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# Analysis and Solution of Flooding Water Problem for EV Passenger Compartment

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**Abstract:** In order to improve the airtightness, safety, comfort and corrosion resistance of the passenger cabin on an electric vehicle, the paper analyzed and studied the problem of water intake in the passenger cabin of an electric vehicle in wading test. By recording all water intake points, find their water inlet path and causes, and classify them, including the bug problems of lack easy glue by reason of body structure design, the no hermetic problems of pipeline and wiring harness clip matching hole, and deficiency hermetic disposal problems after opening channels holes etc. Then, the concrete solutions are presented for every problems. For example, the filling area for coating, the fixing point of lines and pipelines shall replace the buckle holes with welding studs, improve the enclosure sealing structure under the gear changer, improve the structure of the steering column protector and the sealing rubber pad in the air conditioning pipe passing through the holes shall replace the sponge pad. The paddle test is performed again, water cannot enter passenger compartment. Result indicated that daubing all welding line glue, reducing hole and do well hermetic disposal after opening hole for body structure which have hermetic request, can prevent water in letting passenger compartment efficaciously.

**Keywords:** Electric Vehicle, Wading Test, Flooding Water, Improved Design, Program Verification

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## 1. Introduction

Safety is an important performance of electric cars. Besides the safety of electrical parts and the protection of electric shock, its waterproof is also a non-negligible performance. [1-4]. The chinese national standard "safety requirements for electric vehicles" (GB/T 18384.3-2015) has made specific requirements for simulated washing, simulated rainstorm and simulated wading in the section "waterproof". In addition to national standards, there are local standards, and they're stricter. For example, "the technical specification for the operation safety and maintenance guarantee of electric passenger vehicles" in Shanghai (DB31T634-2012) contains the following provisions: a) In the 15cm deep pool, the vehicle was driven at a speed of  $30 \pm 3$ km/h, and the total wading time was 10min. b) In the 30cm deep pool, drive forward and backward at  $\geq 5$ km/h speeds, with the total wading time was 10min. For this reason, in addition to the measurement of insulation resistance value for power system

during the test, the corresponding passenger cabin shall not allow water intake or allow very little water inflow as an evaluation index. [5-7].

The passenger cabin is usually equipped with low-voltage wire bundles and low-voltage electrical appliances, it is a basic requirement to avoid flooding [8]. In addition, the passenger cabin is the sitting space for the driver and the passenger, water entering the passenger cabin will affect ride comfort. [9-12]. Furthermore, the water entering the passenger cabin will accelerate the corrosion of the vehicle. [13-14] and affect the service life of the vehicle if it cannot be fully discharged in time. Therefore, how to strengthen the sealing. [15] of electric vehicle passenger cabin and prevent the water from entering the water in the strict wading test is a subject worth discussing. Based on this, this paper studies the sealing design of electric vehicle passenger cabin.

## 2. Description of Flooding Water Problem in Passenger Cabin of an Electric Car

### 2.1. Basic Overview of Electric Vehicle Passenger Compartment

The passenger cabin of electric car and the passenger cabin of traditional car are much the same as little different, the difference mainly lies in the installation of power battery under the floor, resulting in the local bulge of the floor, as shown in figure 1.

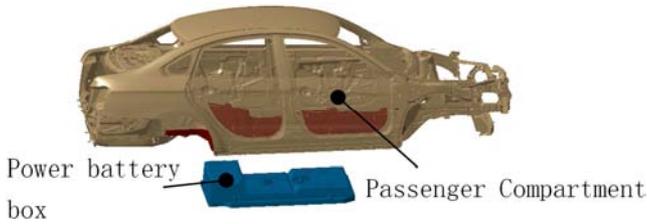


Figure 1. EV passenger compartment.

In theory, the passenger cabin should be a closed space, soundproof and waterproof. But considering the functional requirements of auto parts, the functional requirements of coating process, as well as the manufacturing technology level and so on the actual situation, the passenger compartment of car body is difficult to achieve a real sense of confined Spaces.

