High Durability Terminal for Hot Plug Charger

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Electric vehicles and plug-in hybrid vehicles are now the focus of the world`s attention for their low greenhouse gas emissions. The power chargers for these vehicles are generally used outdoors almost every day. Therefore, the charging connector has to withstand severe conditions such as dust, sea breezes, rain, and numerous mechanical cycles. In developing a charging connector, we used our original contact structure to achieve high durability and a stable performance.

Keywords: charging connector, mechanical cycles, contact, machine cut

1. Introduction

Greenhouse gas emission reduction measures are being promoted in every industry to mitigate global warming. Automobiles are one major source of greenhouse gas emissions. In the automotive industry, both the government and private sector are working on the development and popularization of electric vehicles (EVs/PHVs)[*1, 2]. Electric vehicles use a special charging connector and cable to receive electricity required for driving from a charge station or wall outlet to charge their batteries. **Table 1** shows the basic specifications for charging connectors and cables manufactured by Sumitomo Wiring Systems.

Table 1. Sumitomo Wiring Systems charging connector/cable specifications

Rating	Current	12 A	
	Voltage	200 V AC	100 V AC
Charge time		Approx. 90 min	Approx. 180 min
Safety certification		UL (US market)	
		CE (European market)	
		PSE (Japanese market)	

EV/PHV batteries are mostly charged mostly outdoors. Charging connectors are exposed to dust, mud, sea breeze and rain. The charging frequency is generally once or twice a day, reaching 10,000 or more mechanical cycles during the vehicle's lifetime. Due to these factors, the charging connector contacts are subject to a high level of wearing load while being inserted and withdrawn. Sumitomo Wiring Systems has designed its charging connector contacts with a proprietary structure to make them highly durable and able to withstand numerous mechanical cycles.

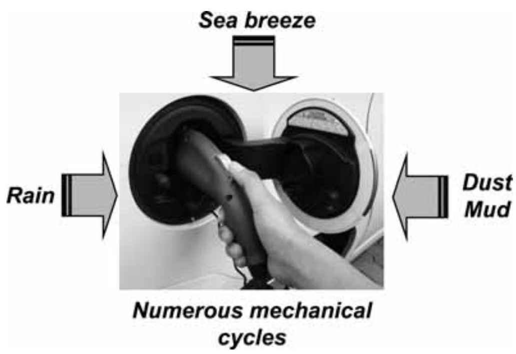

Fig. 1. Charging connector operating environment

2. Charging Connector Contacts

The international standard IEC 62196 provides that the charging connector must have mating compatibility. For common Type 1 charging connectors, for example, 3.6 mm dia. round pin contact terminals are specified for installation in the vehicle inlet power supply circuits, and socket contact terminals that fit the 3.6 mm dia. pins are specified for use in the charging connector, as shown in **Fig. 2**.

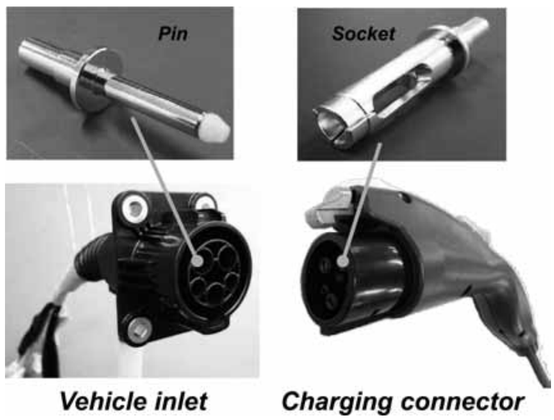

Fig. 2. Charging connector contacts

3. Geometrical Features and Mechanical Durability

3-1 Mud discharging structure

As described earlier, since the charging process takes place mostly outdoors, the charging connector is exposed to dust, sea breeze and rain. Under the above extremely severe conditions, the contact points wear during connector insertions and withdrawals because of the ingress of contaminants. Sumitomo Wiring Systems has developed its proprietary socket terminal shape to improve resistance to mechanical wear. **Figure 3** compares the structural features between our proprietary socket terminal and a conventionally shaped one. The conventional socket terminal allows mud (mixture of dust and rain) in the connector to constantly flow to the area that contacts a mating pin terminal during connection. In contrast, Sumitomo Wiring Systems' proprietary socket terminal is constructed so as to discharge most mud sideways before the pin is inserted.

