ENGINEERING DESIGN REPORT: ORION RACING INDIA

CAR NO. 25

Team goal

While designing the car for reliability, the team looks forward to testing the car extensively for performance. System designs will be validated using sensor data and components will be tested in fatigue. Additionally, the sensors will provide us with data which will help us to tune the car. With the aid of a dynamometer, the aim is to improve and further tune the map table. By physically recreating event specific tracks, the performance of the vehicle is being improved upon.By integrating the above, the team hopes to realize its goal which is to complete and to compete.The design of the car was started by selection of the following three parameters.

1) Tire

Tire has been selected based on the TTC tire data which had 3 tires to compare namely Goodyear D2607, Hoosier and Continental 34M. On comparing the cornering characteristics for the vertical load that was assumed, the Goodyear gave a peak lateral force of 3870 N at 10° slip angle as compared to the Continental which gave a force of 3680 N at 6° slip angle. Keeping in mind the transient response, the Continental tire was selected. On comparing the acceleration characteristics the Continental gave a peak force of 2600N at 5° slip ratio. The low cost and availability of the tires further helped in finalizing the Continental. The increased weight of the Continental tire was a compromise between performance and weight.

2) Engine

With the team goal in mind, the car weight was assumed to be 230 to 240 kg. Thus power to weight ratio was made a main consideration and a 4 cylinder engine with higher displacement became the natural choice. Main criteria while choosing amongst the 4 cylinder engines were availability, torque, familiarity and previous experience. The F4i has 46 Nm of torque (stock) @ 10000 rpm which is more as compared to rest of the engines. The GSX has 46.5 Nm of torque (stock) but at a slightly higher engine rpm i.e. 10750. The peak power of F4i is 109 hp (stock) @ 12500 rpm which is more compared to the other engines. The YR6 has power output of 118 hp (stock) @ 13000 engine rpm but the cost of the engine is more and the torque is less (44.7 Nm @ 11750 engine rpm) as compared to the F4i.

3) Ergonomics

An ergonomic set-up was designed for two purposes:
1) To reduce driver fatigue by selecting an ergonomic position
2) To find the forces which the driver can apply

Each drivers' inputs have been considered and a position comfortable to each driver has been selected. These values acted as an input for designing the cockpit, pedal box, shifter system, seat and steering system. We also consulted a musculoskeletal specialist who helped us select the position in which the driver can apply maximum force with ease.

Vehicle Dynamics and Chassis design

1) Suspension Design

The system design started with the analysis of the tire forces. 13*7 inch Al alloy OZ rims have been selected through a decision matrix made which took into account factors like moment of inertia, upright packaging, weight, cost and availability of the rim.
The ride frequencies were selected at first with 3.3 Hz at the front and 4 Hz at the rear. The wheel base has been set to 1580 mm considering the ergonomics report taken from the chassis team, engine placement and the longitudinal load transfer at 1.2g's.The track width has been set to 1220 mm and 1200 mm at the front and rear respectively considering the lateral load transfer and the width of the track.A camber angle of -2.3 degree at the front and -1.5 degree at the rear have been selected considering tire data for peak lateral force at 6° slip angle and the camber thrust generated. The tie rod

and the steering rack points have been designed for minimum bump steer of 0.4mm at 1 inch of droop and an Ackermann of 98.39% of the wheel base.

The chassis pick up points have been selected considering front view side arm of 735 mm (front) and 1040 mm (rear) to provide minimum camber angle change (0.9°). In the side view, the chassis pick up points have been iterated to give anti dive of 7.8% and 9.8% anti lift.The front and the rear roll centres are at 30.3 mm and 44.37mm from the ground so as to obtain less geometric weight transfer (23 N front and 40 N rear) to reduce jacking forces and to reduce the lag between the front and rear tire generated slip angles during cornering. The motion ratios 1.291 (front) and 1.275 (rear) have been selected taking into account bottoming of dampers and to maintain linear rates.The roll rates at the wheels due to springs have been calculated and an anti-roll bar has been installed at the rear which produced the required frequency at the rear and also the required lateral load transfer distribution.

