Initial Design parameter

The team have aimed to build a competitive car to compete against both electrical and IC cars. Being the first year of competition, the aim is to build a solid foundation for further developments the coming years.

Suspension

The suspension design aims to keep it simple enough to allow full knowledge and understanding of all the contributions to the car's kinematics from the different components. With limited, finite element analysis possibilities, the design needed to be relatively simple so primarily manual calculations could be used. The first choice there was made was to use an SKF hub bearing unit, which would simplify the production and assembly of the upright. Along with the hub bearing unit, 13'' wheels where chosen to ensure freedom with the suspension geometry design. The geometry of the suspension is designed with a wish for a relatively high roll centre, which allows the car to have limited roll rate although the suspension design does not have an anti-roll bar. This made it possible to design the spring and damper connection directly between the lower A-arm and chassis, which significantly reduces the number of components needed. Furthermore, the soft wheel rate and front inclined roll axis should provide forgiving handling characteristics which are ideal for an inexperienced driver. The double wishbone suspension was designed with load paths as the primary focus. In figure XX the front A-arms can be seen (the spring and damper are not in this rendering). At the chassis mounting, rod-ends mounted axially in the tubes are used and at the upright, spherical bearings in a housing, which the tubes are welded to, are used. For the upright, a finite element method analysis was carried out. The upright is milled from an aluminium alloy (AW 6082 T6), which ensures low weight and excellent machinability. The brake disc material is cast iron which was found to be the most feasible option. Satisfying suspension geometry and a simple design to ensure a quick production was achieved.

Cooling system

The car has two different cooling systems. One for the Motors and drives, and one for the battery case. The Motor and drives are cooled by a water cooling system, which is made from:

- Two radiators that are made from aluminium and have a collected capacity of approximately seven litres.
- Two water pumps, Iwaki RD-40, that ensure the water flow through the system.
- Four radiators, EK-CoolStream XE 360 that is placed on the side of the car into side pods.
- Four 120mm fans, NF-F12 industrialPPC-24V-3000 Q100 IP67 PWM, That are placed on the back side of one of the radiators on each side.

This cooling system takes the water from the reservoirs, and then each pump pumps it through a motor and their respective motor drive. The water then flows through the radiators where it is cooled by the wind that comes from the cars driving speed and the four fans. After the water is cooled, it returns to the reservoir. The fluid used in the system is demineralised water, and the motor and drives have a build in cooling system designed for water. The batteries are air cooled by two 140mm fans, NF-A14 industrialPPC-24V-2000 Q100 IP67 PWM, that makes sure that there will be an air flow over the batteries which will enable them to stay cool.

BMS:

The BMS system is continuously monitoring the battery temperature and cell voltages and will keep all the cells balanced and make sure the battery is safe at all times. An Isolation Monitoring Device and a crash sensor will disconnect the battery if a fault or emergency is detected. Several emergency shutdown buttons are installed so a person can manually disconnect the battery.

Pedal sensors

The braking pedal and torque pedal have an identical circuit design except for the BSPD amplifier on the brake pedal, which does not have an impact on this system. It has been our goal to make our pedal sensor designs as safe as possible. Each sensor is constructed using two Bourns 53RAA-R25-A15L potentiometers, to allow for implausibility detection by comparing the values of the two. Both potentiometers go from low to high. All ADC's are 0-5 volts. If a voltage of 0V or 5V is measured it is detected as a short-circuit/open-circuit. Each potentiometer is connected in series with different resistors as to create different slopes for their transfer functions. The connection of resistors in series with the potentiometers ensures that the readings should never reach 0% or 100% allowing us to detect short and open circuit if they do. Furthermore, the pedals should only be to within 5% - 95% of the operating range of the sensors. This allows us to detect a mechanical error if this operating range is exceeded. If the values of the pedal sensors differ more than 10% for more than 100ms, it is detected as an error. If more than 5% accelerator pedal travel is detected while braking or more than 5% brake pedal travel is detected while accelerating it is detected as an error. Any error detected will result in the power to the motors immediately being shut down. The potentiometers from the brake position sensor are also connected to an analogue amplification circuit and carried to the BSPD through a shielded cable. The BSPD disables the tractive system in case power is delivered while hard braking occurs. This ensures that the driver will always be able to press the brake pedal hard to stop the car in case of a tractive system failure.