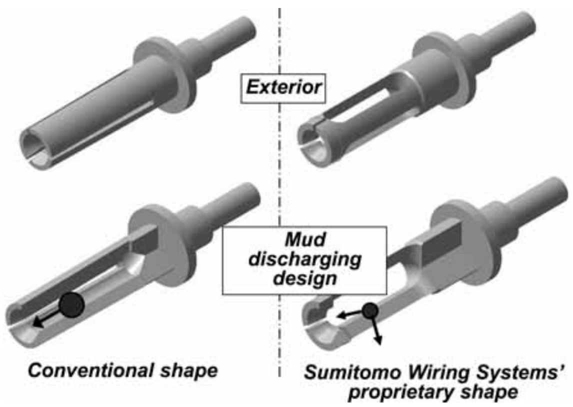

Fig. 3. Mud discharging design

Figure 4 shows the damage observed by optical microscopy (OM), SEM and elemental mapping[*3] of the contact areas of the conventional and our proprietary terminals after 10,000 cycles of the mud / salt water dipping and insertion / withdrawal test based on UL 2251. Contact areas of the conventional terminal were heavily worn, with the silver-plated surface layer being lost and the base copper layer being exposed. Sumitomo Wiring Systems' proprietary terminal shows only minor damage to the contact areas, maintaining its features as an electrical contact.

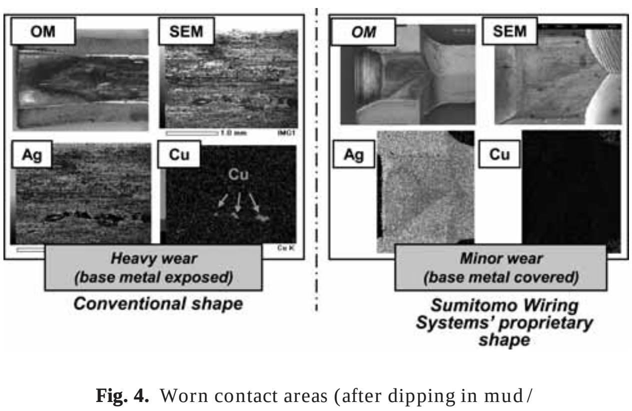

Fig. 4. Worn contact areas (after dipping in mud / salt water and 10,000 mechanical cycles)

3-2 Contact geometry

As shown in **Fig. 5**, while conventional socket terminal has an acutely angled contact edge making a circumferential line contact with the pin, our proprietary socket terminal makes a surface contact with the pin.

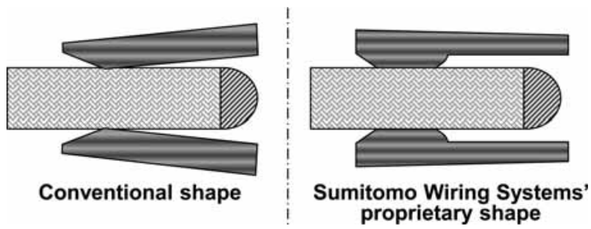

Fig. 5. Contact shapes

Figure 6 shows photos of the contact area at an advanced stage of mechanical wear. In general, mechanical wear begins at the portion that first contacts the mating pin during insertion. The wear progresses gradually rearward. Since our proprietary socket terminal makes a surface contact over a wide area, it takes a long time for the mechanical wear to spread over the entire contact area, ensuring a long useful life.

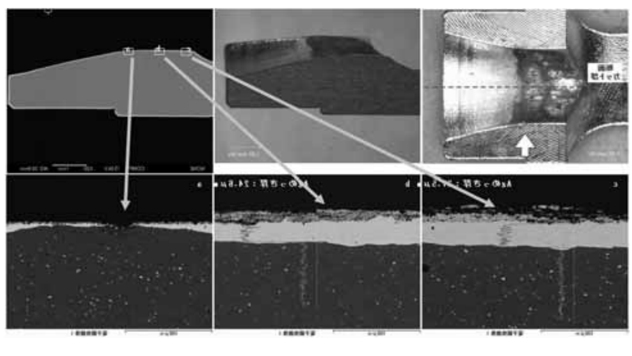

Fig. 6. Advanced stage of wear in the contact area

Figure 7 shows the mechanical durability of Sumitomo Wiring Systems' charging connector verified by the mud / salt water dipping and insertion / withdrawal test based on UL 2251. The useful life of our charging connector is more than three times longer than that of the connector using the conventional socket terminals, with the electrical

