2012 Dalhousie University Formula SAE Design Report

Introduction

The 2012 Dalhousie University Formula SAE Team is competing in Formula SAE, Michigan, for the third consecutive year. For the first time in the team’s short history, the design is an evolution of the previous car rather than an entire re-design. Drivability, reliability, weight reduction and manufacturability were chosen as specific areas of improvement for this year’s team. In the development of the 2012 competition vehicle, a strong emphasis was placed on the car’s powertrain to make the vehicle more driver friendly. This powertrain focus, compliments the 2011 vehicle’s emphasis on the frame and suspension to create a solid foundation for future development.

Design Goals

Drivability: The engine must provide steady torque from 7000 to 12000rpm.
Reliability: The vehicle must complete all dynamic events and place overall in the top 50 percent at Formula SAE Michigan.
Weight Reduction: A vehicle target weight was set at 500lbs, a 5% reduction from the 2011 vehicle.
Manufacturability: The vehicle must be designed such that manufacturing of the vehicle is timely, simple, and cost-effective.

Powertrain

The 2012 team sought major improvements in the powertrain over the 2011 car. The primary goal is to improve drivability by creating a smoother torque curve with 80% of the maximum torque available before 7000rpm.

Engine Selection

For 2012, the team is using a Honda CBR 600RR engine. The team chose to expand on the developments from the previous years’ usage of the CBR engine. With the knowledge gained over the past two years about the intake, exhaust, cooling and oil systems, we were able to utilize more of its potential.

Electrical

The electrical system design incorporates a MoTeC M400 ECU which is smaller, lighter and more capable than our previous ECU. Tuning was done on a PowerDyne engine dynamometer. Injector pulse widths and ignition advance were adjusted at set throttle position and RPM intervals until desirable lambda and horsepower values were achieved. The engine is tuned for improved fuel economy under low loads and for maximum power under high loads. Enrichments for cold starts, air temperature and air pressure were programmed for varying ambient conditions. Traction and launch control were also programmed using Hall effect sensors, which were installed at each wheel. Engine data was acquired and logged on the ECU along with GPS information from a VBOX data acquisition unit. This data helps the
team tune each component during testing. Power is provided by a 12 cell LiFePo4 battery, which is safe, compact, lightweight and capable of starting the car many times without charging.

**Intake and Exhaust**

The intake and exhaust are a crucial part of the goal of increasing driveability. The intake manifold geometry is designed to eliminate sharp bends and corners to help improve airflow. Flow analysis in SolidWorks was used to compare different designs. The design of the transition between the runners and plenum was determined by comparing flow simulation results for different bell mouth styles. This lead to the decision to incorporate flush mounted bell mouths at the top of the runners to improve airflow.

The intake is designed for maximum power in the 8000-9000 rpm range. This resulted in runner lengths of 270mm. The plenum is designed to allow testing of different volumes by inserting spacers in between the upper and lower halves of the plenum. The chosen base volume is 2400cc, 4 times the engine displacement, which results in a balance between throttle response and steady state power. The intake was manufactured using SLA and post cured to withstand temperatures up to 93°C, making it lightweight and durable. This manufacturing process also allows the design to incorporate complex geometry without compromising manufacturing time. The new throttle body is a 28mm diameter barrel style throttle body which replaces the previous car’s 38mm butterfly valve. This was chosen in order to increase throttle sensitivity and remove any restriction from a throttle plate at wide open throttle.

Continuing the team’s goal of improving drivability, the exhaust system was designed using a tri-y configuration with unequal length primary runners. The tri-y configuration was selected in order to increase low end power over the previous vehicle’s 4 into 1 manifold. Unequal length primaries are incorporated in order to spread power over a broader range of rpm. Primary runner lengths are incremented by 1” from 14” through to 17”. Secondary tubes are 15” in length. Together, these design decisions shift the engines characteristics from high peak power to a broader power band, making the car easier to drive.

**Oil System**

A student-designed dry sump oil system has been fitted to the engine. The dry sump eliminates oil starvation problems caused by lateral g forces. This increases the reliability by reducing the amount of wear and heat caused by oil starvation. This modification also allows the engine to be lowered by approximately 4”, reducing the vehicle CG. The design of the oil pan incorporates scavenge pump pick-ups at opposite corners of the pan. This allows for scavenging while the car undergoes steady acceleration in any direction. This improvement during scavenging allows for a reduction in size of the oil tank, further reducing the overall weight of the vehicle.

**Fuel System**

The fuel tank is designed with internal baffles to prevent fuel from sloshing during cornering, which can cause starvation. The fuel system uses a double filtration configuration, with one filter to protect the pump, and a second filter to protect the injectors. All fuel lines are connected with threaded fittings to prevent leaking.
Cooling System

The 2012 cooling system design features several improvements over the 2011 design. Firstly, the radiator is lighter and smaller, with the inlet and outlet centered for improved flow. It is also ducted to increase the flow of fresh ambient air. Additionally, Aluminum tubes are used for cooling lines. Using Aluminum tubes instead of rubber hoses results in additional heat being rejected from the system while the cooling water flows through the lines. This makes the cooling system more effective. One last improvement is the addition of a swirl tank, which allows for easy filling of the cooling system and helps remove any air trapped in the system during operation.

