2008 Hunan University Formula SAE West Design Report

1. Introduction

HNU Racing Team is a second year competitor in the Formula SAE West competition. After summing up the experience of the 2007 competition, we made some guide lines of our design, in summary:

·**Reliability:** After our discussion for the 2007 competition after finishing, we made the conclusion that reliability was the most essential design component of HNU2008. We want to have a car that is engineered to last and to be reliable in all components.

·**Simplicity:** Get the car running on time with a simple and practical design easy to manufacture, or simply purchased. Keep it simple is the key.

·**Weight Reduction:** Compare with the cars of other teams, HNU2007 was too heavy. One of the most important guide lines was reducing the weight as much as possible. According to the design, we'll reduce weight of HNU2008 by 80 kg (176 lb).

·**Ease of servicing and maintenance:** when something was wrong with HNU2007, we couldn't repair it easily and quickly as a result of design. We paid more attention in design to make HNU2008 easy for maintenance.

In order to meet these requirements and manufacturing deadlines, we have relied extensively on the use of computers. Several different design, simulation, optimization, and manufacture packages were used to enhance our design process as the table below.

Design Section	Design	Analysis /Testing
Suspension and Steering System	Modeling in Unigraphics, AutoCAD	1. Dynamic Analysis in ADAMS 2. Designed in Matlab 3. Simulated and optimize in Lotus Suspension Analysis
Impact attenuator		1. Simulated in LS-DYNA
Frame		1. Use of PVC models for optimization. 2. Chassis stiffness calculation & optimization in ANSYS.
Powertrain		1. Injectors flow-tested to determine characteristics. 2. Dynamometer mapping of ECU. 3. MatLab employed for drivetrain optimization.
Drivetrain		1. Dynamic Analysis in ADAMS
Aerodynamics		1. Use of Fluent for testing & optimization
Ergonomics		1. Calculated in Excel 2. Use of PVC models of the frame to validate driver's comfort and room.

2. Design Review

2.1 Brakes System

The braking system is great important for the vehicle' performance. Reliability, safety and braking performance were our first design tasks. To maximize the reliability and safety, we considered the following factors:

Individual hydraulic circuits for the front and the rear have individual reservoirs for each circuit. As a result two master cylinders were employed. The bore of the front master cylinder is 7/10 inch, and the rear bore is 7/8 inch. The balance bar transmits the force which was applied to the pedal and distributes it to the front and rear master cylinders. Each reservoir was directly mounted onto the master cylinder and is packaged as a single assembly so as to reduce the possibility of leakage or other damage. Four discs are the same dimension 220 mm (8.66 in). Front calipers are a dual piston floating caliper with 27 mm (1.06 in) diameter piston, rear calipers are a single piston floating caliper with 34 mm (1.34 in) diameter piston. The pedal box and the bracket are designed and fabricated by students. The pedal box is constructed from aluminum alloy. It cleverly angles the master cylinders to give it a short overall length. With above measures, our brake system is able to make a good performance on the track that the friction coefficient range from 0.6 to 1.6, and the brake deceleration can reach to 1.6g as maximum.

2.2 Frame

The chassis is based on space-frame concept and the usage of #20 (equals to 1020-Normalized) tubes ensures enough torsion stiffness and bending rigidity. This was chosen over other chassis types such as monocoque chassis due to its ability to retain high efficiency without difficult design and much manufacturing processes.

This year the main considerations in the design of the frame were the safety of the driver, ergonomics, packaging criteria and overall strength, which still considered the safety as the most important point. The entire frame is designed just around the driver, giving him or her the right amount of space and thus reducing the length of the members and shaving off excess weight. By using CAD (Unigraphics) to find the best compromise between driver CG and comfort such as seating position, visibility, steering wheel angle etc.

The total weight of the frame was optimized using tubes of lower thickness and OD in areas of low stress which still meet the rule. Our goal is to reduce the frame weight from 45 kg (99 lb) to 32 kg (70.5 lb), which have achieved. This goal was met by the optimized member placement using results of FEA analysis (ANSYS). Analysis of the frame was performed for several cases by loading at the front suspension points with dynamic loads. The frame was designed such that the forces generated at suspension points, engine mounts and the drive train assemblies were effectively dissipated through the structure, ensuring higher load carrying capacity. The torsion stiffness of the frame was effectively increased by the use of cross members and a final figure of 2500Nm/deg was obtained through ANSYS. The Special fixtures were designed to minimize the effect of warpage of the frame during the welding.
The front impact attenuator was simulated in LS-DYNA. A crush zone made of aluminum honeycomb was provided and was designed to absorb 8000 joules of energy.

