

Rainfall simulation analysis of front windshield lower trim panel system based on SPH method

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Abstract. Based on the smooth particle hydrodynamics method, a rain simulation model of the front windshield lower trim panel system was established in AVL PreonLab simulation software, and it was found that the risk of air conditioning inlet and wiper motor is low risk under the original scheme, but the risk of water in the cabin is greater. Considering the weakening of the sealing effect after the durability of the sealing cotton, the water may flow into the cabin; secondly, the water barrier bars on both sides of the wiper cover are not wide enough in the Y direction, and the water will flow into the cabin when the rain is heavy. Through the simulation analysis of the optimization scheme, the problem of water in the cabin can be solved, and the problem can be found in advance at the design stage, and the optimization scheme can be proposed to reduce the development cost of the whole vehicle, which is an important guidance for the development of water management of the whole vehicle.

Keywords: Rainfall simulation; SPH; Water management.

1. Introduction

With the progress of science and technology and the improvement of living standards, people's requirements for automobile modeling and performance are increasing. The whole vehicle water management key performance index in the development of the whole vehicle, but also one of the most perceptible performance of consumers, mainly to study the waterproof performance of the car in the rain, wading, rain and fog, car wash and other conditions, the status of the car in the development of the whole vehicle is also becoming more and more important [1-2]. The front windshield lower decorative plate system is located between the front windshield and the hair cover system, which is mainly composed of the front windshield, wiper system, wiper cover, hair cover system, fender, front enclosure water trough sheet metal, etc. [3], as shown in Figure 1, under rainy conditions, it plays an important role in the water ingress into the engine compartment and water ingress into the air conditioning air intake.

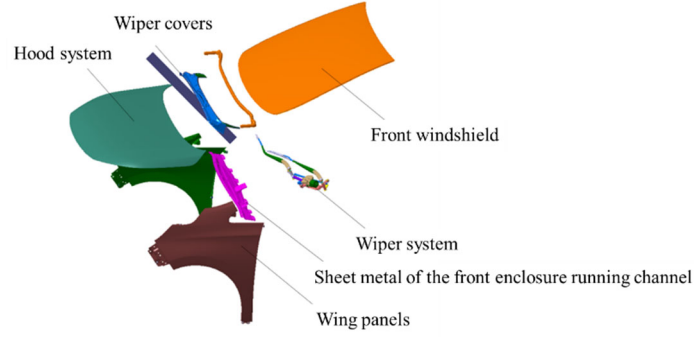


Figure 1. Front windshield lower trim panel system.

At present, the development of water management performance of the whole vehicle mainly relies on the previous failure model and experience to do design avoidance, as well as the means of experimental verification in the late stage of the project, which has the shortcomings of high cost of engineering changes and long change cycle [4]. In this paper, the hydrodynamic method is used to simulate the rainfall process of the front windshield lower trim panel system, which can reduce the development cost of the whole vehicle by identifying the problems and proposing the optimization scheme in the design stage in advance.

2. Introduction of SPH method

Smooth Particle Hydrodynamics method SPH is a continuous fluid (or solid) described by interacting groups of plasmas, each material point carries a variety of physical quantities, including mass, velocity, etc., by solving the kinetic equations of the group of plasmas and tracking the orbit of the motion of each plasma point, to obtain the mechanical behavior of the entire system. In this paper, we use PreonLab software developed based on the SPH method to carry out the subsequent simulation study. PreonLab is a very powerful and practical meshless fluid CFD simulation and analysis software, which does not require pre-processing, and can greatly shorten the simulation time.

3. Organization of the Text

3.1. Geometric model preparation

Since PreonLab does not require preprocessing, the parts of the front windshield lower trim panel system are imported directly in stl format, as shown in Figure 2. The air conditioning intake grille holes of the wiper cover plate have a very small size, in order to accurately simulate the effect of these holes on the liquid flow, it is necessary to use a very small particle size in the simulation process, but if all liquids are solved with such a small particle scale, the computation time is very long, which is impractical in terms of the efficiency of engineering applications.



