Cooling system

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1 Introduction

The cooling system serves to keep the tractive system cool enough to work in a safe condition. The system has the objective of dissipate the heat generated by the two inverter and two electric engine, and is made of a single radiator, that is used as heat exchanger between water and air; paired with two electric fan and with inside water. The water is forced to flow by an electric pump. There are also other auxiliary components: a catch can and expansion tank. The main challenge of this year is able to exchange the dissipated power with a low temperature gradient between the internal water and the external air. The maximum temperature reached by the inverters and the motors are both 60°C at the inlet of the water heat exchanger. We are decided to mantain a single circuit layout with the motor in series at the inverters so our maximal temperature at the inlet of the inverter is about

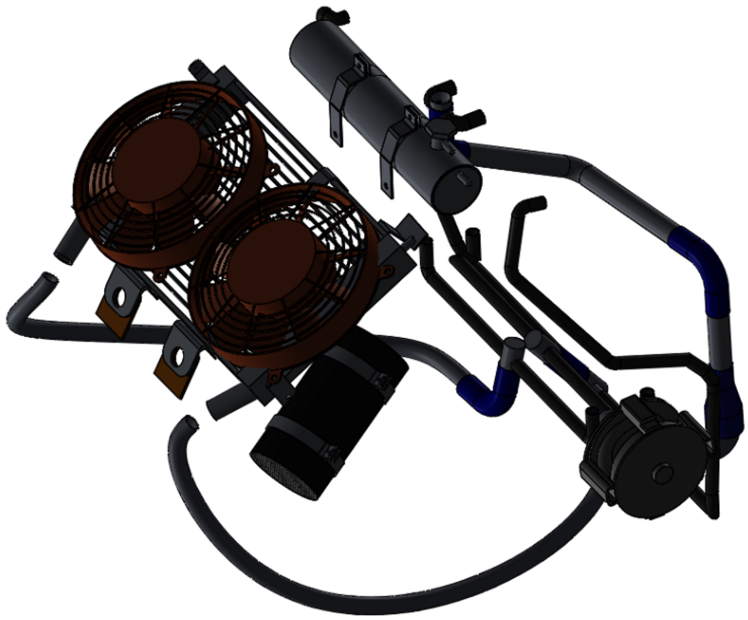


Figure 1: Layout cooling system

2 Constraints

The design of the cooling system has to respect some constraints given by the regulation.

- Plain water is the only fluid possible to use.
- Separate catch cans must be employed to retain fluids other than plain water from any vents of the cooling system or combustion engine lubrication system. Each catch-can must have a minimum volume of 10% of the fluid being contained or 900 ml whichever is greater
- Ensure the absence of fluid leakages from the system
- Any vent for systems containing plain water must have a catch can with a minimum volume of 10% of the fluid being contained or 100 ml, whichever is greater.

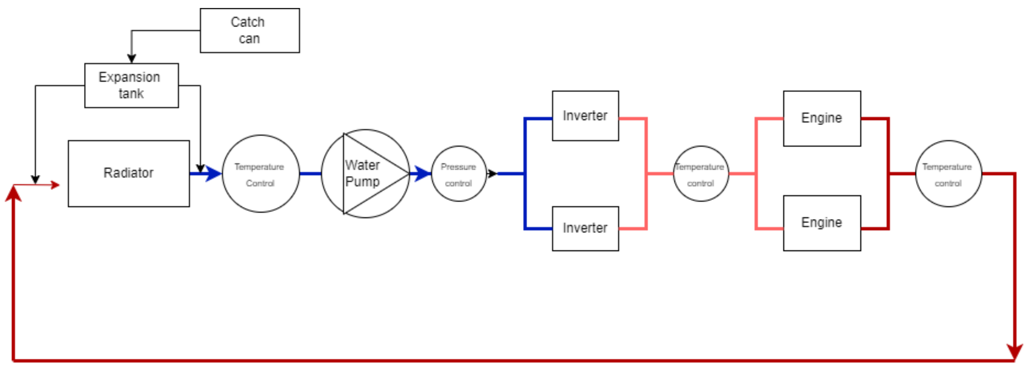
- Cooling systems using plain water (except outboard wheel motors and their cooling hoses) must have a heat resistant (Permanently rated for at least 100 °C), rigid and rigidly mounted cover which meets the requirements of T 4.8.2
- Any cooling or lubrication system must be sealed to prevent leakage
- All parts of the engine cooling and lubrication system, including their mountings, must be rated for at least 120 °C or the temperatures the respective fluid may reach, whichever is higher
- Catch cans must be rigidly mounted to the chassis and located reaerwords of the firewall below the driver's shoulder level.
- Any catch can must vent through a hose with a minimum internal diameter of 3 mm down to the bottom level of the chassis and must exit outside the bodywork.