2.3 Body

The main aim is to reduce the weight of the body. Since racing on the track in competition is at relatively low speeds (60km/h speed on the average), the aerodynamics of the vehicle is not so important. The bodywork was therefore shaped to fit the frame and show the style of a race car. The idea of the body style was from high speed motorbikes and racing cars. We tend to make the vehicle's style different from other teams'.

At the same time, our new vehicle has these new characteristics for high performance as following:

1. In order to get more air to cool the engine, we decide to add an intake at either side of the vehicle.
2. The whole body is designed accord aerodynamics for lower resistance.

We made the 1:1 model of the bodywork from plastic foam by CNC and manufactured the final body with fiber glass.

2.4 Suspension

Nature frequencies were set to 2.6 Hz and 2.8 Hz in the front and rear respectively. Higher rear rate was determined for ride reasons. We positioned roll center to 14mm above ground in the front, twice the value (28mm) in the rear. They were set to this low height to reduce jacking force, while would never go across the ground plane and remain within the track in roll even in extreme conditions.

Lessons had learnt from last year, we added Anti-Roll Bars on HNU2008, thus the roll gradient was greatly improved to 1.02 deg/g. The ARBs were designed such that they could be easily adjusted by altering torque arm length, resulting in roll rate distribution varying from 40/60 to 60/40.

Suspension kinematics & dynamics was simulated and optimized in ADAMS and Lotus Suspension Analysis. Longer links (compared with HNU2007) were selected to minimize parameters change. Front swing arm length was set to 3000mm. It was determined to keep the front wheel upright under braking. As a result, the camber gain is 0.53 deg/in in bump and 0.79 deg/deg in roll. The tradeoff was large caster angles and minimum KPI angles. We ran 7 degrees of caster and 2 degrees of KPI. KPI was set for steering arm packing reasons. And the angle was the same value as the maximum static negative camber, allowing the steering axis parallel to the wheel installation surface, which resulted in easy manufacture. While in the rear, the SAL was halved to about 1200mm, slightly larger than the track on the side, because of no compensation of steering effect in roll. Besides, much less braking force is generated in the rear, there's of less importance to keep the wheel upright. The result of camber gain is 1.26 deg/in in bump and 0.50 deg/deg in roll.

KS-KIND coil-over shocks were employed on four corners. Opposed package was preferred for load transmission balance as well as minimizing the effect of frame stiffness. As for the bell cranks, special attention was placed on them because the Big Mac on HNU2008 astonished everyone. The reduction of weight was a main concern. Analysis in ANSYS proved the success of light weight. Kinematics was simulated and optimized in ADAMS, so the motion ratio changed within a minimal field.

The goal in upright design is to reduce the weight and keep the enough strength. The front and rear upright was made by aluminum and were very simple design for easy to process by CNC machining. Rear upright was designed to T shape for two reasons. One was to enlarge toe base as well as eliminating bump steer. The other was to increase upright stiffness by splitting upper load to tie-rod and upper A-arms.

2.5 Steering System

According to the team's latest tyre data and calculations, we chose to use upper steer .By using the positive Ackerman, the HNU2008 had been achieved using longer steering arms than the HNU2007. The HNU2008 used the rack housing as the HNU2007 which had been modified to reduce its weight obviously by using aluminum to take the place of steel. By giving a final steering ratio about 4:1, and keeping the minimum steering diameter to about 7 m, we aimed at giving the driver a steering with a prompt response without being too difficult to steer.?

We used ADAMS for simulation and optimization to get the accurate data and minimal change of toe angle during wheel bump. Optimization in Matlab assures our geometry almost 110% Ackerman which provides good handling and the ability for sharp corners.

2.6 Powertrain

The HNU is powered by a Jialing JH600 F02 engine, an upgrade from the one installed in 2007. The engine has significant improvement such as the cylinder and ECU.

The intake manifold has been specially designed to reduce losses and maximize the volume flow rate into the engine. An air chamber was designed to make intake pressure stable, in order to reduce the influence of pressure waves to the sensors and reduce the noise of the exhaust system. The mandatory 20mm air intake restrictor per FSAE rules was not ignored. With the 20mm restriction on the air intake between the throttle and the engine, the power output is severely limited. In order to increase the power output whilst restricted, the restrictor was given a streamlined form to accelerate the rate of the flow.

The fuel system has been implemented as an efficient, low weight, low cost and performance oriented design. The fuel tank was designed to adapt the body and frame of the racing car and steel was selected as the primary material of it both due to its superior strength, stable on heating and lower price. It's also easy to manufacture for a complex shape using 1.5 mm steel sheet.