Figure 2. Simulation model of the front windshield lower trim panel system

In order to ensure the efficiency requirements of engineering applications, the simulation requires the program to be able to intelligently carry out particle refinement and particle merging, and the continuous particle size (CPS) algorithm in PreonLab can well meet this requirement, and the near-wall particle refinement function can be utilized to set the air conditioning intake grille holes around

the wiper cover plate into small particles, and the other areas into large particles, as shown in Fig. 3, which can shorten the simulation time.

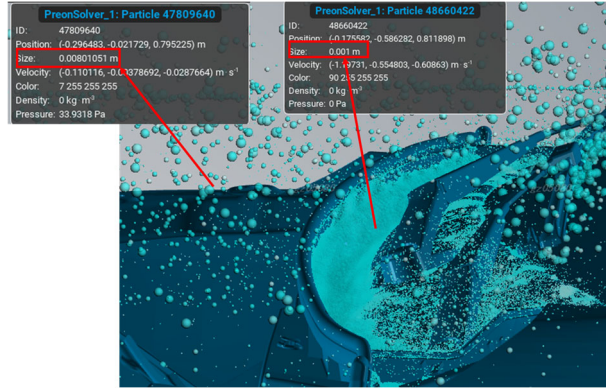


Figure 3. Schematic illustration of particle refinement on the near-wall surface

The opening of the wiper system affects the drainage of the front windshield lower trim panel system, when the wiper system is not in motion, all the rainfall is discharged by the front windshield lower trim panel system, and the depth of water on the cover is more severe relative to the movement of the wiper system, therefore, the wiper system is not in motion during the simulation of this paper.

3.2. Physical model and boundary conditions

The physical parameters and model settings of rainfall are shown in Table 1. Among them, the adaptive time step is set, the implicit algorithm is used to solve the problem, and the rainfall condition is a flat rainfall with a rainfall rate of 24 mm/min.

Table 1. Physical properties of rainwater and model settings

Parameter	Value
Density of water $\rho/(\text{kg}\cdot\text{m}^{-3})$	998.2
Surface tension of water $\sigma/(\text{N}\cdot\text{m}^{-1})$	0.072
Dynamic viscosity of water $\mu/(\text{Pa}\cdot\text{s})$	0.001
Surface tension model Potential Force	Potential Force
Viscous model Newtonian	Newtonian
Adaptive time step	Yes
Maximum time step	0.2
CFL value	1

4. Simulation results

The rainwater management of the front windshield lower trim panel system is mainly to design a reasonable structural arrangement to guide the rainwater along the designed route to be discharged out of the vehicle, so that there is no accumulation of water and no seepage. Requirements for the front windshield lower trim system are: ① air conditioning air inlet can't enter the water; ② wiper motor function is not affected; ③ water can't flow into the front cabin, this paper is mainly from the three points of the calibration.

4.1. Air conditioning air intake rain checking

In order to avoid the air conditioning air intake into the water, wiper cover air conditioning grille inlet hole arrangement should try to avoid the air conditioning port, so that the arrangement can be avoided

from the water is sucked into the blower system, while the air conditioning air intake to the lower edge of the sheet metal to the water tank Z distance to try to be as high as possible.

The Y-distance between the grille air inlet and the air conditioning air inlet of this model is 90mm, and the air conditioning air inlet is 73mm away from the sheet metal, as shown in Fig. 4. From the simulation results, rainwater flows from the grille inlet holes into the running channel and then flows away smoothly from the drainage holes on both sides of the sheet metal, and no water enters into the air conditioning air inlet, as shown in Fig. 5.

