Quick Charging Connector for Electric Vehicle

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Since an electric vehicle has an effect on greenhouse gas (CO_2) reduction, which contributes greatly to preventing global warming, the use of electric vehicles is considered to be expanded increasingly from now on. For the spread of electric vehicle, infrastructure improvement for charging is indispensable. An easy-to-use connector with a lead cable for a charger, which can be used not only by a specific person but also by men and women of all ages, needs to be developed so that charge operation does not become an obstacle to the spread of electric vehicles. Paying attention to (1) small manipulation force and (2) simple operation, we adopt a lever method to enable operation by small force, using the principle of leverage for movement. Moreover, we developed such a connector, focusing on angle of grip and operation method of the lever. Also, in order to ensure user safety, we adopted a cable compliant with the Electrical Appliance and Material Safety Law, and the connector has a structure where electric locking is provided so that it may not accidentally drop off during charging.

1. Preface

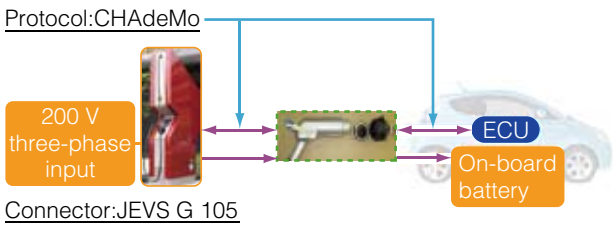
In recent years, the problem of global warming has attracted attention worldwide, and greenhouse gas (CO_2) reduction is demanded. Japan's transportation sector accounts for approximately 20% of CO_2 emissions, and the electric vehicle (EV) is expected to serve as a next-generation car under such an environment.

In addition, the electric car is placed, in the smart grid concept, as a battery charger for load adjustment of each household and, since the Great East Japan Earthquake, has attracted attention as an emergency power supply during disaster.

Charge systems of electric vehicles are of two types; one is a system called the standard charge which uses AC power supply (single phase AC 100 V or single phase AC 200 V) like that found in ordinary homes, and charging takes about 5 to 24 hours. This system takes too much time, if charging away from home is assumed. Thus, the role of a quick charge system, which can charge in a short time of about 30 minutes, becomes very important.

2. Quick charge system

The quick charge system is based on the standard specification recommended by CHAdeMO Association. AC power is converted into direct current by the dedicated charger, and charging in a short time of about 30 minutes becomes possible by using a maximum of 50 kW (the standard charge uses 1.5 kW to 3 kW). Since an electric vehicle can run about 100 km on one charge, in use in an urban area (around 40 − 60 km per day), even the standard charge is considered sufficient. However, considering convenience equivalent to that of a gasoline automobile, at the time of running out of electricity, charging is needed in shopping malls, on highways, etc. For this reason, it is thought that a quick charge system with short charging time is indispensable to the spread of electric vehicles.



Connectors applicable to Quick Charging System at Eco-Station for Electric Vehicles

JEVS:Japan Electric Vehicle Standard
JEVS is enacted in foundation Japan Automobile Research Institute(JARI).

Fig. 1. Outline of the CHAdeMO method [1)]

Since an electric vehicle has an onboard ECU (Electric Control Unit) that always supervises battery status, charge operation is controlled by a signal which the ECU commands, and the quick charger supplies direct current electricity. [1)]

3. Development target

Since the connector for the charger plays an important role as the interface between the quick charger and the vehicle, the targets for an easy-to-use connector are secure connection and achieving optimal values for manipulation force, angle of grip, etc., from the viewpoint of ergonomics.

1 Power & Telecommunication Cable System R&D Center

Connectors are roughly divided in 2 types by the attachment-and detachment method. One candidate is a system where attachment and detachment system that uses manipulation force applied by a person as is, and another is an attachment-and-detachment system that uses a lever, etc., to reduce manipulation force. We quantified the degree of ease-of-use while reducing manipulating force by the latter system, and selected the optimal structure.

Since the cable contributes greatly to operability, cabtyre cable is being used in consideration of flexibility, safety, and durability.