### 2.2. Record for Flooding Water Problem of Passenger Cabin During the Wading Test

When an electric vehicle was subjected to the local standard for wading, it was found that there were several water inlet points on the passenger cabin floor and front panel. After the test, there was a large amount of water in the low-lying areas of the floor, which was located at the driver's foot place and the co-pilot's foot place, as shown in Figure 2 (a) and Figure 2 (b).



(a)



(b)

Figure 2. Water spots in the passenger cabin.

Record the entry points of the passenger cabin as follows: there are 6 places in total.

(1) The middle floor of the car body

The water inlet point is located in the middle of the middle floor at the back end of the middle passage. At the position of the circle in figure 3, there is a large water flow.



Figure 3. Water inlet in the middle of the middle floor.

(2) The right side of the middle floor

The water inlet point is located at the right end of the beam under the rear seat, as shown in figure 4, there are drops of water running down.



Figure 4. The water inlet at the right side of the middle floor.

(3) The wire harness buckle place on the inside plate of the body side longitudinal beam

The water inlet point is located at the position of the wire harness buckle on the inner plate of the longitudinal beam on

the left and right sides of the body, as shown in Figure 5. Water drops appear at the cable harness buckle installation on the right longitudinal girder of the car body.



**Figure 5.** The water inlet is at the wire harness buckle place, at the right longitudinal beam of the car body.

(4) The installation position of shifter

The water inlet point is located around the installation position of the gear shifter, as shown in figure 6. There are water drops flowing out along the periphery of the gear shifter and both sides of the middle channel strengthening plate.



**Figure 6.** Water inlet on position of gear shifter.

(5) The hole position of the steering column

The water inlet point is located at the position of the steering column hole in the cowl panel, as shown in figure 7. There is a large amount of water in the sinking platform of the steering column hole cover.



**Figure 7.** Water inlet at the through-hole position of the steering column.

(6) The through-hole position of air conditioning pipe on the cowl panel

The inlet point is located at the through-hole position of air conditioning pipe on the cowl panel, as shown in figure 8. The sound insulation pad in the cowl panel is removed, and it is also found that the sound insulation pad on the cowl panel corresponding to the air conditioning pipe passing through the hole is wet.



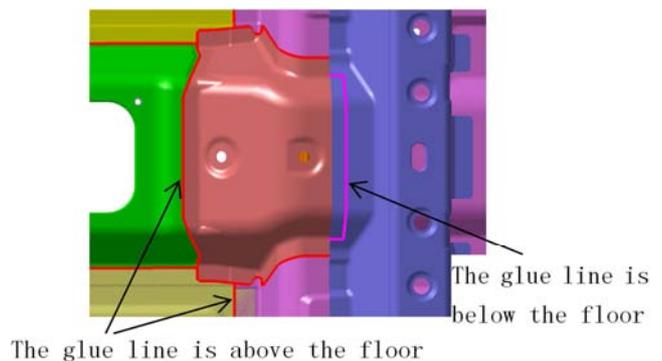
**Figure 8.** Water inlet at the through-hole position of air conditioning pipe.

### 3. Cause Analysis of Passenger Cabin Water Inflow

In view of the above passenger cabin inlet point problem, the reasons are analyzed, and the results are as follows:

#### 3.1. Reason on Flooding Water the Middle Part of the Body Middle Floor

Check the car and found that the original mathematical model defined on coating line, as shown in figure 9, the local not besmear in real vehicle is shown in figure 10, and it is located in the sheet metal pieces of the corner, considering the manufacturing technology level, set aside a large gap, as shown in figure 11. Therefore, if the place is not covered with glue, when the vehicle wanders into the water, there will be a large water flow into the vehicle.



**Figure 9.** The glue line definition of body middle floor.



Figure 10. Leaking glue under the floor.