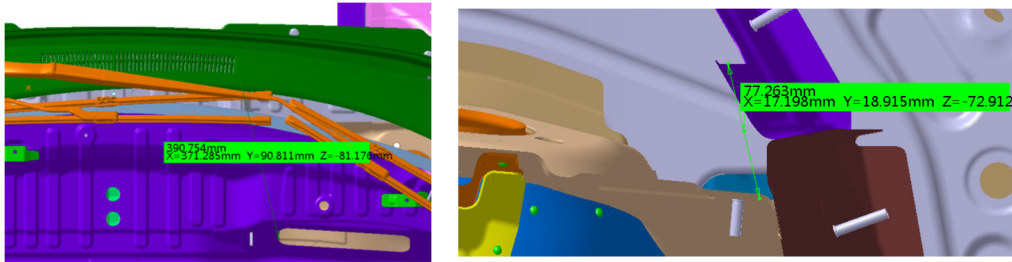


Figure 4. Schematic diagram of air conditioning air intake

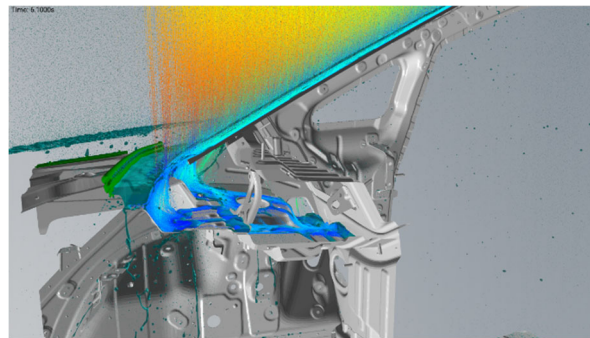


Figure5. Water flow path around air conditioning air intake

4.2.Wiper motor rain checking

Wiper shaft position opening, rainwater is easy to flow through this opening along the wiper shaft to the wiper motor, wiper motor damage. Figure 6 shows the statistical results of the wet wall area percentage of the wiper shaft and ball head. The cumulative wet wall area has been stabilized at 3s, with a percentage of 2.8%, and the risk of water ingress at the wiper rotor and ball head is small.

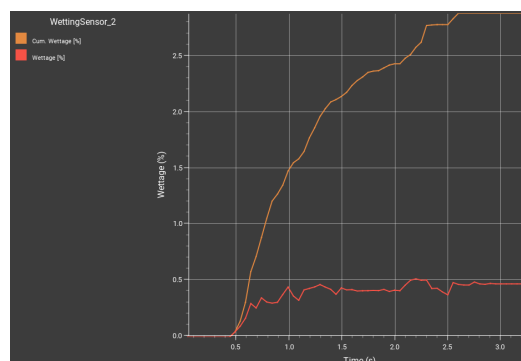


Figure6. Wet wall area share of wiper swivel and ball head

4.3. Front cabin rainwater calibration

There are two ways for the rainwater to be finally discharged out of the vehicle: one is through the drainage holes on both sides of the front circumference flow channel, and the other is through the exterior of the wing panel wheel cover, so the water guide channel of the front windshield lower trim panel system can be designed according to this path. This model adopts the first type of drainage holes on both sides of the front circumference flow channel, and the water flowing from the front windshield, part of it flows away from the drainage holes on both sides of the windshield wiper cover plate, part of it flows away from the air inlet of the windshield wiper cover plate grille, and part of it flows away from the windshield wiper axle holes, as shown in Fig. 7.

