Tokai Formula Club G.R.-section

# 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.
Tokai Formula Club G.R.-section
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 from 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.

Tokai Formula Club G.R.-section

# Fig. 1 Side view

Tokai Formula Club G.R.-section

# Fig.2 Top view

Tokai Formula Club G.R.-section

# Fig.3 Front view

# (left:R suspension right:F suspension)

Tokai Formula Club G.R.-section

Fig.4 collar

Fig, 5 Rear section

Fig.6 R upright

Fig.7 F upright

Fig.8 R mono

Fig. 9 F mono

Fig.10 Air box

1. 車輛的摘要

Formula SAE 方程式車輛分為鋼管框架和 CFRP 單體構造，然而，我們覺得多數的車輛有著相似的風格且設計太過於飽和。因此我們在下一個階段設計一個新的車輛品牌。為了設計我們的 Formula SAE 賽車，我們重視輕量、高可比性的剛度、低重心的、均勻的應力分布、在中低轉速有高扭力及有高品質創新的設計。空氣動力學和最大馬力不採取優先考慮期間佈局和最高速度的限制。車輛動態圖像是清晰的彎道、小姿態的變化、少數滾動改變、低劣的過度轉向與良好的牽引力。

2. A7N01 鋁合金雙管架

我們的車輛最強的一個點就是 A7N01 的鋁合金雙管架。此結構具有位於駕駛員的兩側的兩個大的矩形管及由頂面和底面的懸架臂來輸入在轉彎力[Fig.4]。鋁套環坐落於管內以避免壓碎或穿過連接在上下懸架臂的管子及長的螺絲。由於焊接管架時，銲接接頭會在溫度高的影響下變弱，且會造成底座的剛性變低，因此，A7N01 有一個特別的功用，被用來避免這個問題。鋁在正常的淬煉下有很好的抗老效用，且在焊接完的一個月後，鋁的強度會恢復到百分之九十。更多有關車架材質的細節已經顯示在我們的 structural equivalency 表格了。為了讓框架能更小型輕便且車輛具有減去後懸和後隔板連接在雙管

的底部[Fig.5]，切割隔板的重量只有 1.5 公斤，它被安裝後懸架臂，腳尖控制臂，後曲柄，雙後減震器，後穩定桿，L.S.D.的後方情況下，主圈支撐，發動機座，換檔執行器千斤頂和消音器。當隔板被切掉不必要的體積時，首先需要的體積是在周圍留下的每一個孔，然而，ribs會根據推進力和方向。

而調整所在的位置主要支撐環連接隔板向後讓主圈和主要支撐環之間超過了 30 度，因為後車架很短。該支具彼此互相交叉，是為了在橫向滾動的情況下得到足夠的力量。

Tokai Formula Club G.R.-section

3. 懸掛系統

3.1基本原理

懸架幾何結構則認為輪胎胎面必須保持隨時接觸與地面適當的角度，但是懸架幾何是不能滿足所有的需求。在聚焦室加速度和減速度下接地平面的變化的情況下，等於和平行連桿系統是最佳的幾何形狀，但幾何形狀在轉彎下不是很好因為滾轉角。然後在聚焦它轉彎下的情況下，接地面的適當房室改變得到使負房角與使用不相等的和非平行連桿側傾角相對角。然而該幾何形狀在加速下和減速下不是很好，懸掛幾何形狀找不到完美的需求，尋找滿意的妥協。相對生產需求的一個主要因素被視為是汽車的滾動角度。因此，在apposite chamber地面下的所有動作將會被用去抑制這滾輪，此外，考慮到懸掛幾何結構，輪

胎具體的特點,像轉彎力角度彎曲是絕對必要的,但是數據沒有公布。如果不知名的輪胎移動太多次可能將會很難留在理想的範圍內,其結果是,有著穩定器的平衡及平行連接系統會被拿取。

3.2 後柱

後柱的手臂支架上有著跟框邊一樣的懸臂式風格,因為輕量化和緊湊的設計圖[Fig.6]。The M8 bolts mount suspension rod end and they are penetrate the M12 bolts which have M12 male and M8 female threads,然而M12被連接在鋁柱上面。M12避免螺栓藉由意外而脫離垂直的內部。鋁柱的Female M12具有沿著切線連接的軸承箱柱,是為了使應力分布均勻,所以這柱子只有300克重。在支撐軸的情況下,支撐軸會變的越來越少發揮,會盡可能的變寬來分離兩個支撐點,因此兩個會縮到適合柱子兩邊的大小。在框架邊的後臂上有兩隻平行桿,所以最初始的外傾角調整螺紋,這外傾角的變動也會在上臂的柱邊使用墊片調整。

3.3 前柱

front upright有別於一般的框架和rear upright風格,基於阿克曼轉向幾何學(Ackerman geometry)需在機械臂和upright之間加入墊片。然而因結構組合需要在鋁塊中盡量減少體積是有一定難度的。因此upright是以焊接鋼所製。結構的內部因考慮到流動力學,所以ribs會與主軸

外殼的切線連接。upright在初期的外傾角有所調整，弧度有所改變，中心立軸的傾斜度和腳踏所使用的墊片都與阿克曼轉向幾何學有關

Tokai Formula Club G.R.-section

3.4 尾部緩衝系統 (Rear damper system)