A worst case situation of braking and cornering has been considered after a track simulation. Loads in the various linkages have been calculated using vector analysis and designed for fatigue failure for the above case. This has helped in designing of the components of the system and selection of bearings. Three axes accelerometer has been mounted near the CG to validate the load calculations. The suspension setup started with implementation of the tire temperature sensors and comparing it with the values given in the tire data. The motion ratio rates are to be justified by the shock travel sensors and various values of bump. The ride frequencies are being validated by test data from the vibrometer.

2) Chassis

After selection of the space frame type chassis, emphasis was on making the car ergonomic to the driver and to the other systems for easy assembly.The bulk head has been raised by 56.64 mm above the ground which has helped to improve the crash-worthiness of the car. Width of the cockpit region at the MRH has been increased by 20 mm for ergonomic considerations and to increase torsion stiffness. MRH bracings have been set apart by 30 mm more to increase the envelope of engine area for ease in installation of the engine.

Material used this year is DIN 2391 ST-52 which has a better stiffness to weight ratio than ASTM A179 which was used last year. This time gas tungsten argon welding for fabrication was used with P20 of 1.6 mm and 2.4 mm thick as the filler alloy since its UTM test results were positive. Effort has been made to reduce the heat affected zone in the weld areas to avoid localized hardening. A ± 3% accuracy of the suspension pickup points and nodes of the chassis have been maintained with the help of a coordinate measuring machine.

ANSYS has been used to study and analyse various load conditions such as braking, braking while cornering, torsion, vibration and impact. Amongst all these, the torsion was physically validated with the help of a torsion rig setup. An acoustic analysis has also been done on ANSYS and is going to be verified with the help of a vibrometer.

3) Brakes

The design of the braking system started with the coefficient of friction (Tire data report) and the force that could be applied by the driver (taken from the ergonomic report). The discs and callipers have been selected on the basis of the braking torque calculated. Flexible brake lines have been selected for ease of assembly. Master cylinders of unequal diameter have been selected to maintain a natural bias of 61% in the front.

To reduce the static undesirable friction between the pads and the discs, floating disc system has been implemented. To account for the thermal expansion and the manufacturing tolerances a radial compliance of 0.5 mm and axial compliance of 1.5 mm was decided.

The pedal box was decided after taking inputs from the ergonomic report (the load that the driver can apply with his legs was taken) and the force required to actuate the clutch, brakes and the throttle valve. The calliper and master cylinders have been selected based on their respective decision matrices.

Powertrain

1) Air Intake & Exhaust

The goal of the system is to achieve a flat torque curve and peak power between the rpm range of 6000 to 10000. The rpm range has been obtained from the logged data and analysis of the FSG track. The key feature in our design is the shape of the Plenum which ensures equal distribution of air in the runners as observed on flow simulation. A subsonic restrictor is designed in coherence with the air box. The volume of Air Box is kept 1.54 litres to provide sufficient air along with a throttle response as desired by the driver. The length of the intake runners is derived using the Helmontz wave theory.

The exhaust system consists of a 4-2-1 arrangement; this is selected so as to achieve our aim of flatness in the torque curve. The lengths and diameters of the tubes used in the system are computed with the help of Ricardo WAVE simulation software.

The restrictor, air box and the injector seats in the intake system are manufactured using Selective Laser Sintering method made of Durafoam PA for weight reduction and ease of manufacturing. A free flow muffler was manufactured using light weight glass wool and a glass fibre cylinder.