Fig. 2. Structure of the connector

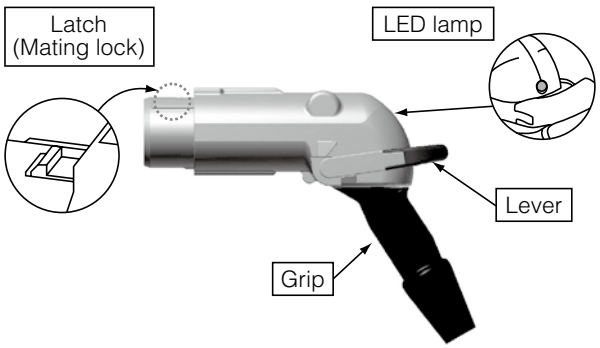


Fig. 3. Structure of the connector

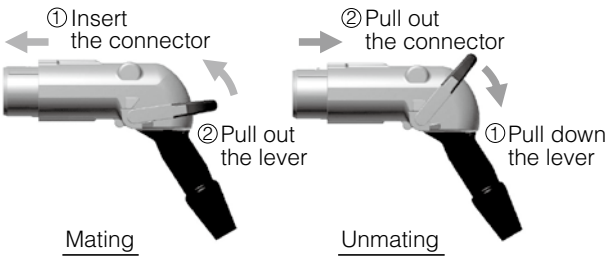


Fig. 4. Operating procedure of the connector

4. Connector

4.1 Connector structure

The structure of the developed connector is shown in Figures 2 and 3. The structure reduces manipulating force, by employing a lever. The operation method is ergonomically easy to understand to anyone. By means of the internal mechanism, the movement mechanism is designed that there is one lever, whose direction of movement is the same as that of the connector, so that anyone can understand it simply by feel. (Fig. 4)

4.2 Manipulation force

Generally, manipulation force of a person has a limit. According to the data of respective age groups, men's manipulation force is 80 N on average and women's is 60 N. (Fig. 5) Therefore, we designed manipulation force of the lever to be about 40 N as the targeted value to meet the needs of men and women of all ages. Manipulation force of the completed connector is 28 N at the time of insertion and 17 N at the time of pulling out, thereby realizing further reduction of manipulation force from the targeted value.

4.3 Optimization of grip angle

Design of grip angle is a factor that has great influence on operability. Since the mounting position and angle of the connector at the electric vehicle side vary according to vehicle type, as shown in Fig. 6, we verified the optimal grip angle on a verification stand that can change the position and angle of the vehicle side inlet. Verification evaluated operability by usability test, supposing EVs of three vehicle types at a given grip angle of connector (on a four grade evaluation from BAD: zero point to GOOD: three points). Figure

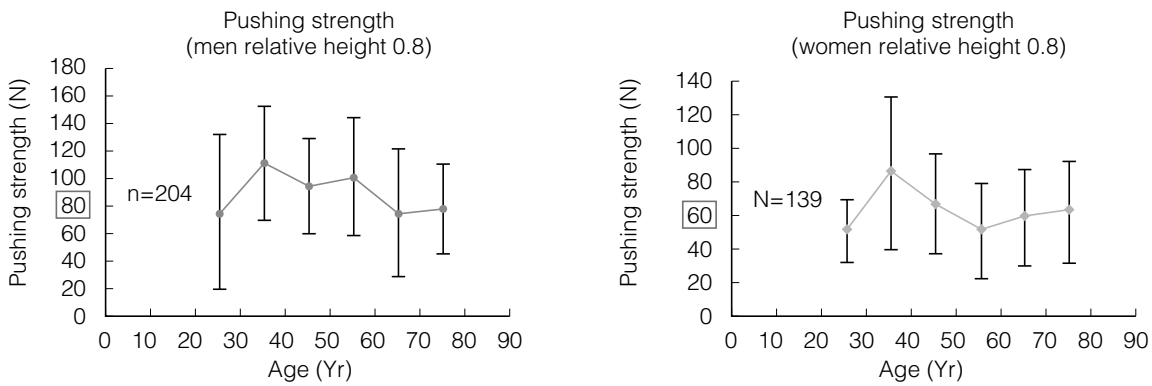
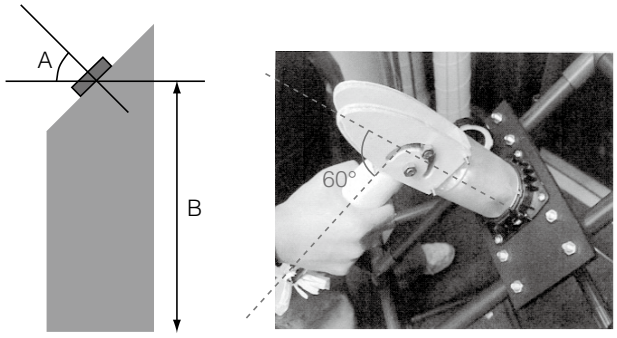


