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Influence of Aerodynamic Pressure Drop in Cooling Module on Backflow in PHEV Condenser

HAIBO WU [1) 2)] SICHUAN XU [1)] JIANGBIN ZHOU [2)] WENSHI CUI [2)]

1) Tongji University, Shanghai 201804, China

2) SAIC Volkswagen Automotive Co., Ltd., Shanghai 201805, China

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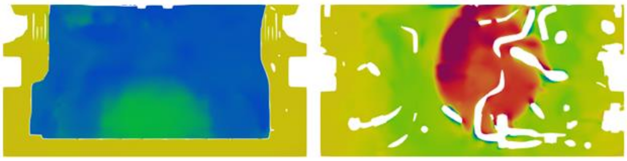
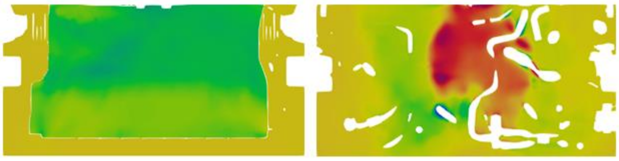
In order to meet the requirements of vehicle thermal balance performance during different working conditions, the minimum and maximum open areas of the grille are s=405cm^2 and s=925cm^2. This paper takes the backflow and pressure of cooling module as the research object. In order to ensure the accuracy of numerical solution, the meshes of the body surface, grille area, and cooling module are refined. According to the boundary layer and volume meshing requirements, the number of polyhedral meshes for OpenFOAM software is about 80 million. Increasing the number of meshes has little effect on the calculation results. In the boundary conditions, velocity inlet and pressure outlet of computational domain are set as inflow condition and outflow condition, respectively. Meanwhile, the ground is set as non-slip wall. Previous studies have shown that the results based on Reynolds average equation turbulence model with wall function realizable k-epsilon can accurately predict the flow of the cooling module, so this method is available for simulation research. The numerical simulation and test results of open grille area (s=463cm^2) are 0.75kg/s and 0.83kg/s. The calculated and measured results of s=925cm^2 are 1.25kg/s and 1.33kg/s. The difference between CFD and wind tunnel test is within the range of 2%~5%, indicating that the simulation accuracy is acceptable. Therefore, the following cases all adopted the numerical simulation method of this section.

For idle condition of s=925cm2, the main reason for the change of the flow field and pressure is the airflow suction effect formed by the fan rotation, which makes the highest static pressure behind the fan. As shown in Fig.7, the pressure on the leeward side (x=-0.8m) is much lower than that on the windward side (x=-0.55m), which results in the positive pressure difference between the front and rear of the cooling module. With the positive pressure difference, the airflow moves back into the area in front of the condenser from the gap of the condenser frame and the edge of the deflector, which forms complex backflow. with flow rate of the airflow through the grille increase, the velocity, total pressure and static pressure on the windward surface (x=-0.8m) increase.



(a) s=463cm^2, x=-0.8m (b) s=463cm^2, x=-0.55m



(c) s=925cm^2, x=-0.8m (d) s=925cm^2, x=-0.55m

Fig.7 Static pressure contours of idle condition

With the area of high-speed airflow passing through the windward of the condenser enlarged and the fan rotation speed unchanged, the airflow dissipation through the condenser increases and the static pressure declines on the leeward side (x=-0.55m). Therefore, the pressure difference of the cooling module and the rotating streamline decreases, which results in the reduction of the backflow flux from sides of the condenser.

For s=463cm^2 of the cruise condition, the rise of vehicle velocity leads to increase of total pressure, so the static pressure on the windward surface raises accordingly. In the meantime, the pressure drop of the fan itself decreases. The static pressure on the windward side is greater than the leeward. The pressure difference of cooling module at cruise condition is negative, while the idle condition is positive.

The numerical simulation of the backflow and pressure distribution results with different grille structures at idle condition and at cruise condition are investigated. Following conclusions are obtained.At idle condition, with the open grille area increases, the pressure difference of the cooling module decreases, which results in weakening of the backflow and the reduction of the proportion of the backflow through the condenser.At cruise condition, the open grille area has little effect on the pressure difference and the change of the backflow.