3 Layout

The entire cooling system is made of

- Radiator
- Radiator fans
- Water pump
- Expansion tank
- Catch Can
- Pipes

The engine and the inverter have an heat exchanger integrated, with whom is possible to dissipate the heat generated during the operative phase. The circuit is with inverter and engine in series.At the beginning water pass in the inverter, than into the engine and after that comes back in the radiator so is possible cool the water and restart the cycle. This configuration is possible because of the different operative temperatures of the components, the inverters have to be below 110°C and the internal part of the engines 120°C and so even if the water flow before inside the inverter is still possible to cool sufficiently , under 60°, the tractive system. This configuration allow to make the circuit easier, because the symmetry guarantee the same flow rate in both the side of the circuit.



4 Radiator

The radiator is a water-air heat exchanger, with the air forced to flow by the two electric fan. This choose was made because of the necessity of having a sufficient heat dissipation.
The main characteristic are reported in the following table.

Parameters	Dimensions
Header to header length (mm)	350
Core width (mm)	250
Fin depth (mm)	30
No. of tubes	25
No. of fins at metre	750
Thermal conductivity (W/mK)	250

Table 1: Datasheet radiator

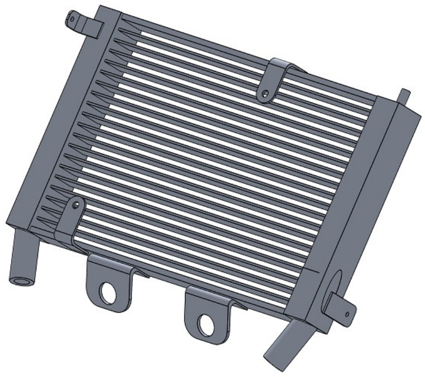


Figure 2: radiator

4.1 Design radiator

The radiator has to be able to dissipate enough heat derived from the engine and the inverter. The first one is sizing the heat exchanger surface at the maximum power losses, that is about 12 KW.
The equations used in the sizing are the following:

$$\dot{Q} = (UA)\Delta T_{ML} \tag{1}$$

$$UA = \frac{1}{(\frac{1}{h_{air}}A_{fin}\eta_{fin} + \frac{1}{h_{water}}A_{water} + R_{cond})} \tag{2}$$

The second one, that one chose, is sizing the surface at the mean power, and using the capability of accumulate heat of the mass of water flowing in the circuit as an heat accumulator. In fact the water peaks are enough rare and slow, for this reason we check that the heat exchanger surface is sufficient for the dissipate heat in one lap and not at the maximum power. This solution allow us to reduce weight of the possibility of use a single radiator, and also give a lower complexity at the circuit.

$$Q = mC_p\frac{\Delta T}{\Delta t} \tag{3}$$

For validate this choice we analyze the previous year telemetry of a lap of endurance and evaluate the temperature and the hypothetical dissipated heat during the lap. We can appreciate that the temperature at the exit of the circuit becomes lower during the lap and the inertial mass of the water is used like an heat capacity to maintain the temperature in the right interval also when instantaneously the heat exharger is not able to dissipate all produced heat. The ambient temperature considered is T=40°C.