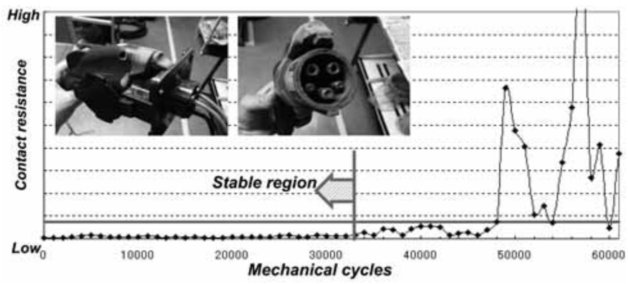

Fig. 7. Life limit verification by mud / salt water dipping and mechanical cycle test

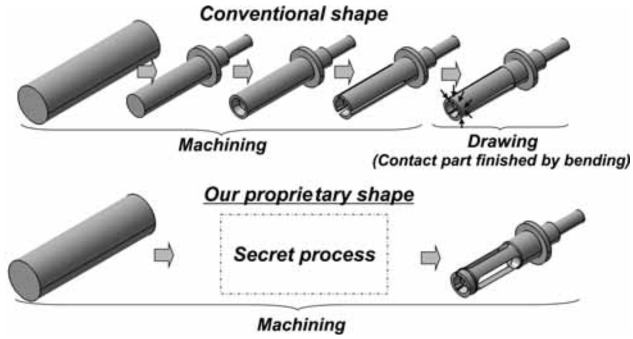

Fig. 9. Socket terminal fabrication process

contact resistance being stable even after 30,000 mechanical cycles. Such a level of durability is highly significant because damaged contact surfaces can lead to serious accidents such as overheating during charging, resulting in fusion and fire.

4. Engineering Features and Dimensional Stability

The sectional front view of the contact part of a socket terminal is noncircular before connection but circular after connection to match the diameter of the mating pin as shown in **Fig. 8**.

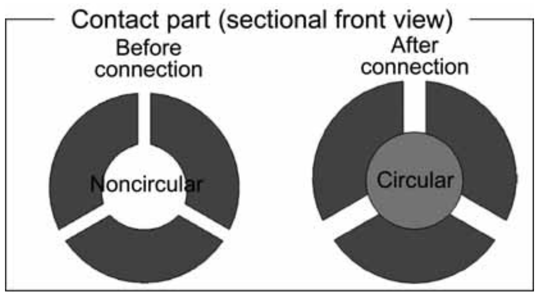

Fig. 8. Front view of contact part

Figure 9 shows the manufacturing process of socket terminals. The conventional socket terminal is manufactured by machining processes of turning, boring and slotting, followed by a drawing process to form the contact part (shape shown in **Fig. 8**). In contrast, our proprietary socket terminal is fabricated and completed by using our proprietary integrated machining process and proprietary special tools without using a drawing process.

Since the contact parts of our proprietary socket terminals are formed not by drawing but by machining, their dimensional stability is excellent, free of the effects of residual stresses resulting from bending. **Figure 10** compares histograms of variations in the inscribed circle diameter of

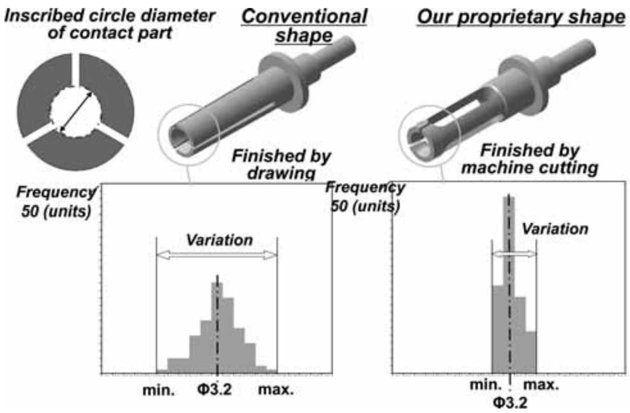

Fig. 10. Dimensional stability of contact part

the contact part between conventional and our proprietary terminals. The variation of our proprietary terminals is less than one-third that of conventional terminals. The dimensional accuracy of the contact part is extremely important for stable contact performance of charging connectors. Our proprietary terminals achieve a favorable contact condition both in radial and axial directions, as shown by the photos in **Fig. 11**.

