AERO 101

Greetings again and welcome to the eleventh segment of Aero 101. Sorry we're a day late! Today we will talk about hood vents and internal airflow. Cooling inlets (ducts) and exits, much like the exterior of the car, need to be designed properly to ensure the air flows smoothly. Ducts can have many shapes, including scoops, ram air (or straight through) and NACA approved design ducts. As always, please don't feel afraid to ask questions!

Like the exterior of a racecar, the path of a cooling duct follows the shape of a venturi tube. The short inlet, in this case, acts as the diffuser, slowing down the air. They must be placed in an area of high pressure. The air then passes through the heat exchanging element, and finally is ejected through a contracting duct into a low pressure region. The low pressure region ensures that the pressure difference between the inlet and exit drives the flow. As the flow passes through the heat exchanger, the static pressure drops, due to the heating and friction effects, which further helps drive flow. Exits usually increase the boundary layer thickness behind them, and this in turn increases the likelihood of flow separation. The most common place of exit you see is out the top of the hood, but in other cases, such as LMP cars, the heating exits may be into the wheel wells themselves. A common exit on Formula 1 cars is at the rear of the vehicle, between the rear wing and the diffuser. This works because there is already a large are of massive flow separation, and the low pressure behind the car can also speed up the cooling flow.

Straight through Ducts

Straight through ducts are most commonly used as radiator inlets. The inlet should have a radiused lips all around to ensure the flow does not separate as soon as it enters the duct. A general rule of thumb is to make the inlet 30-33% of the cooling matrix, to ensure there is sufficient pressure drop to feed air into the system. In reality, the design of the duct really depends on spatial restraints. Generally, you do not want the diffuser angle to be larger than 15*; if space dictates the angle needs to be larger, internal vanes must be employed to prevent flow separation. A common misconception is that the larger the duct, the more it will benefit the cooling system. If you try to force too much air into a system with restricted capacity efficiency, external flow separations can happen. There is only ONE optimal speed for a radiator to function at its optimal efficiency.

Scoops

Internal flow also covers intakes for the motor. A common intake seen on Formula 1 cars is the raised air scoop. The air scoop must be elevated above the boundary layer, and the internal diffuser must be well matches to the external flow to avoid flow separation. A radiused lip is still needed when designing an air scoop, but since it feeds the engine intake, the diffuser and contracting section are not required. The air scoop inlet should ideally be small, and properly sized to feed the intake the appropriate amount of air. There is a simple formula for calculating the cross-sectional area of the column of air entering the inlet (Volume flow rate divided by car’s speed).

NACA Duct

Another common intake is the NACA duct, which, due to its shape, has a high efficiency with little additional drag. NACA ducts, for proper operation, usually need to be mounted where the boundary layer is very thin (which is usually at the front of the vehicle). The air flowing towards the narrow opening of the duct is encouraged to flow down the ramp, because of the air flowing outside the duct which flows over the sharp edges. This creates 2 counter rotating vortices which draw in more air down over the edges. Fortunately, there is already data and information on how to properly design a NACA duct.

Hood Vents

Hood vents should be placed properly in areas of low pressure. In certain instances, these exist very far or on the outside edges of the hood. However, this can be combated. Our friends over at Singular Motorsports have created hood vent louvers with a gurney flap to help extract air from inside the engine bay. The gurney flap here works exactly the same way as it does on the wing. Creating a high pressure region directly in front of the vent means that the air in the vent has lower pressure. Ideally, the radiator should be ducted to these vents for it work efficiently, but any decrease in under hood pressure (and temperature) helps. Since the vents are pretty close to the radiator, the flow through the radiator can exit rather quickly. The center vent in their design is in a neutral pressure zone on the NA Miata hood, but since a gurney flap is employed, this now becomes a negative pressure zone.

Source: Competition Car Aerodynamics by Simon McBeath & Race Car Aerodynamics by Joseph Katz