2) Drive train

The final drive ratio has been decided based on the tires' longitudinal accelerating force of 2600 N and torque-power characteristics of the engine at different RPM's which were obtained from the dynamometer graphs. From track analysis the maximum speed achievable in the competition is around 120 km/hr and the average speedsaround 40–50 km/hr increasing the benefits of better acceleration and lowering the importance of top speed. As a compromise between the different events viz. acceleration, autocross and endurance, it has been decided to use a drive ratio of 4.36.
The Drexler LSD has been selected which gives variable setup possibilities in terms of ramp angles. The current setup is the stock setting of 50/40.
Considering the suspension travel, tripod joints are implemented that give an articulation angle of 23 degrees. The axles are hollow as opposed to solid axles used previously resulting in an overall weight reduction of 16.96%. An eccentric chain tensioning mechanism allows the centre to centre distance to be changed by a maximum amount of 10mm giving an adjustability of one and half links. The assembly has been conceptualized to allow easy removal of the differential for servicing without having to remove the mounts from the engine.

3) Cooling

The main aim of the cooling system is to maintain the engine at a temperature range of 90-95 degree Celsius. To account for the deviations in the practical and theoretical calculations, the pump speed was controlled using PWM controller. After testing the cooling system during the endurance, a flow rate of 25 LPM was decided. The NTU method has been used to calculate the amount of heat rejected for the radiator design. The double pass aluminium radiator comprises 29 horizontal tubes. Solid aluminium tubing has been used between the radiator and the engine. These tubes reject heat from the coolant while it passes through them thus making the cooling system more effective.
For the cooling to work while the car is at a low speed, an 8 inch Davies Craig fan is used to give an air flow of 5 m/s thus maintaining the engine temperature at 92±2 degree Celsius.
A shroud and duct are to be implemented based on testing values to further improve the air flow through the radiator and increase the overall efficiency of the system.

4) Fuel tank and Shifter

The fuel tank has been designed to maintain the fuel pressure for the acceleration values obtained from the last year's log data. The design of the fuel tank has been analysed for fuel sloshing under different dynamic conditions. Fuel sensor readings were satisfactory thus validating the fuel tank design.
A Walbro GL393 pump has been selected based on the pressure required across the injectors and their flow rates. Analysis has been done to see if the pipe losses are overcome by the pump and the required pressure is delivered.
A manual shifter mechanism has been chosen over the electronic system for its simplicity in design, cost effectiveness and power management. As a result of the ergonomic report the shifter arm has been placed behind the steering wheel to assist the upshifts during the acceleration event.

5) Electronics

The goal for the electronics team this year is to design, build and implement an efficient electronics system which not only ensures higher reliability but also aides in vehicle analysis and tuning. The MoTec M400 ECU is selected over the Stock ECU based on its availability of features like launch and traction control, gear change ignition cut, the use of closed loop lambda control for dynamic fuel saving and one of the best GUI available for easy tuning.
The centralised telemetry system is self-designed to provide a wireless communication at 60MB/s over a range of 1 km and unlimited logging using a video capture system. The MoTec M400 data logging system is used to log sensor data at 200 Hz and i2 Standard is used to analyse the data. A sensor hub is made to provide plug and play of 14 sensor logging.

To reduce trouble shooting time the wiring harness is named and colour coded. PCB mountable relays have been used to reduce space by 70 %. The overall weight reduction in the electronic system is 2.71 kg i.e. 62 %.

Seat and Bodyworks

Seat: The design of seat was initiated by taking values from the ergonomic report and driver feedback from previous years' taking into consideration the Percy template. The width of the 'seat bottom' was decreased from 480mm to 380mm to prevent the lateral motion of driver during turns. Flanges were provided on the seat for serving two purposes, elbow support and a snug fit on the chassis thus helping in driver comfort and preventing seat motion in the cockpit respectively. The seat was manufactured using positive MDF pattern using glass fiber.

Bodyworks: The bodyworks was designed by taking into account the cost of manufacturability and quick, convenient assembly and disassembly. Various iterations were carried out for the shape of the nose-cone and analyzed to take into consideration the effect of frontal area on drag and down force produced.