Figure 11. There is a large gap between sheet metal on the corner.

### 3.2. Reason on Flooding Water the Right Side of the Middle Floor of the Car Body

In comparison, there is no water drop on the left side of the floor, and there is water drop on the right side. Check the real car and the number model, and confirm that the water drop is from the installation of the brake pipe lug, as shown in figure 12. It is caused by the failure of complete sealing between the buckle and the hole of the brake tube. Refer to figure 13(a) the buckle structure and figure 13(b) the gap between the buckle and the hole.

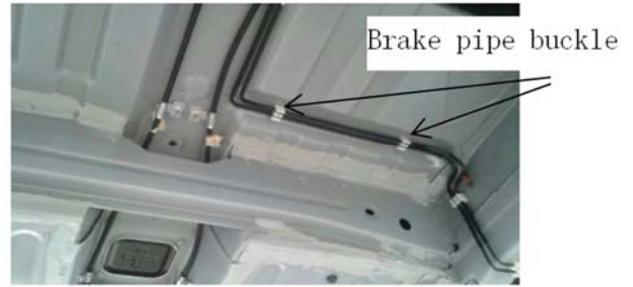


Figure 12. Brake installation line.

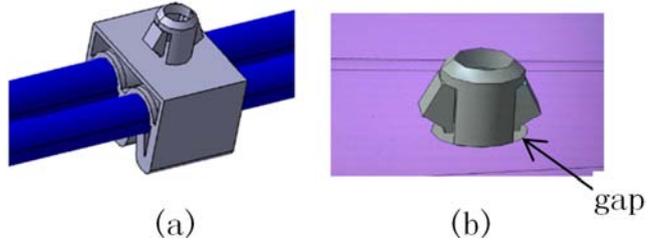


Figure 13. The mounting structure of brake pipe buckle.

### 3.3. Reason on Water Inlet at the Wire Harness Buckle on the Inner Plate of the Body Longitudinal Beam

The low-voltage wiring harness layout of passenger cabin is shown in figure 14. The wiring harness is positioned on both sides of the floor and is fixed to the inner plate of the side longitudinal beam by clamping.

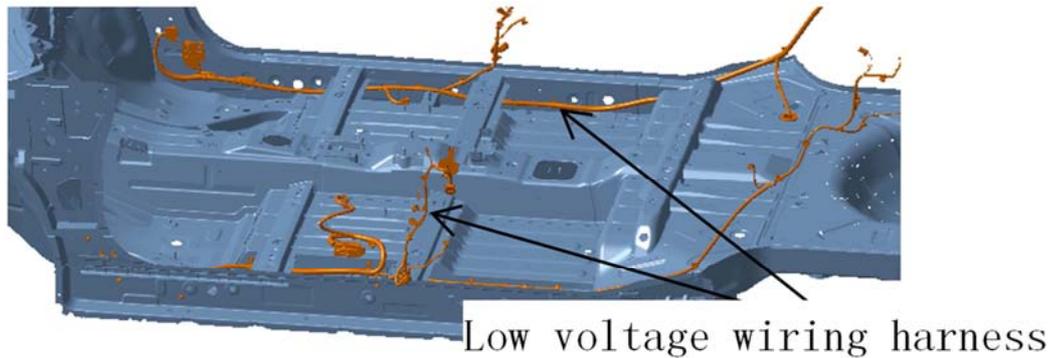


Figure 14. Low pressure cabling arrangement in passenger cabin.

The wire harness buckle is also a common clasp, and it is difficult to ensure complete sealing between the mounting hole and the wire harness buckle, as shown in figure 15.