Master OS

The primary task of the master controller is to interface with all electronic subsystems and calculate torque vector and detect errors in the vehicle. The master control unit is a National Instruments cRIO, which features a processor and an FPGA. The FPGA is a real-time system and is programmed to handle all safety critical events such as error detection and shutdown signals. The processor handles trivial events and torque vector calculations.

Intercommunication system (CAN bus)

We have chosen to convert all analogue signals into digital signals before transmitting them to the master controller to minimise noise and error risks. All analogue inputs and all output devices are connected to a subsystem consisting of an ATMEGA328P microprocessor and MCP2515 CAN-interface IC, which communicates with the master and other subsystems through the CAN bus.

Brake lights

To minimise the risk of a brake light malfunction we have chosen to build two independent light emission circuits. If one circuit fails, half of the brake light should still be operational. Furthermore, the circuits are controlled by an active high signal, which means the brake lights will be activated if control signals are lost.

Steering wheel sensor

The steering wheel position is measured using a Formula Seven Pro Steering Rack, which produces a 0.5 - 4.5-volt signal depending on the angle. If a signal exceeds the operating range of the steering wheel, this is detected as an electrical error. The data is used to calculate a target torque for each motor and detect implausibility of the brake pedal and speed pedal.

Ready to drive sound

The ready to drive sound is produced by a 105dB siren. This sound is activated whenever the car is ready to drive. The siren sound is easily recognisable and not a sound that can be produced by the car.

Battery

The main accumulator used in the vehicle will be based on lithium polymer cells. It will have a nominal voltage of 104 V and store roughly 30 MJ divided into seven segments. The amount of energy stored will likely prove to be excessive, but we have gone for this configuration to secure crossing the finish line in the endurance test. Safety has been the highest priority when designing the accumulator, which has led to the decision of using a lower voltage than is usually seen in electric vehicles. This, in turn, means that the accumulator must be able to deliver a high current. To facilitate this, all wires and components in the accumulator must be rated at a minimum of 800 A, which only a few and usually industrial grade components on the market are able to deliver on. Therefore, our main accumulator is built to be very robust, due to the large number of heavy-duty components used. The cells themselves are added to the accumulator in a modular fashion. This makes the accumulator easy to service, should this become necessary. Additionally, our design allows for safe assembly, as the cells will have male connectors whereas the accumulator will only have female connectors. This way the assembler will only ever be able to be exposed to the low voltage from the cells. To manage the accumulator, an Accumulator Management System (AMS / BMS) by industry leading manufacturer Lithium Balance will be used. The AMS will provide balancing of the cells, temperature management and a slew of other safety features like charging control, which is necessary when working with LiPo based cells. Th,e, main accumulator, will power the drives (inverters) and the motors. All low voltage control systems will be powered by a secondary low voltage pack, with a nominal voltage of roughly 22 V. This secondary pack will be situated in its own container.

Body panels, Aero:

To maximise cornering speed, an aero package was designed for the car. The rear wing consists of two fixed elements, in the future DRS will be included in the rear wing design. The size of the rear wing is maximised within the aero rules and placed high enough, so they are not blocked by the driver's helmet. For simplicity, being our first car, the wing profiles used on the rear wing are also used for the front wing, with variations on the width. An undertray was also designed to further help the overall downforce of the car. Wings are produced in carbon fibre with a foam core, cut with hot wire. The undertray is made of aluminium, making sure they will not break under load and when moving the car around. The actual body panels are made of aluminium sheets, which are formed around the tube chassis to close of the car.