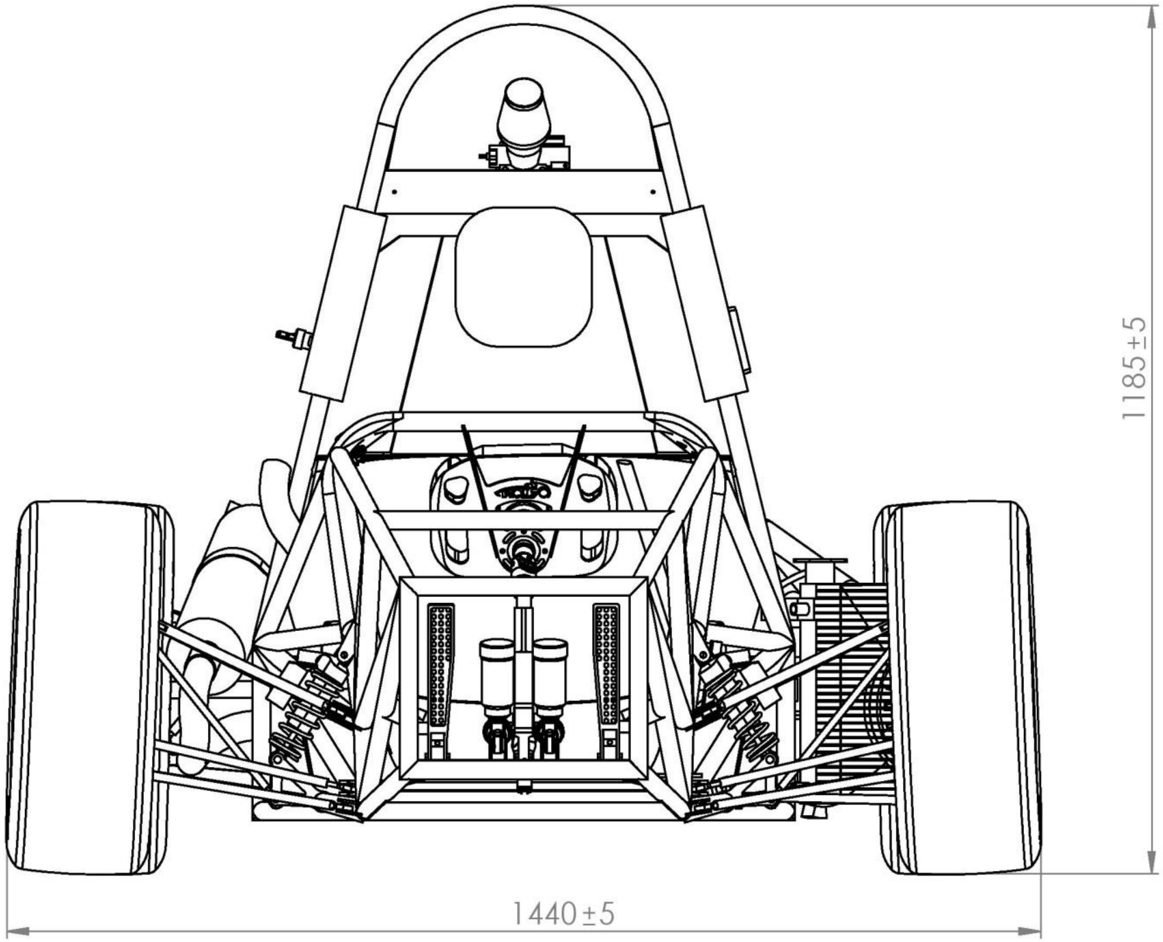
Testing and Tuning

The testing and tuning has been divided in three parts

1) Base Map Tuning
   It is decided that time devoted to tuning should be increased over previous years'. The tuning was started with basics as the current tune was to be completely overhauled. The first step was to generate a flat map (a table of amount of fuel added vs. RPM vs. Throttle position) based on calculations, which would allow us to run the car in all conditions. With this map we ran 2 endurance events. The log files from these runs provided us with lambda values over a good range in the map. We constructed a basic "Aim lambda" table and then used the "Lambda Was" feature from the ECU which checked the aim values vs. the recorded values changing the map accordingly to achieve the aim lambda value. The areas not covered by our recorded values were smoothened over the map by experience. At the conclusion of this process we ended up with a base map which served as the base to help us tune for specific events. Locations on the map which affected the outcomes in the dynamic events were tuned for power or economy as required with use of dynamometer and track data.