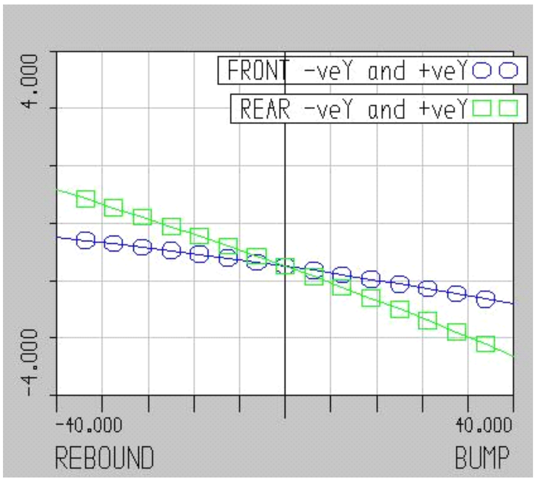
The cooling system is composed of a radiator with a fan mounted on the back, an overflow bottle and coolant lines. The radiator is one of the attachments of the engine. As larger convection area is needed for high efficiency, the radiator was located in the side of the body, which is better for the engine compared with previous years' car.

We are using a modified stock muffler to provide a good packaging for other parts such as the A-arms, CV and half shaft. One more important consideration was to keep it as low as possible to lower the CG.

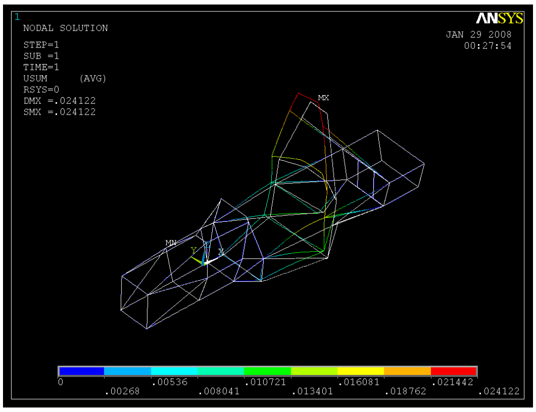
2.7 Drivetrain

The final ratio is 3.0 (45/15) which provided the driver as much torque as possible, while at the same time reducing the frequency of gear changes. The differential, together with the CV joint and half shafts were purchased used in an Xiali Car. The differential mounts were made by aluminum and was processed by CNC machining. Computer calculation proved them to be sufficiently strong and less weight.