### 3.4. Reason on Water Inlet at the Gearbox Installation

Check the real car. There is a gearshift box below the middle channel, as shown in figure 16. Further inspection of the mathematical model reveals that there are holes on both sides of the under gear shifter box. Refer to figure 17(a) left side of the under gear shifter box and figure 17(b) right side of the under gear shifter box. The hole corresponds to the shaft line of the shift handle, and the seal is not considered in the design. When the vehicle waded into the water, it was easy to get water from the hole into the inside of the gear shifter, which then flowed up and into the car cabin.

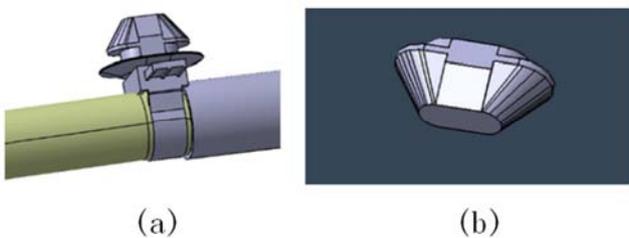


Figure 15. The mounting structure of wire harness buckle.

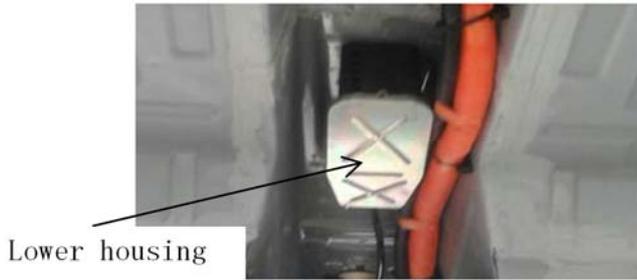


Figure 16. The shifter structure below the middle channel.

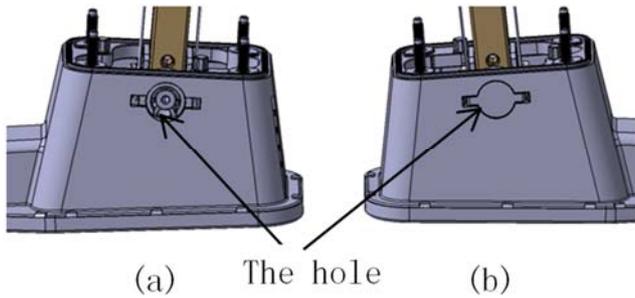


Figure 17. The structure of the lower box on gear shifter.

### 3.5. Reason on Water Inlet at the Through-Hole of the Steering Column in Cowl Panel

As the steering shaft sleeve is connected to the body only by elastic extrusion, it is easy to be deformed with the wheel beating and steering, resulting in a large amount of water entering the cabin and flowing to the driver's foot place.

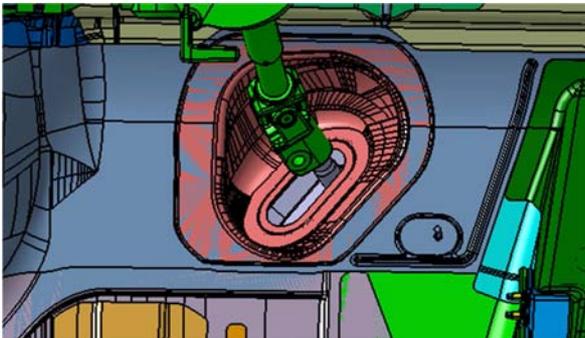


Figure 18. The structure of the steering column through the hole.

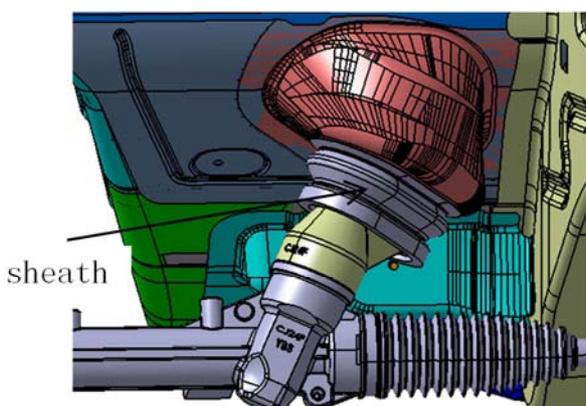


Figure 19. The sealing structure of the steering column sleeve.