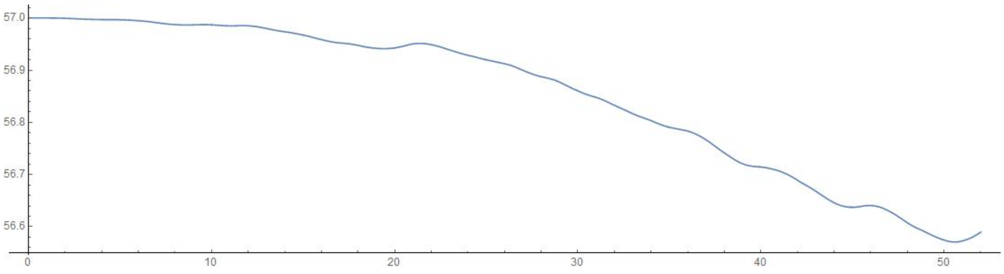


Figure 3: temperature at the entrance of radiator

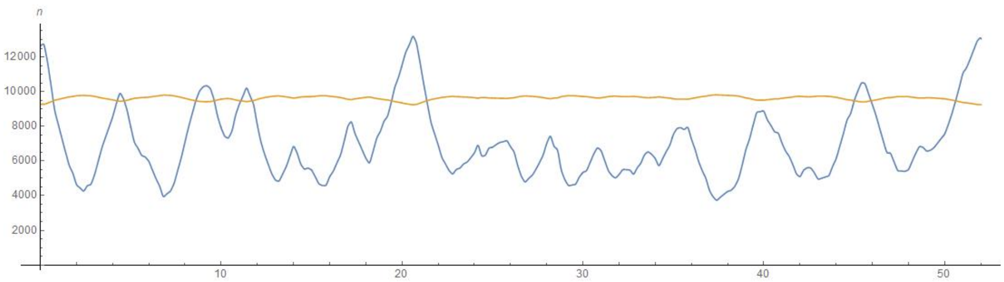


Figure 4: heat dissipate by the radiator(orange), heat produced by the components(blue)

4.2 Other function

In the circuit the radiator have the main function to dissipate heat, but have also the structural function to supported all components on the rear. The radiator is the only element of the cooling system of assembly on the rear of the car connected to the chassis through 4 plates and acts as the main support for the fans and for the conveyor.

5 Water pump

The electrical pump has the aim of supply a sufficient flow over the entire circuit. The pump used is from the past year, because it is able to supply the quantity of circulating water needed for a correct dissipation of heat. The target chosen for the flow rate is 20 l/min, the theoretic capacity(the flow rate in absence of pressure drop) of the pump is 80 l/min. The dimension of the pump, is made not only of the flow rate but also by the correct prevalence offered by it at the circuit flow rate.

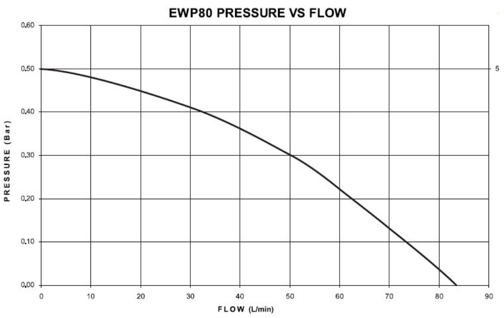


Figure 5: characteristic curve of pump

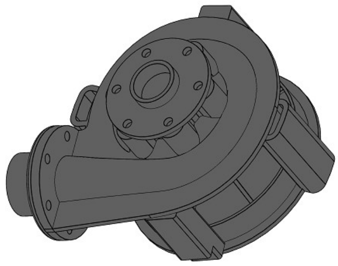


Figure 6: pump

6 Radiator fan

In the configuration chosen for this year are used twin fans, with counter-rotating blades, and entirely cover the heat exchanger, its is used to let air to crossing the radiator surface. At the maximum speed the fan is able to constrain about 620 $\frac{m^3}{h}$ of air, and it absorbs 60W.