Chassis

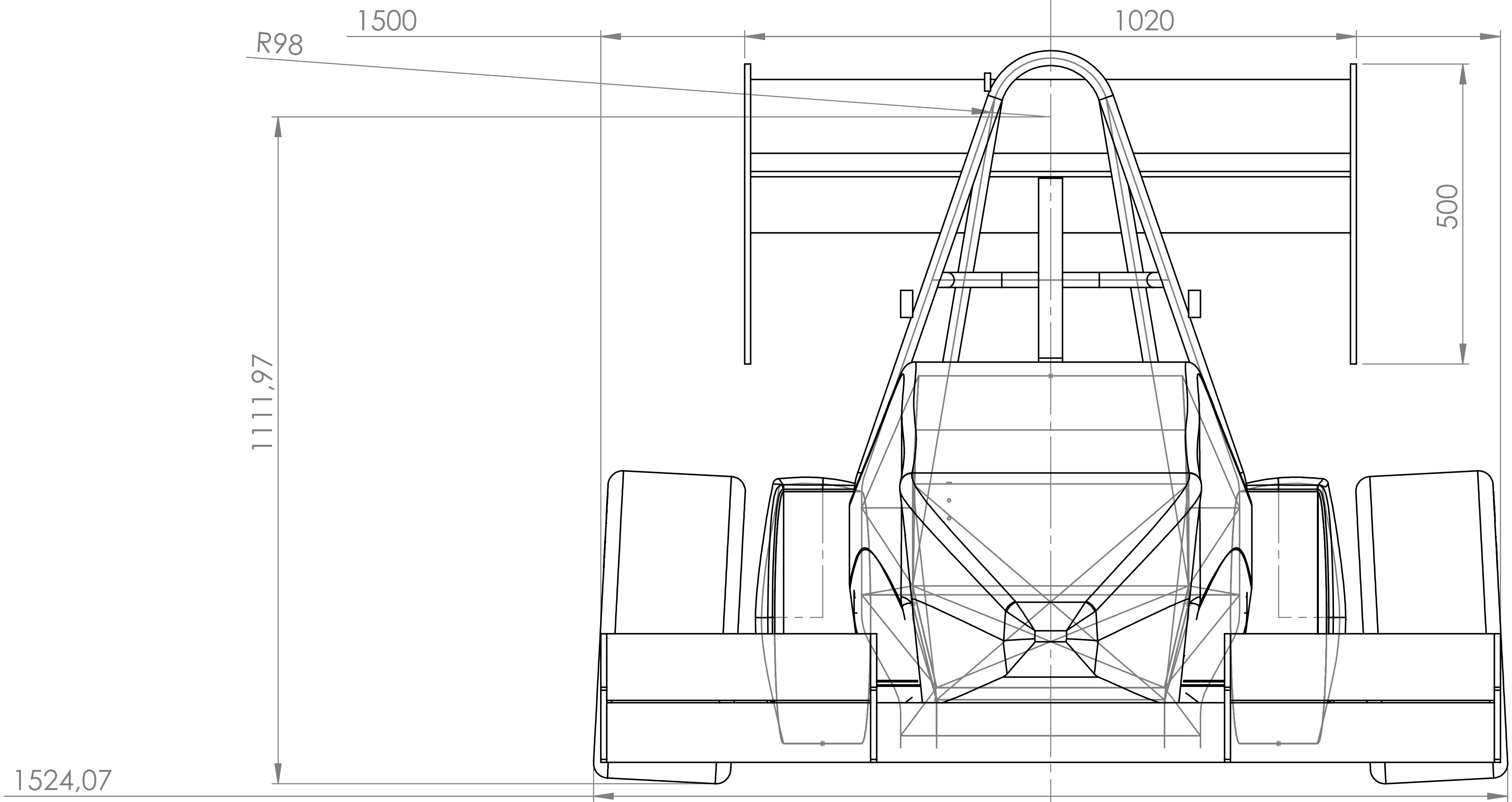
The chassis has been designed to be as simple as possible due to this being our first car. The chassis is constructed from steel tubes according to the rules. The chassis was one of the first finalised designs of the car. Therefore almost any component has been designed to fit the chassis, instead of the other way around, resulting in only very few design requirements. The chassis has been designed to be made from steel tubes and to comply with a few geometric specifications. We aimed to build a car with a low centre of gravity, and to minimise drag by minimising the front cross-section area while maintaining prerequisites for good driver ergonomics Preliminary some tubes had specified positions to accommodate the chosen suspension geometry, primarily the mounting points of a-arms have been considered as essential design parameters when designing the frame. The structure itself has been designed to be robust and strong rather than light. Even though this reduces competitiveness, building a safe and reliable car, increases our chances of competing, rather than risking not to pass inspections, or having critical failures before the competition.