### 3.6. Reason on the Through-Hole Position of Air Conditioning Pipe

When the air conditioning pipeline passes through the front fender, it does not effectively seal the through-hole, resulting in a small amount of water from the air conditioning pipe passing through the through-hole into the cabin. Figure 20 shows the air conditioning inlet and outlet pipeline structure. Figure 21 shows the hole in the enclosure spacer, only one hole is added with the cushion block, but it is a sponge cushion, which has no waterproof effect.

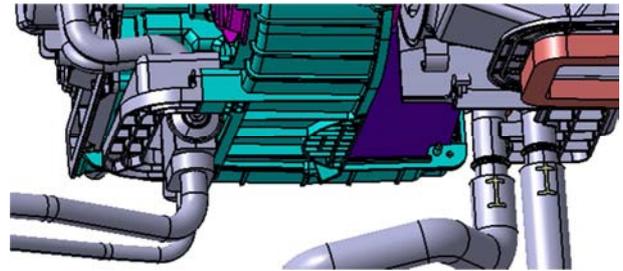


Figure 20. Air conditioning piping structure.

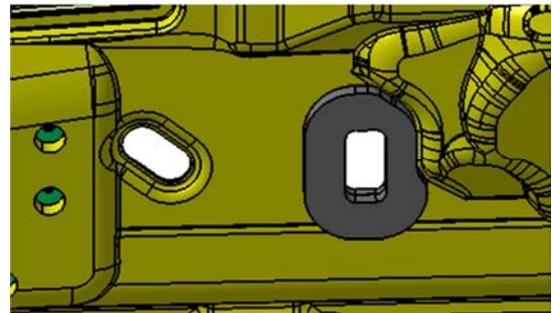


Figure 21. Front enclosure soundproof pad with through-hole structure.

The reason analysis of the above water inlet points is classified as shown in table 1.

Table 1. Summary of reasons for passenger cabin entry point.

Number	the location of the water inlet	reason
1	Water enters the middle of the middle floor	Structural and process problems
2	Water enters the right side of the middle floor	Fixed clasps are not waterproof
3	Water enters at the buckle on the longitudinal beam	
4	Water enters at the gearbox installation	Self-defect
5	Steering post through hole	Seal design
6	The air conditioning pipe enters water through the hole	Through hole unsealed

## 4. Solution and Validation

### 4.1. The Measures

(1) To solve the problem of water inlet the car body middle floor, the temporary solution is to fill up the glue that is leaking. Permanent solution is to improve the local structure of body floor, to cancel the local strengthening structure on the

rear beam of the rear seat, figure 22 (a) is before the change, while figure 22 (b) is after the change, so as to realize the continuous glue application above the floor, so as to achieve the convenience of glue application. As shown in figure 23.

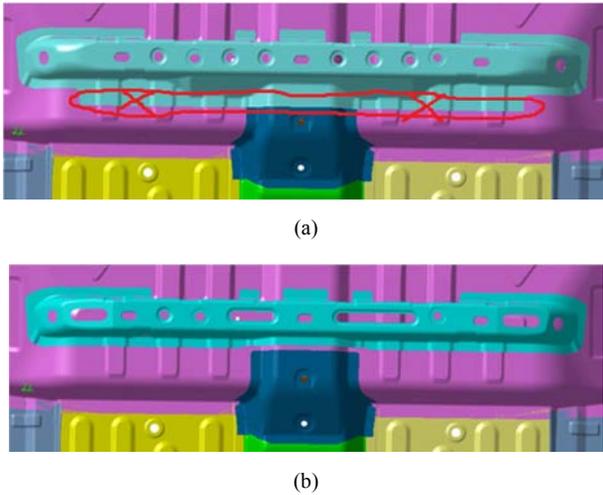


Figure 22. Changes in the structure of the lower beam in the rear seat.