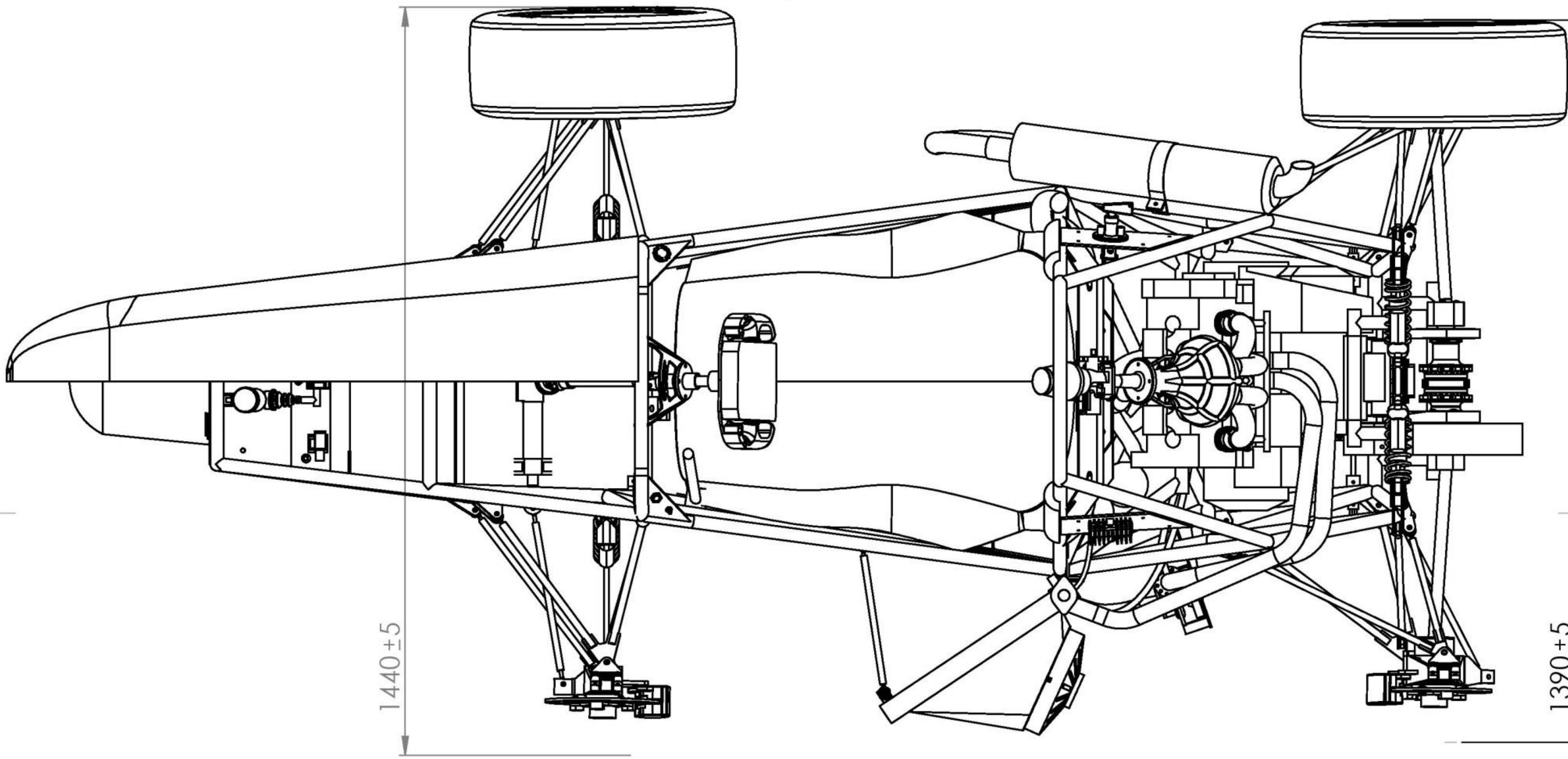
2) Launch and Traction Control Setup
   After the acceleration map set up, launch control setup was the next step. It was done with the help of the ECU. The theoretical rpm limit values were calculated from the chassis dynamometer graph and tire data (Longitudinal force vs. slip ratio graph). After the initial setup the tuning was done, based on the driver feedback. The traction control is being done with the help of track simulation on IPG.