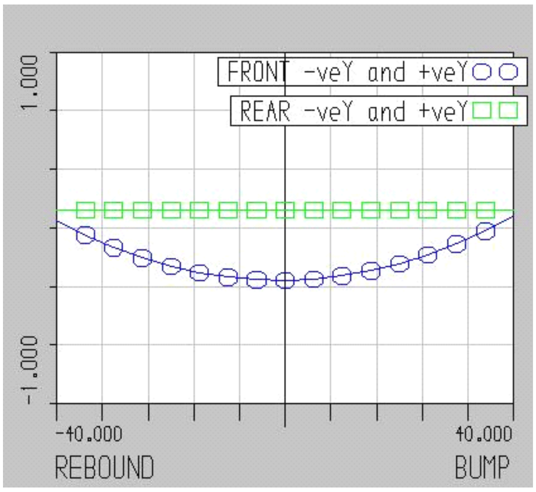
3. Additional Material



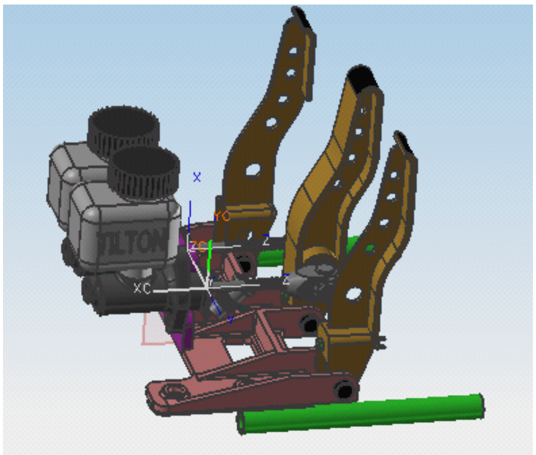
Camber Angle VS. Wheel Travel



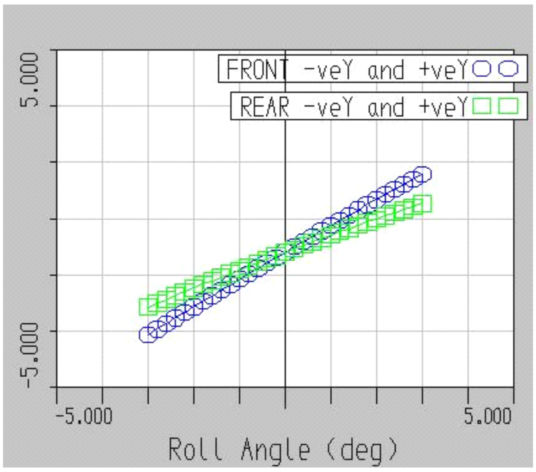
Analyze in ANSYS



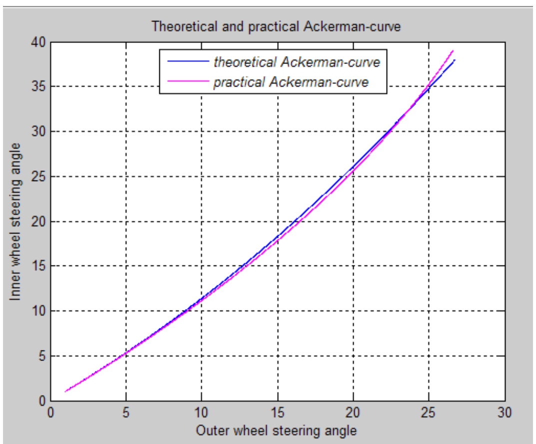