尾部的緩衝系統可使用獨立的緩衝系統或是雙緩衝系統[雙緩衝-Fig.5，獨立-Fig.8]，後曲杠桿設於固定框近上方的位置。而後穩定桿安裝在自升式桿裡,位置正正在固定框下方。然而 穩定器軸是與曲杠桿和穩定桿連接在一起的。穩定器的強度則視乎穩定桿轉動慣量的強度在雙緩衝系統的情況下,緩衝系統會與穩定桿和上方的駕座連接。在獨立緩衝系統的情況下,緩衝系統則會與穩定桿和較硬的穩定器連接而每個懸架裝置都有把幾何學設為考慮因素。

3.5前方單一緩衝系統

前面單一緩衝系統不同於後方單一緩衝系統,前方有一個被縱向安裝的緩衝系統稱作DALLARA F305[Fig.9]。前鐘形槓桿的旋轉軸被連接有著被焊接前環的毛毯中。前方推桿被連接到位在槓桿(bell crank)兩端的毛毯上。在相同力量的情況下，輸入兩個前輪胎就像是直線煞車的狀態下，透過不同的程度差，只會在軸邊旋轉。然而，在不同力量的情況下，輸入的每個前輪，如轉彎與煞車轉彎，bell crank會試著讓兩個前輪胎有同樣的動作。Bell crank 自身具有穩定的機制且可以限制車輛滾輪的角度,限制的強度會被軸環的材料而被調整為不同的變

化。

4.動力系統

4.1引擎

由軌道的特定特性所知，緊湊且重量輕的單缸引擎被裝在我們的車輛中，在Yamaha的耐力摩托車中被當成引擎使用，稱為WR450。這個引擎只有30公斤重、5氧化鈦閥門、5速及乾油槽系統。最初在9000rpm下最大的馬力是44.1千瓦(60.0PS)且在6500rpm的最大扭力是52.9 N•m(5.4kgf•m)。這引擎只有汽化燃料輸送系統，這在方程式賽車中不是很好，因為規則中有限制油門的位置。油門在位於節流器上方的情況下，無法傳送足夠的控汽燃料混合物到燃料室，因此馬力必須在3000rpm下。為了改善這樣的問題，我們換成使用Haltech E6X燃料注入系統，是一個可以改變燃料消耗及角度的系統，然後高轉速是被節流器所限制，為了較低的範圍，low cams被安裝在最大馬力跟最大扭力的換檔轉速中。如果引擎被橫向安裝，很難確保有安全足夠的空間進氣和排氣系統。

Tokai Formula Club G.R.-section

在引擎的進氣方向裡有一個座位且在排氣出口背後有一個緩衝系統，因此，引擎被安裝的經緯度在進氣與排氣的設計圖裡面有擴大的可能性[Fig.1]。然而太多的運轉角度會造成引擎的螺旋軸方向改變，因此，

直到運轉角度變成零的時候引擎才能被傾斜，因為這在機油的運輸系統裡是一個很嚴重的問題，所以濾油器要被調整。引擎跟發動機架後面的隔板被傾斜相同的角度，這樣才可以穿透隔板。

4.2進氣系統

在我們的計算中，節流器的最小氣流可以到達超過6000rpm聲速，因此，節流器有長期的擴散器去抑制壓力的損失且空氣箱被安裝是為了影響節流器衰弱。空氣箱的容積是2500cc是發動機排氣量的5.5倍，而節流器被安裝在空氣箱裡面為了得到足夠的體積及保持緊湊的方式。吸引管長度對輸出有影響，因此吸氣管有些部分會被調整。節流器和空氣漏斗是由CFRP製作而成的，輕量且強度高。

4.3 限滑差速器(LSD)

LSD是連接著固定框(rear bulkhead )的裝置，用於一款LT-A700XK5的Suzuki’s ATV上，而其轉矩偏離率(torque bias)為3.7，齒輪減速比為3.5。駕駛座組件與機身做工。油門和剎車踏板連接著後方的座壁

而踏板的位置會和車輪之間的墊片一同調整。其主油缸正正位於駕駛員的大腿之下。剎車的組件(brake bias bar)連接著主油缸，而這組件會因應油門左側的專屬線路而改變。比例閥(proportioning valve)位於底部的左側用於代替後輪的剎車器。駕駛盤是由碳纖維增強複合材料(CFRP)所製造，而離合器的撥片設於駕駛盤的後方以及左右方。換檔

按鈕( shift buttons )同樣設於駕駛盤的後方，當駕駛員切斷離合器，換檔後變速器會因應換擋驅動器而作出調整換擋驅動器連接到固定框的左下方此裝置會令變速器改由換檔按鈕所驅動數據監控器連接著駕駛盤並具有測速、機油壓力計、電壓表、警示燈和換檔指示器的功能機身是由鋁板所製並且根據空氣動力學所設計而成，車底的前半部分是以流線型設計，而後半部分和車尾的甲板則以擴散型設計車頭設計得離地面較近而機身透明的設計讓獨立避震器清晰可見。