3) Suspension Setup
   The braking bias was then decided based on the brake pressure sensor. Corner tuning is being done with the help of shock travel sensor, accelerometer, steering angle sensor and the wheel speed sensor. The suspension was setup on the acceleration and skid pad tracks. The damping was decided based on the driver feedback and damper dynamometer graphs. Since the have testing area is constrained, testing for the endurance track is going to be done in sections. A best setting based on the track simulation acceleration and skid pad data will be decided for each section. Endurance lap will be performed with each of the setting and the setting with the minimum timing will be chosen.



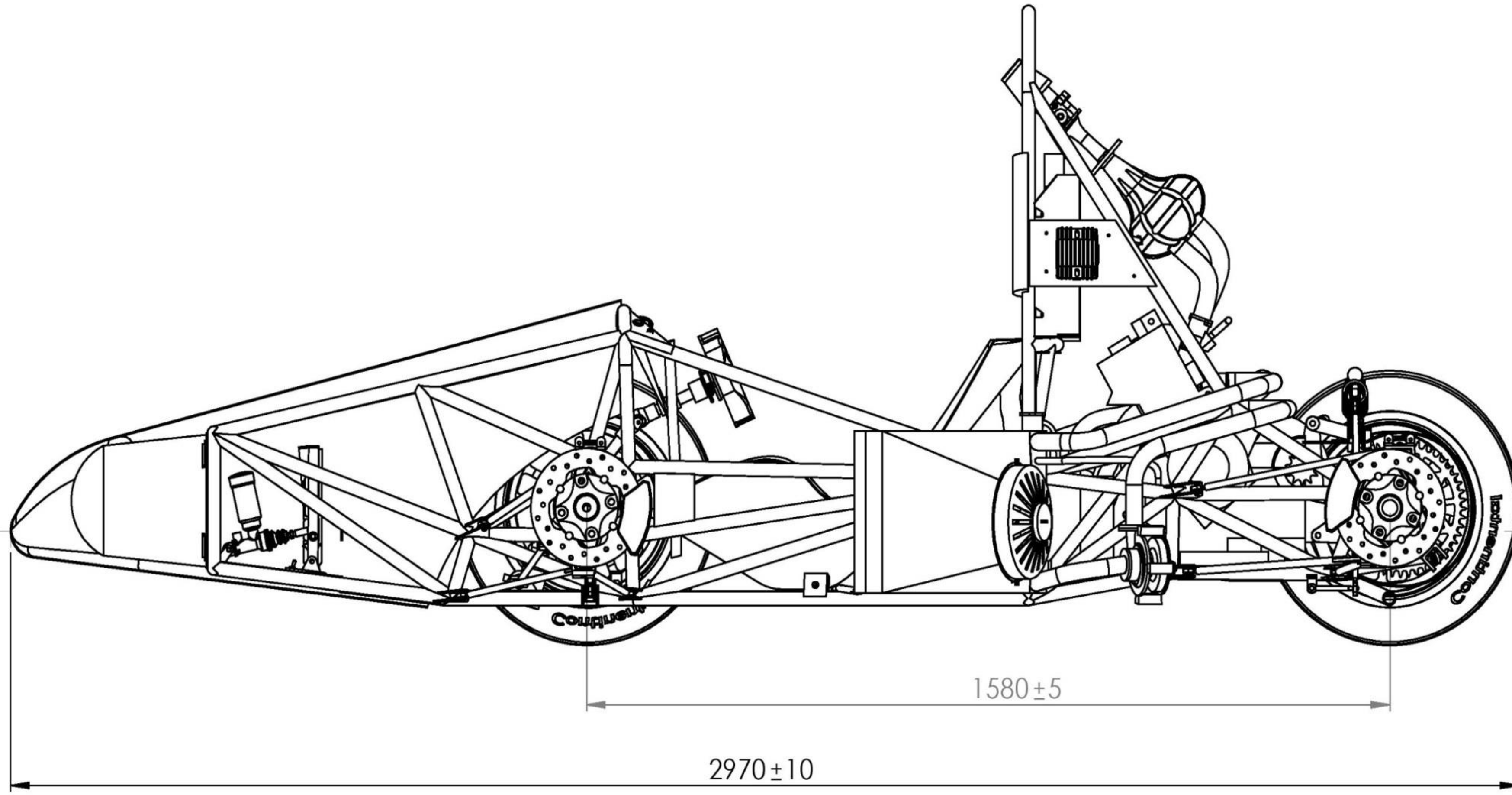
All dimensions are in mm

University name:	**MUMBAI SOMAIYA**
View: **FRONT ELEVATION**	Car # **25**



All dimensions are in mm

University name:	**MUMBAI SOMAIYA**
View: **PLAN**	Car # **25** ORION RACING INDIA