Toe Angle VS. Wheel Travel



Brake Assembly



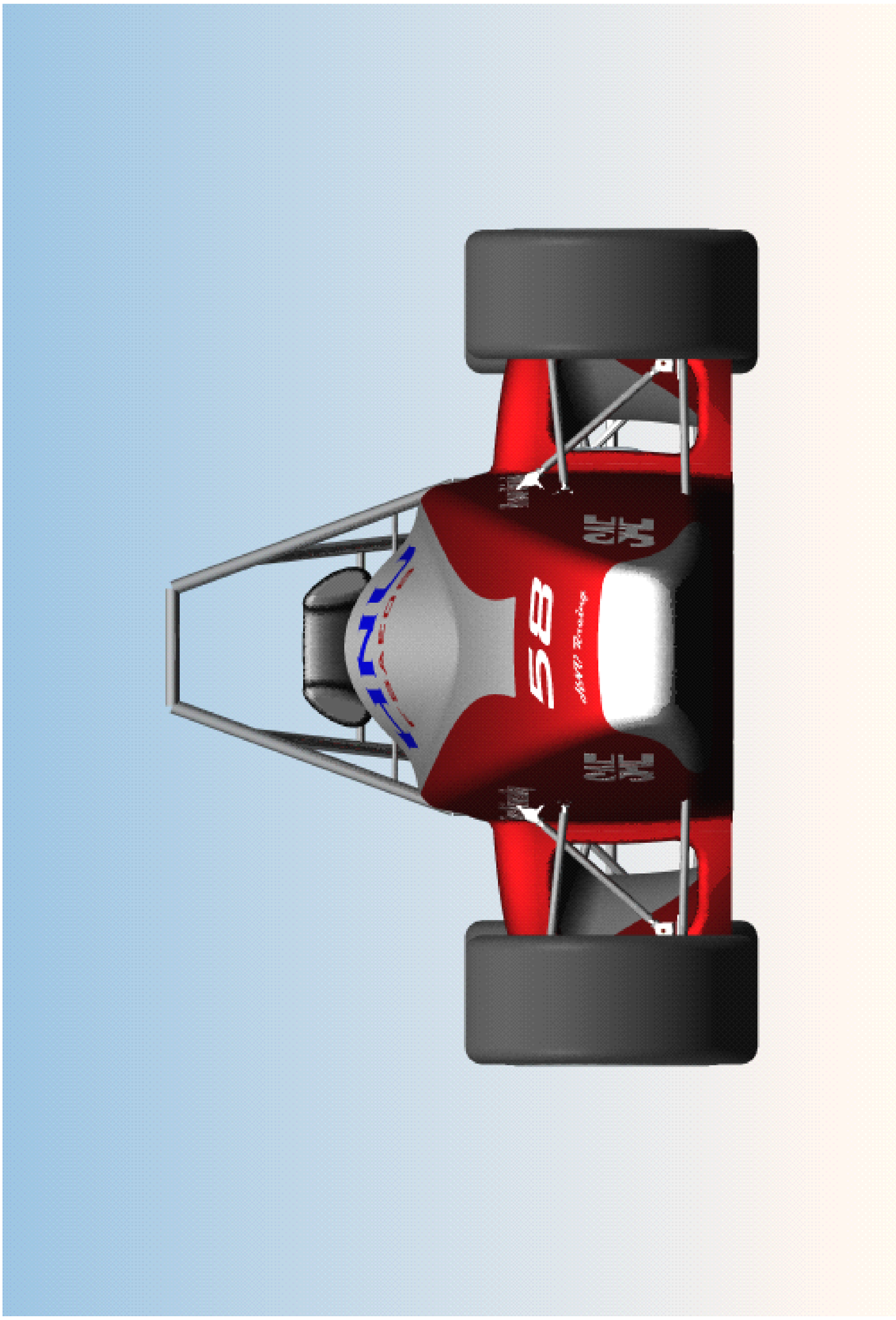
Camber Angel VS. Body Roll Angle



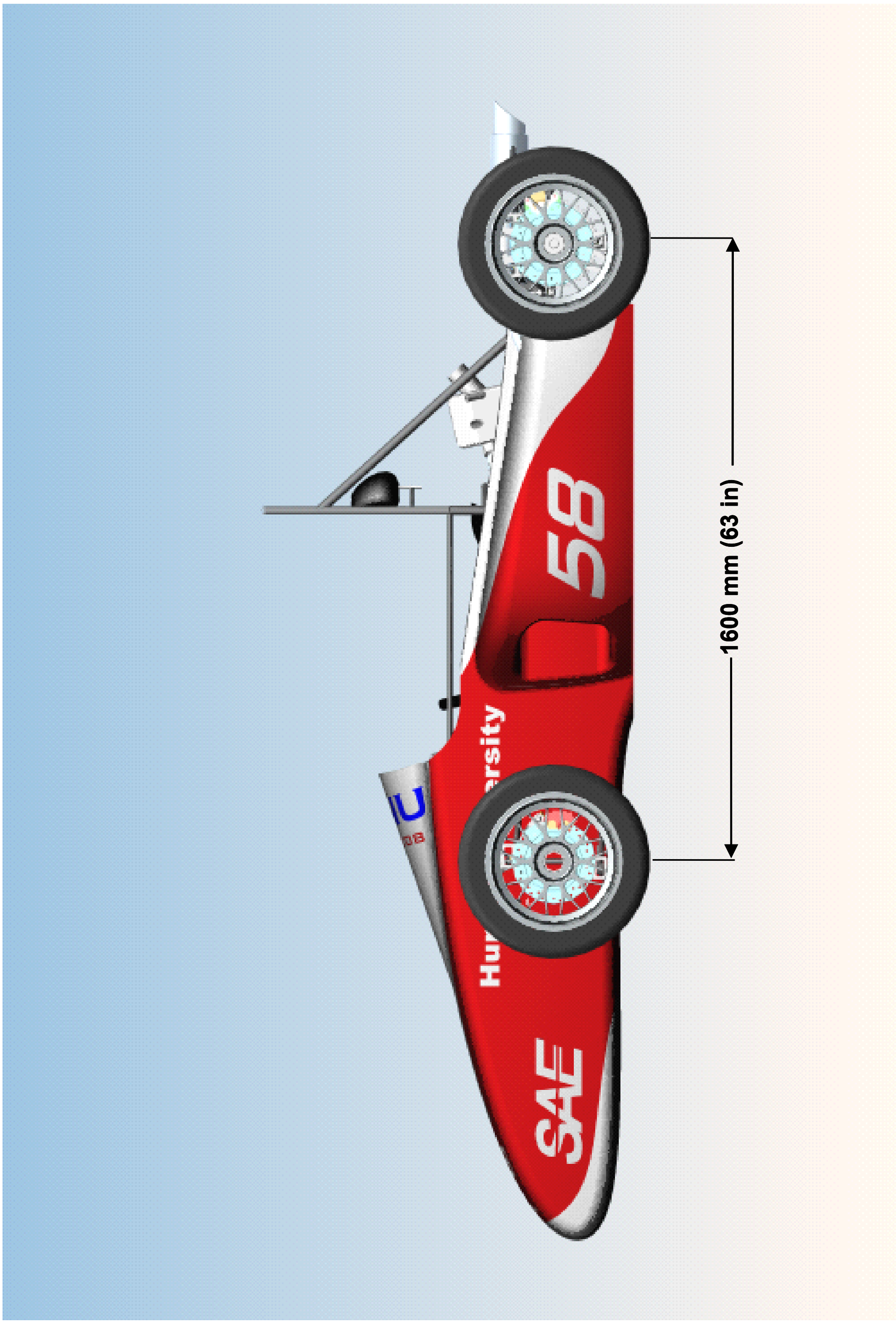
Ackerman Curve

4. Engineering Drawings

4.1 Front View



4.2 Side View



4.3 Top View