Cockpit

The cockpit design has been made so it would comply with the regulations. This is the first year the Technical University of Denmark is competing, and our primary goal is the car complies with the overall regulations. The cockpit has been designed with help from section T.3 [1], the cockpits internal cross-section, T3.2 [1] had to be fulfilled so Percy would fit. Percy from section T3.3 has been modified in Solidworks 2017, to indicate if he would fit. Through the design of the cockpit, we had to modify the overall length and height of the car so that Percy would comply with the rules. From figure 11, section T3.3.4 [1] we had an idea of how Percy should be seated. The major question here was how much room we needed after Percy's feet, so we would have enough room to fit the pedal box and the sensors needed. From Percy's hip to the end of his feet there had to be a minimum distance of 915 mm. Another thought was it would be wise to incorporate a railing system in the pedal box, which would allow it to be moved to an optimised position for the driver. It was chosen to use Wilwood pedals because they are made from aluminium which is durable and light. The pedals must withstand a force of 2000N when pressed all the way forward, T5.1.8 [1]. The pedal box was decided to have an overall length of 400 mm. In this area, we would have to fit an accelerator pedal and brake pedal, which includes a master cylinder for the brake, brake lines and an accelerator pedal position sensor (APPS). After talking to the electrical department, we knew exactly how much space they needed for the sensors and electronic, which was equivalent to a box of maximum 13x13x7 cm. The next step was to draw the pedals, master cylinder, reservoir and electronic box in front of Percy so we knew if it would fit. After this was combined with the full chassis model, we had roughly about 80 mm clearance to the impact attenuator which will be useful at some point. The steering of the car is entirely mechanical and was decided to be a rack and pinion. The thought is, the steering goes down in the middle of the driver’s legs, so one leg of each side of the steering rack. The steering wheel measures 250x200 mm which allows proper clearance. The driver has to be seated in a position like Percy, so we comply with the regulations. Behind the driver, we need a firewall. The firewall has to be made from a non-permeable surface, and have to be made from some fire resistant material for example aluminium, section T3.8 [1] provides the essential information. Design is currently underway for a combined seat and firewall.

Motor control

The motors - a pair of Emrax 228s - can separately provide an output up to 42 kW, and the drives - a pair of EmDrive 500s - can separately support up to 60 kW. Each motor has a drive attached to it, so the motor is controllable. Each drive contains different parameters, such as Integrated velocity and position regulator and throttle input controls for the motor torque. The motor torque is controlled by an integrated four quadrant control, which enables accurate control of both increasing and decreasing motor torque in both forward and backward motion. Furthermore, log files such as motor voltage, motor current, motor speed, can be retrieved from the drive and analysed. This enables us to regulate the two motors behaviour so they do not exceed an output above 80kW. The Emrax 228 motors and EMdrive 500’s will be physically implemented to prevent the motors and drives from overheating and to ensure the connection between the drive and motor, thus avoiding endangering the driver of the race car from a short circuit.