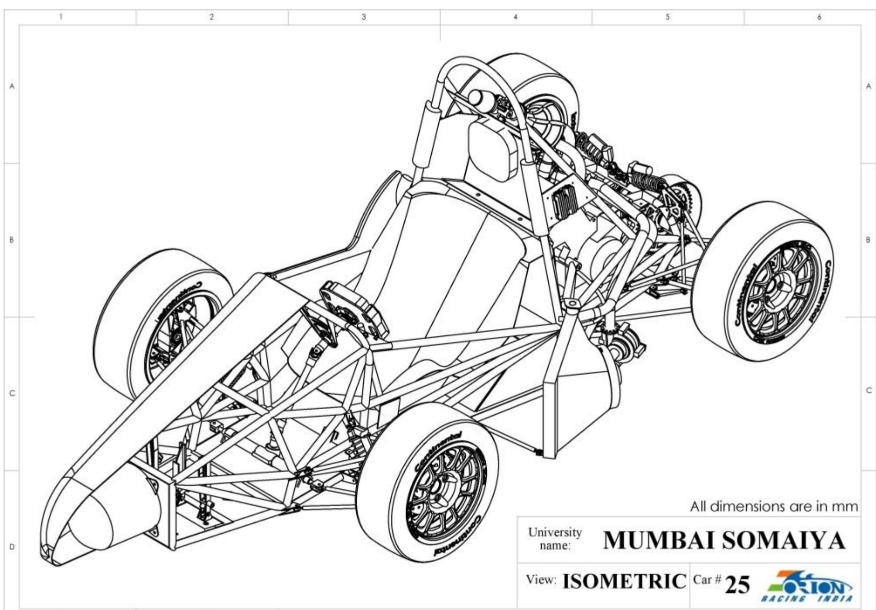


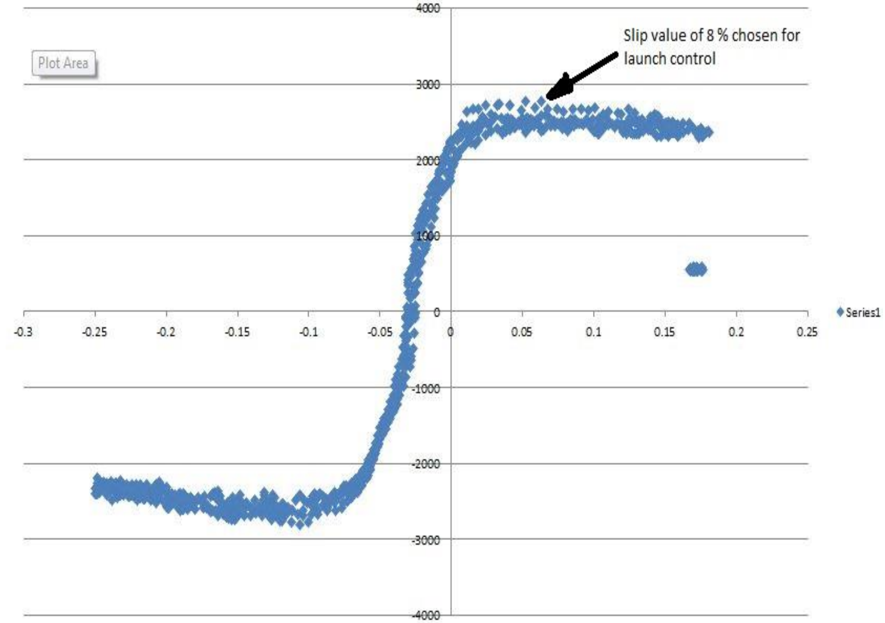
All dimensions are in mm

University name:	**MUMBAI SOMAIYA**		
View:	**SIDE ELEVATION**	Car # **25**	ORION RACING INDIA