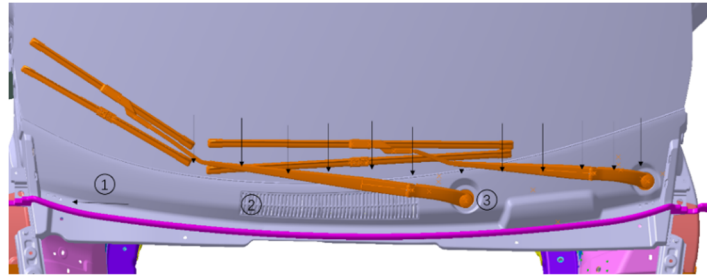


Figure7. Rainwater Drainage Path

Regardless of which holes the water flows through, it will only end up draining through the drain holes on either side of the running sink sheet metal. Considering that there are more electrical parts in the cabin, water flowing into the cabin may cause panic and bad sensation to customers. Through the simulation, we can see that the water flowing away through the grille air inlet, the water droplets fall on the horizontal surface of the sheet metal of the water tank, because of the water adsorption effect of the water along the cover X direction of the water flow forward, although there is a sealing cotton between the wiper cover plate and the sheet metal, taking into account that the sealing cotton after aging sealing effect is weakened, the water may flow into the cabin. Figure 8 below shows the simulation without sealing foam, and you can see the water flowing into the cabin.

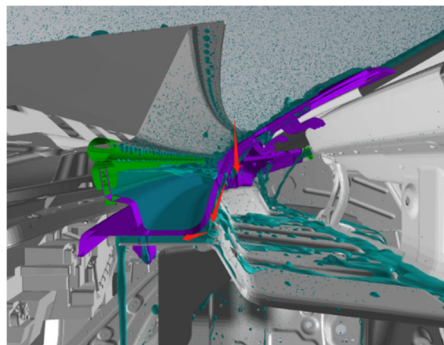


Figure8. Direction of water flow through the grille air inlet of the wiper cover

In addition, by analyzing the data of the wiper cover, it was found that the Y-direction of the baffle rib on both sides of the cover was not wide enough, and the water would flow over the baffle rib to the cabin when the rainfall was heavy, as shown in Fig. 9.

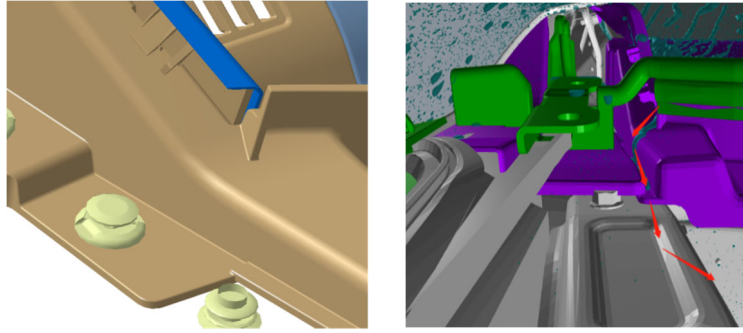


Figure9. Water flowing into the cabin from both sides of the wiper flap

5. Optimized Solution

In the original solution, the flow channel sheet metal and wiper cover plate overlap with a longer horizontal plane, resulting in water flowing forward into the cabin after falling down to the horizontal plane of the flow channel sheet metal, as shown by the blue line in Fig. 10. The improved gutter sheet metal reduces the length of the horizontal plane of the lap with the wiper cover, as shown by the purple line in Figure 10. At the same time in the wiper cover grille inlet below the increase in the water barrier, as shown in Figure 11, the simulation results show that the water flow through the grille inlet, directly lowered to the flow channel sheet metal after the flow away, to solve the problem of water into the engine compartment.

