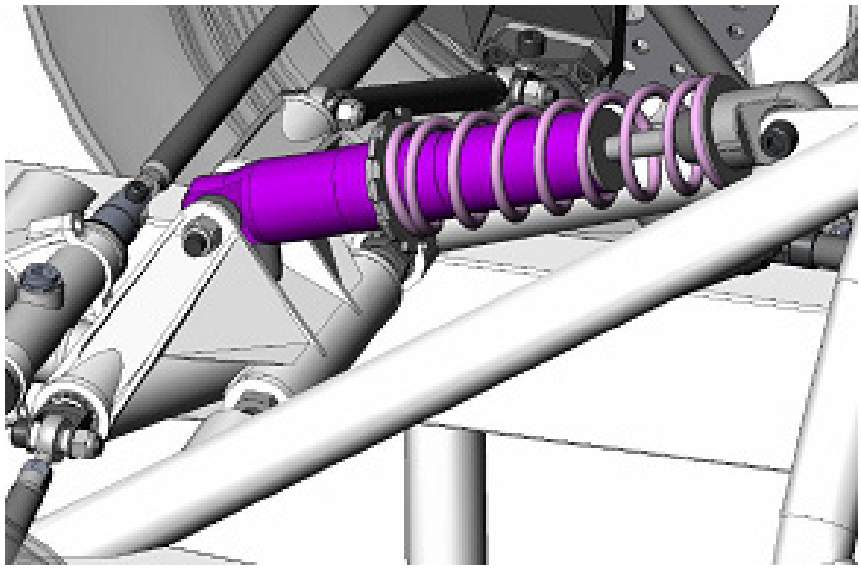


Fig. 9 F mono