Drivetrain

The 2012 drivetrain design focuses on proper chain alignment and rigidity. The differential is mounted directly to the engine which makes chain alignment simple, while eliminating direct load transfer to the frame. The differential mounts feature eccentric centers which eliminate the possibility of misalignment when tensioning the chain. This increases the reliability of the drivetrain system.

Frame

The 2012 frame is designed to incorporate the successful features of the 2011 frame while improving upon certain key aspects. The 2011 frame was lightweight, simple to construct, and spacious enough to allow for driver ergonomics. The 2012 frame improves on four features. The bottom of the front cockpit is narrowed by 100 mm to accommodate longer lower A-arms and allow for improved front suspension geometry. The cockpit length is extended 50 mm to allow more room for the pedal assembly. The vertical gap between the rear bulkhead frame members is increased so that the rear sprocket and differential are mounted closer to the engine, therefore decreasing the angle of incidence of the rear axles in the rear hubs. This angle of incidence contributed to the failure of the tripod joint in the 2011 car during the endurance event. This is a design improvement that increases the reliability of this system. Finally, the main roll hoop is raised 25 mm, increasing the outside envelope of the car and allowing for the addition of spacers in the adjustable air intake plenum.

Material

The frame is constructed using a 4130 steel spaceframe design. The ease of manufacturability, rigid structural guidelines (eliminating the need for material testing) and the reduced cost of the steel are the primary benefits that result in the selection of the steel spaceframe. The team aimed for a frame weight of 75 lbs or less and produced a frame weighing 65 lbs. This was accomplished through careful consideration of member placement and component packaging. Square tubing was used for the lower frame members in addition to the front and rear bulkheads. The selection of square tubing was made for ease of manufacturing, as it simplified the jigging of the frame and lower suspension mounts.

Suspension

The team decided to maintain the use of 13” wheels, to provide room for the upright and A-arm configuration, despite the added weight of this larger wheel. Pushrod suspension was chosen because of the wide range of adjustability and packaging options that it provides. Many of the suspension mounting points remain consistent with the previous car, where a large focus was placed on extensive iterative design using Optimum K suspension software to establish properly triangulated load paths. It was
determined that the lower front A-arms could be increased in length by reducing the width of the lower footwell area. This increase in A-arm length provides improved camber control through the wheel motion. Another improvement to the suspension this year is the design of the bell cranks. The new bell crank geometry achieves rising wheel rate as the suspension compresses, this decreases the likelihood of the suspension bottoming without increasing the static ride height.

For the 2012 car, new A-arm spherical bearing housings were designed in order to increase the accuracy of the A-arm dimensions during fabrication. These housings also incorporates the mounting points for the suspension push rods, thus bringing the line of action closer to the spherical bearing and reducing the bending moment on the A-arm.

Uprights
The uprights were redesigned in order to improve the attachment between the uprights and the A-arms. The new design allows the mounting plate of the upright to be parallel with the A-arms while at static ride height. This enables the A-arms to have a greater range of motion relative to the uprights before the parts interfere. The uprights are designed to be universally compatible with only changes to the mounting plates required in order to change suspension geometry. Finite Element Analysis (FEA) was conducted on the uprights to ensure these components could withstand the necessary applied loads with the material selection of 6061 aluminum.

Hubs
The hubs are designed to mate with center locking 13” OZ racing wheels and are the same design in the front and rear. A floating hub design was selected over a fixed hub design as this allows for more design freedom and eliminates the need for splines, simplifying the assembly and reducing the overall weight of the design. The hubs are manufactured out of 7075 aluminum instead of 4340 steel which was used on the previous car. This change allows for a total savings of 8 lbs in un-sprung, rotating mass over the previous car. FEA was used to confirm the new hub design could withstand the torque applied by both the wheels and the brakes. The aluminum rear hubs incorporate a hardened steel tripod housing that is inserted into the hub, eliminating wear issues with the aluminum.

Steering
The steering system uses a manual rack-and-pinion mounted to the base of the frame. The rack is bottom-mounted to lower the CG of the rack, pinion, and tie rods. This results in approximately 3 kg being lowered 400 mm (16 in), compared to a top-mounted rack. The chosen rack housing is smaller than the previous model to reduce weight while retaining mounting points at the end of the housing, providing more rigidity than housings with only center mounts. This decreases the amount of play in the tie rods while cornering at high speeds. The bottom-mounted rack and the placement of the brake calipers resulted in the team using a steering arm forward of the wheel center. The newly fabricated carbon fiber steering wheel provides the benefits of more leg room and better visibility due to the flat top and bottom, all while being lighter than the previous model.
Car # 47

Drawing No: DFSAE-100
Material: N/A
Scale: 1:10  QTY: 1

Team: Dalhousie University
Part: Full Assembly - Top View
Comments: All dimensions in mm.
Figure 1: Bell-mouth Design Comparison (#5 Selected)

Figure 2: Barrel Style Throttle Body Flow Simulation

Figure 3: Rendering of 2012 Competition Vehicle