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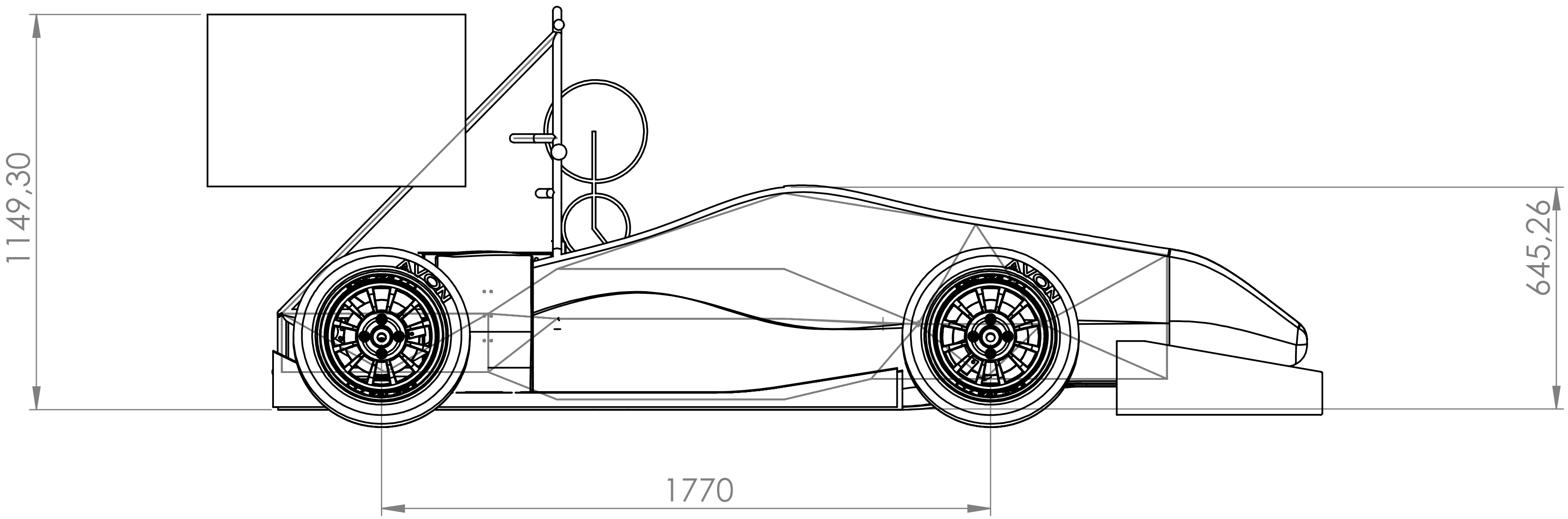

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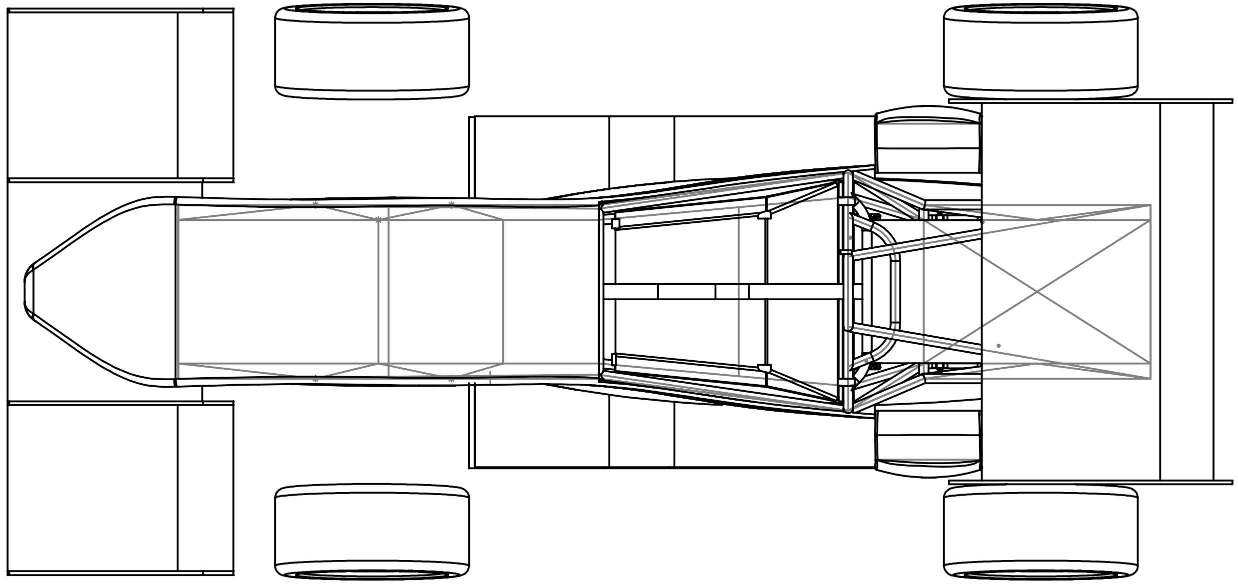

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