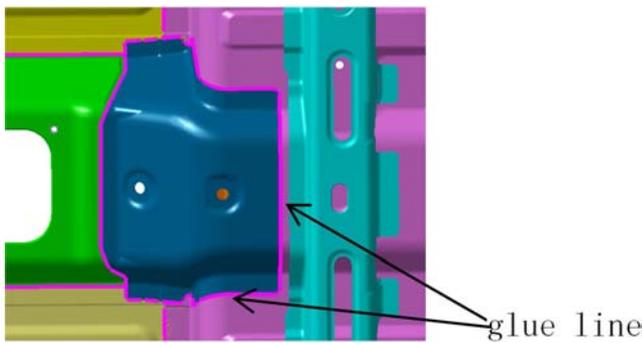


Figure 23. All the glue line above the floor.

(2) To solve the problem of water inlet at the right side of the body floor, the solution is to change the fixed way of the brake pipeline, and change the clamping hole from the clamping hole to the welding screw column, as shown in figure 24. No more clamping holes are designed on the floor.

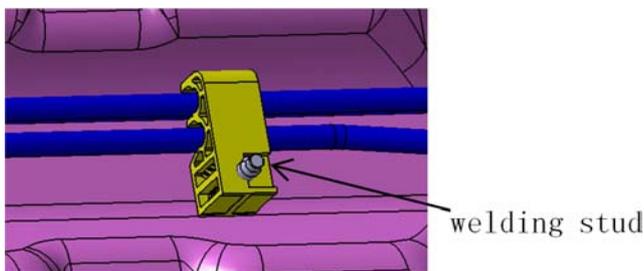


Figure 24. The brake pipe buckle is fixed to the welded stud.

(3) In order to solve the problem of water inlet at the wire harness buckle on the inner plate of the body longitudinal beam, the solution is to change all the wire harness buckle holes into welded studs, as shown in figure 25.

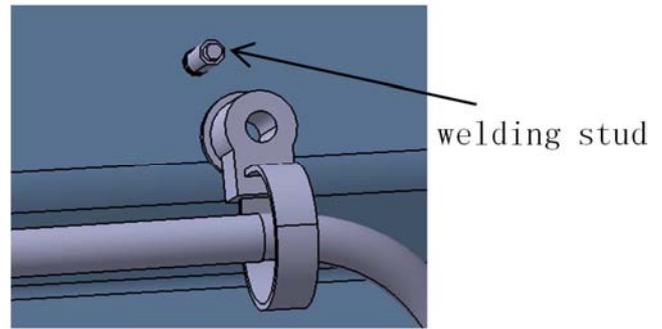


Figure 25. The wire harness buckle is fixed to the welded stud.

(4) To solve the problem of water inlet at the gear shifter installation, the temporary solution is to put a plug in the box with holes on both sides of the box under the gear shifter, as shown in figure 26. Permanent solution is to improve the structure of the box under the gear shifter, or use other types of gear shifter to solve the sealing problem.

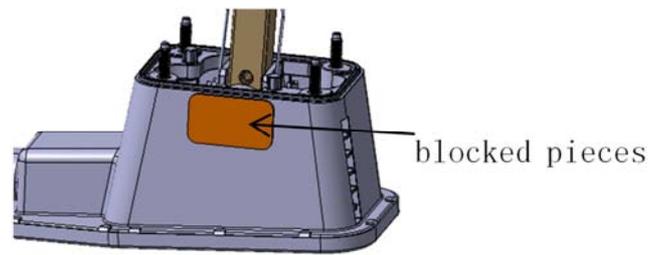


Figure 26. Gear shifter under the box seal scheme.