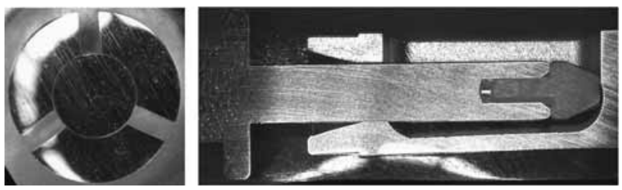

Fig. 11. Contact condition of our proprietary socket terminal

5. Surface Treatment

As explained earlier, the charging process, which takes place mostly outdoors, is naturally subject to exposure to a corrosive environment, such as rain and sea breeze. **Figure 12**

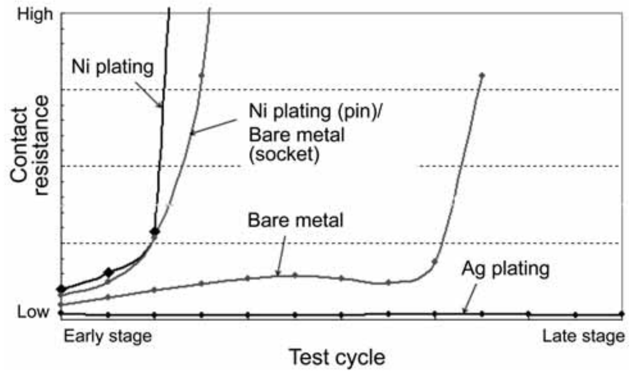

Fig. 12. Surface treatment and electrical contact resistance

shows an evaluation of the stability of connector terminals in the electrical connection, tested through a repeated process of immersion in high-concentration salt water and exposure to the air. The electrical contact resistance of Nickel-plated contact surfaces, commonly seen on home appliance plugs, or of bare contact surfaces increases possibly due to the formation of an insulating oxide film. Silver plating is virtually immune to that effect. For charging connectors intended for outdoor use, stability in the electrical contact resistance of silver plating is highly assuring. Sumitomo Wiring Systems' connector terminals also employ silver plating.

6. Conclusion

To develop a charging connector for electric vehicles (EVs/PHVs), Sumitomo Wiring Systems provided socket contact terminals with a proprietary design. The proprietary socket terminals exhibit high mechanical durability in the assumed outdoor environment and have nearly three times longer useful life than that of conventionally shaped socket terminals. Moreover, our original engineering method has enabled an integrated machining process to manufacture and complete contact parts with high dimensional stability and high quality. Sumitomo Wiring Systems commenced mass production of the charging connector in 2012, achieved regional safety certifications (US UL, European CE Marking, etc.) and has been shipping it to various countries. Our charging connector is expected to come into wider use as ecological EVs and PHVs become popular in the future.

Photo 1. German user Sumitomo Wiring Systems' charging connector

Technical Terms

*1 Electric Vehicle (EV): A vehicle driven by an electric motor. In contrast to this, gasoline-fueled vehicles burn the fuel to drive. In recent years, EVs have come into focus against a backdrop of natural resource constraints and environmental problems.

*2 Plug-in Hybrid Vehicle (PHV): A hybrid electric vehicle that uses external power sources to charge. PHVs offer the advantages of an electric vehicle that emits no CO_2 or other exhaust gases during driving and of a hybrid electric vehicle that uses both a gasoline engine and electric motor to enable long-distance driving.

*3 Elemental Mapping: An elemental analysis method that uses characteristic X-rays. Elemental mapping scans an electron probe and images differences in X-ray emissions from different points, using the counting rate of X-rays at a specific energy as the signal.

References

(1) IEC62196-1, -2
(2) UL2251
(3) SAE J1772

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