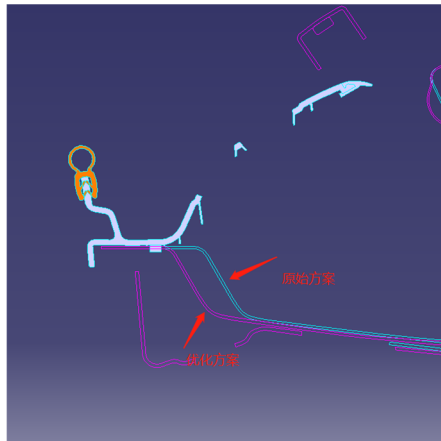


Figure10. Schematic diagram of flow channel sheet metal

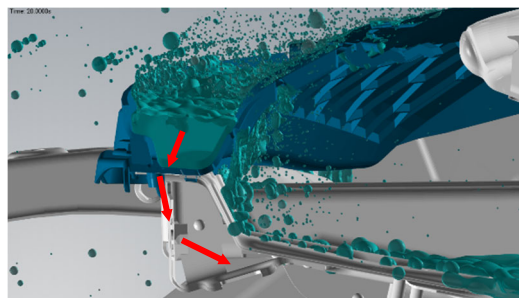


Figure11. Optimized water flow direction of wiper cover grille air inlet

In order to solve the problem of water flowing into the cabin from both sides, the wiper cover is widened in the Y direction on both sides of the baffle rib, and at the same time, a baffle plate is added on the overlapping surface with the sheet metal and a hole is made in the sheet metal, which can guide

the water flowing from both sides to flow away from the holes in the sheet metal and prevent the water from flowing into the cabin, as shown in Fig. 12.

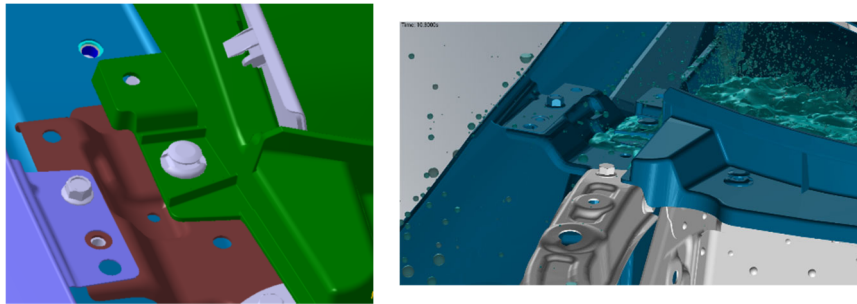


Figure12. Optimization of water flow direction on both sides of the rear wiper flap

6. Conclusion

Based on the SPH method and PreonLab software, the rainfall simulation model of the front windshield lower trim panel system was established, and the rainfall calibration of the air conditioning inlet, wiper motor, and front nacelle was analyzed, and the main conclusions are as follows:

- (1) The wiper cover air conditioning grille air intake hole arrangement avoids the air conditioning port, the water drains smoothly from the running channel sheet metal, and the air conditioning air intake does not get water.
- (2) The wet wall area of the wiper rotor and ball head accounts for 2.8%, and the risk of water ingress at the wiper rotor and ball head is small.
- (3) The risk of water flowing into the cabin after the water flows through the air conditioning grille air intake in the original proposal. By optimizing the wiper cover and the sheet metal pattern of the running channel, the problem of water flowing into the cabin is perfectly solved, and the problem is found in advance at the design stage and the optimization proposal is put forward, which reduces the development cost of the whole vehicle.

References

- [1] Li Sai, Zuo Huihui, Kang Ning. Investigation on Wading Simulation of Battery Electric Vehicle Based on SPH Method[J]. Chinese Journal of Automotive Engineering, 2020, v.10; No.59(06):72-79+82.
- [2] Li Ming, Yang Zhiguang. The Research of Vehicle Water Management Performance and Development[J]. Urban Construction Theory Research(CD-ROM), 2014(25):2815-2817.
- [3] Wang dong Chen shufan Application and Development of Computational Fluid Dynamics for Water Wading Performance Development of Passenger Vehicles [J]. Shanghai Auto, 2020, (4):9-15
- [4] Wang Yuquan, Liu Deman, Rao Yang. The Water Management Design Research Of Cowl Top[J]. AUTO SCI-TECH, 2017(3):90-94.
- [5] Zheng Xin, Su Donghai, Qi Kai. Simulation study of automobile drenching[J]. Journal of Automotive Engineering, 2019, 9(6):452-455.