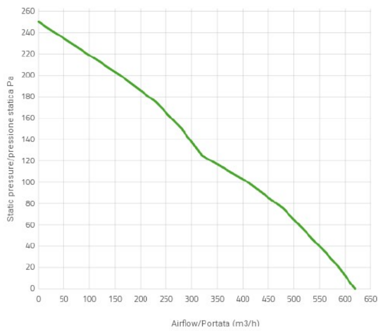


Figure 7: characteristic of fan

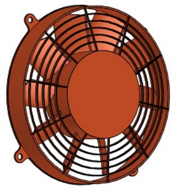


Figure 8: fan

Some simulations have been done for analysing the configuration with the fan in the back of the car.

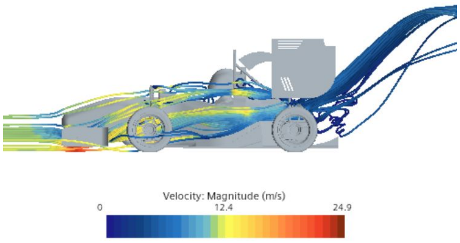


Figure 9: Flow field

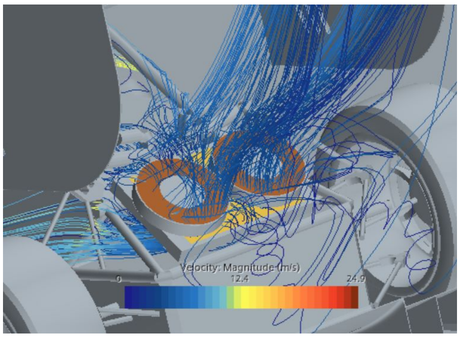


Figure 10: Flow field on the radiator

The results show that is possible to have a sufficient flow velocity on the radiator,and so is possible to put the radiator in this configuration. The results are showed in the 10.

7 Catch can

The catch can has the function of retaining possible fluid vents from the circuit. The dimensions are defined by the regulation,our system contains 2L of water and according to the rules previously defined we opted for a 1L catch can. The position of can is in the back of the car.

Figure 11: catch can

8 Expansion tank

The expansion tank serves to adsorb the variation of volume of water caused by the variation of temperature of the system. The volume of the expansion tank is 10% of the total volume of water circulating in the system, according to the regulation.

9 Pressure sensors

Only one pressure sensor works in this water circuit and it due to check the correct working of the pump.

10 Temperature sensors

There are three temperature sensors to check the temperature in the three nodal point of the circuit: after the heat exchanger to control the water flux at the begin of the circuit, at the end of the inverters to check

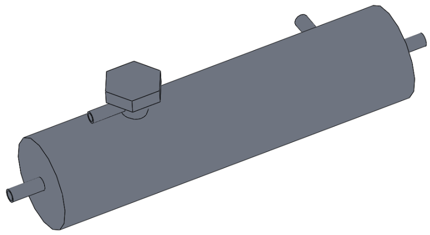


Figure 12: expansion tank

the temperature at the enter of the electric engines, and the last one at the exit of the engines to control the temperature of the water at the entrance of the radiator.

11 Pipes

There are two different types of pipes used in the circuit. The first type is made of aluminum, because of the necessity of using rigid component if these are out of the chassis. The other type is made of silicon, with an heat resistance above 120°C, to let the conjunction between the different part of the circuit.

Parameters	Dimensions
Radiator to pump (mm)	16
Pump to inverter (mm)	11
Inverter to engine(mm)	11
Engine to radiator(mm)	16

Table 2: Dimensions of pipes