Discussion on the technology of high voltage cable for hybrid electric vehicle

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Abstract: Hybrid drive system is one of the technical directions of future vehicle development. The design of high-voltage cable is the key technology to ensure the reliability and safety of the system. In this paper, the differences and difficulties of high voltage cable design between hybrid vehicle and traditional vehicle are studied. Besides, the electromagnetic compatibility and sealability of cable under high voltage are also discussed.

1. Introduction
As the hybrid power adopts the high and low voltage hybrid power supply system, the adoption of the high voltage system puts forward higher requirements for safety and reliability than the original low voltage system. As the physical transmission carrier of the high voltage power supply system, the high voltage cable is particularly important for the cable design applicable to the high voltage circuit and the requirements for connector.

2. Requirements for cables
In order to achieve the purpose of wire harness lightweight, the hybrid model needs to use as thin cable material as possible, so it adopts high-voltage transmission, instead of the 28V power supply of the traditional model. Due to the introduction of high voltage, hybrid cars also have other imperfections, such as how to shield the electromagnetic wave generated by high voltage operation of hybrid cars, interference of wiring harness, sealing performance of wiring harness and connector.
First of all, the low-voltage and high-voltage wiring harnesses coexist on the vehicle. In Figure 1, the solid line is the high-voltage wiring harness, while the dotted line is the low-voltage wiring harness. The type and type of wire harness used are different for different transmission currents and different transmission signals. Secondly, signals in important systems, such as engine speed, electric engine and wheel speed, must ensure the reliability and correctness of information transmission. In order to ensure the accuracy and timeliness of the signal, the type and length of the wire harness are regulated, and the influence of the existing electronic equipment in the vehicle or the interference of the installed electronic equipment on the hybrid vehicle itself is also considered.

A braided shielding layer is used to cover the wire core and the outside of the insulator in the traditional vehicle models, which is a potential safety hazard in the high-pressure environment of hybrid electric vehicles. The hybrid electric motor-powered wire harness and the inverter-powered wire harness are made of aluminum alloy wire cores. To ensure safety and electromagnetic compatibility, the wire harness is different from the traditional car harness. The conductor and the insulator are coated with two layers of protective film. The first layer is a braided shield to prevent electromagnetic interference and noise, and the second layer is designed in the way of insulator, which is made of polyvinyl chloride (PVC), and braided shield is made of tinned copper wire [1].

With the development of vehicle information technology, more and more electronic systems need to use more transmission media, especially hybrid vehicles, high quality and stable transmission media is indispensable. Therefore, automotive wiring harnesses will continue to play an important role in hybrid vehicles in the next few years.

### 3. Cables installation

During the installation of high voltage cable lines, metal sheathed wires shall be segmented or connected to form a cross-interconnection connection after insulation. In order to reduce the induction voltage of the single core cable line to the adjacent auxiliary cable and communication cable, it is necessary to adopt the cross-interconnection wiring. For short cable length, single point grounding can be used. To protect the sheath insulation of the cable, a sheath protector, such as the bellows in Figure 2, should be installed on the ungrounded end.
Figure 2: Protector – bellows

It is well known that the energy of electromagnetic radiation and electromagnetic coupling is proportional to the area of the wiring circuit and the current that the wiring flows through. In order to reduce the electromagnetic interference caused by radiation and coupling, the wiring circuit area should be minimum. This requires the wiring of strong current and electronic circuits to be parallel or stranded in pairs. Under the condition that strong current wiring meets the requirements of electrical strength, the current line and the backflow line should be as close as possible.

It is particularly emphasized that the backflow line should be set up independently and the casing should not be used as the backflow line. The ground wire of strong electricity should also be independently laid and earthed from the housing only at one point or a few points.

4. New challenge

Hybrid electric vehicle power voltage is generally used is 520V, a lot of problems must be solved, such as: corrosion, electromagnetic noise, arc discharge, leakage, etc., the arc discharge is the most dangerous, but also the most difficult to solve the phenomenon.

Arc discharge refers to the discharge phenomenon that occurs when contact or terminal is separated during electrification. The arc discharge is also very energetic. The central temperature of the arc is several thousand degrees, which is very dangerous. In particular, the arc discharge occurs when the plug is pulled out. Due to the direct contact with people, we currently believe that the following methods can effectively reduce the arc discharge energy.

4.1 The cartridge case is improved to increase the pulling speed of the cartridge.
4.2 Utilized the optimized terminal material.
4.3 Effectively disperse the arc discharge energy of the terminal double contacts.
4.4 Use magnets to eliminate arc discharges

Among them, magnets are considered to be the most effective way to limit arc discharge in large and medium current passing occasions. This means that the arc is distorted by the action of a magnetic field and increasing the gap between the contacts also has the same effect [2].

5. Electromagnetic compatibility of high voltage cable

Hybrid cars get a lot of attention for their fuel economy, but they also pose a design challenge: electromagnetic interference (EMI). It is always necessary to optimize electromagnetic interference with electronic module and wiring harness design.

Hybrid cars rely on high-current and high-voltage inverters to drive them. However, the high-power inverter will produce electromagnetic interference with frequencies ranging from 100.0kHz to 200.0MHz. The high-power AC and DC conversions of these inverters make the electromagnetic interference problem of hybrid cars even worse. There are other high-voltage electrical devices in hybrid
vehicles that generate more EMI because the high-voltage wiring harnesses act as emi antennas and transmit the emi throughout the vehicle.

In traditional vehicles, the most effective way to suppress emi noise is often the use of capacitors, sensors, diodes and other components. But now, shielding electronic modules and wiring harnesses are becoming a more economical solution for hybrids[3], because they are smaller and lighter than traditional suppressors.

6. Discussion on sealing of high voltage cable and HVIL

To ensure the safety of drivers and maintenance personnel in high-pressure environments, we must consider a range of complex factors of electrical systems to ensure reliability and optimality. The connection system is the key component of high voltage electrical wiring harness, especially the design of high-power wiring harness. From the safety point of view, two aspects should be paid attention to in the design of high voltage connection system, namely high voltage interlock loop (HVIL) and environmental seal of connector (avoid short circuit between high voltage terminals when the vehicle is used).

The sealing of high voltage lines is critical because unsealed lines can lead to failure modes such as short circuits. As we all know, water and electricity are incompatible. The use of a wire ring seal and a connector peripheral seal will allow the connector to be truly sealed, ensuring that moisture cannot enter and will not cause overheating or sparks. A high-voltage system requires a stronger seal than a conventional low-voltage system, because the higher the voltage, the more likely it is to jump.

High voltage interlock loop (HVIL) is one of the characteristics of high-power connection systems[4]. It is necessary to avoid the disconnect and jump fire of connectors used in power electronic equipment. Special considerations must be taken to ensure that the connection system does not disengage when it is live. When the connector is about to disconnect, the high-voltage interlock loop sends a signal to disconnect the power in time. This feature is necessary in the event of an accident or when maintenance personnel need to disconnect power for vehicle maintenance, and it helps to protect occupants, maintenance personnel, or first responders in an accident.

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