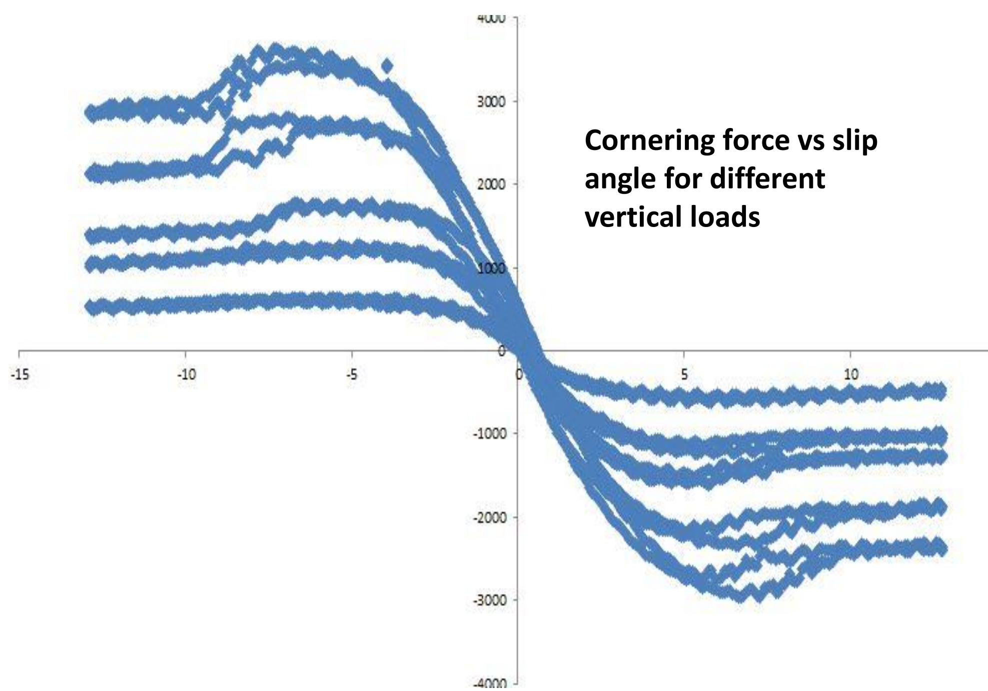
Torsion rig setup

Glass fibre muffler





Longitudinal force vs slip ratio graph used for launch



Cornering force vs slip angle for different vertical loads