(5) To solve the problem of water inlet at the through-hole of the steering column on the dash panel, solutions are within the steering column sheath set card hook structure, will cover the collection on car body, as shown in figure 27 and figure 28, through the card hook card tight sheath, keep sheet metal sheath and body moment in the compression state.

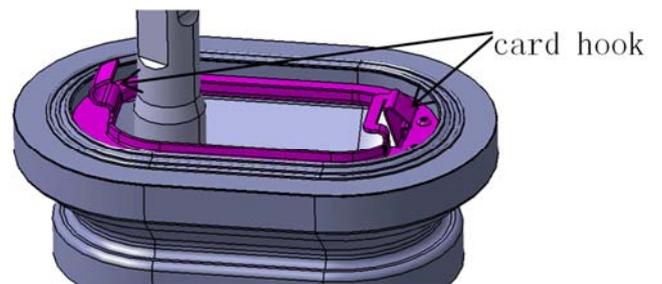


Figure 27. The hook structure is set in the sheath.

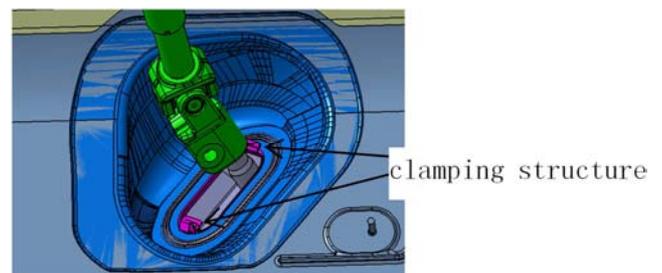


Figure 28. The buckle buckling body.

(6) For the air conditioning pipe passing on the small hole water problem, the solution is to cancel the small sound insulation mat cushions, rubber mat in air conditioning body side, at the same time the air conditioning on ontology local reinforcement plate to plane, to increase the contact area, the maximum possible to stop the water flow into the car, as shown in figure 29.

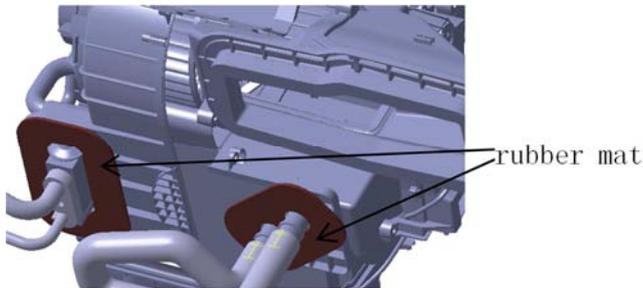


Figure 29. Add rubber gasket seal structure.

#### 4.2. Test Verification

The above solution is applied to the real car, again wading test, respectively into 15 cm deep pools and 30 cm deep pool, as shown in figure 30, 31, running back and forth 10 min, has not found inside the passenger compartment with clear water, show that passenger compartment seal get larger ascension.



Figure 30. 15cm deep water tank wading test vehicle.



Figure 31. 30cm deep water tank wading test vehicle.

## 5. Conclusion

The tightness of passenger cabin is related to the safety of low-voltage electrical parts, the comfort of passengers and the corrosion resistance of vehicles. Electric cars are more waterproof than conventional cars. This paper analyzes and solves the water inlet problem of an electric car, and concludes that improving the airtightness of passenger cabin mainly includes the following aspects, for the body structure with sealing function, for example, the front, middle and rear floor, middle channel, side longitudinal beam inner plate, front panel, etc. the structure design should take into account that all the welds are easy to apply glue and seal, so as to avoid the appearance of easy to ignore glue line. In addition, that fixing points such as wire bundles and pipelines are arranged, the form of open hole fixation should be avoided, and welded stud fixation is recommended. That opening through hole, such as gear shifter, steering column, pipeline, line, and overhaul channel, must be well sealed protection. Analyze all kinds of possible water inlet ways, strive to achieve the sealing without dead Angle.

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