Fig. 5. Pusing strength [2)]



EV1	EV2	EV3
A : 40° B : 85 cm	A : 0° B : 85 cm	A : 45° B : 75 cm

Fig. 6. Test composition of usability test

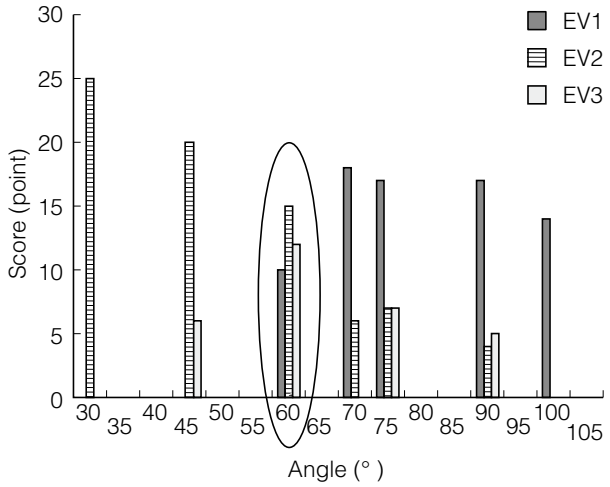


Fig. 7. Result of usability test

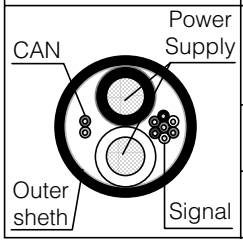
Structures	Type	Size	overall Diameter	Mass
	Power Supply	2 core × 38 mm²	Approx 30 mm	Approx 1.4 kg/m
	CAN	1 pair × 0.75 mm²		
	Signal	7 core × 0.75 mm²		

Fig. 8. Constraction of cable

7 shows the overall result, and we set the grip angle applicable to every vehicle as 60 degrees.

5. Cable

5.1 Cable structure

The cable used for connector with the lead cable for the fast charger consists of a power line and a control wire, as shown in Fig. 8, and we developed it based on our knowledge of rubber cabtyre cable, which has a track record as a cable for mobile use. By adopting rubber material for the insulating coating and sheath, the cable is also excellent in heat resistance and cold resistance, not to mention pliability.

Table 1. Result of durability test

Content	Requirement	Result
Twist (at 25°C)	At 25°C, ±90°, 10000 cycle	Good
Twist (at 25°C)	At −30°C, ±90°, 10000 cycle	Good
Cable bend	10000 cycle, bend radius 4D	Good
Cable bend (curtain)※	10000 cycle, cable length 2 m	Good
Crushing	Add load 100 kgf with a plate of 50 mm in width	Good
Abrasion-resistant	Equivalent of dragging a cable 50 km	Good

※Fix a cable horizontally, change distance of fixation point from 1 m to 2 m

Fig. 9. Twisting test under −30°C

Table 2. Result of specification testing for JEVS G 105

Content	Requirement	Remark
Insulation resistance	Over 100 M Ω	DC 500 V. Adjoin terminal and against ground
Withstand voltage	No damage	AC 2200 V 1 minute. Adjoin terminal and against ground
Operation force	90N max.	-
Current test	Surface: 15 deg rise or less Terminal: 40 deg rise or less	Power line 150 A. Saturated temp Signal line 1 A. Saturated temp
Impact test	No damage	Fall to a concrete floor from heigh of 1 m
Waterproof	No leak	JIS D 0203 S1 (rain test)
Withstand vibration	No damage	4.4 G, 33 and 67 Hz
Mating cycles	10,000 cycle	-

5.2 Flexibility, durability

Although the cable for quick charger conforms to rubber cabtyre cable specified in the Electrical Appli-

Table 3. Result of special tests

	Content	Requirement	Result
environmental	Temperature humidity cycle	Heat cycle (−20°C ⇔ 60°C) 90days	Good
	Salt fog	Cycle (wet ⇔ dry) 90days	Good
	low-temperature	At −20°C, operating and drop the connector	Good
	High-temperature	At 60°C, operating and drop the connector	Good
	AC withstand under water spray	AC2200 V Water spray (80 L/min)	Good
	AC withstand after sink the water	AC2200 V Sink a sample in the water, and take out a sample	Good
mechanical strength	Twist and Bending	Twist the cable with connector 10000 cycle	Good
	Cable pulling	100 kgf	Good
	Vehicle driveover	500kgf	Good

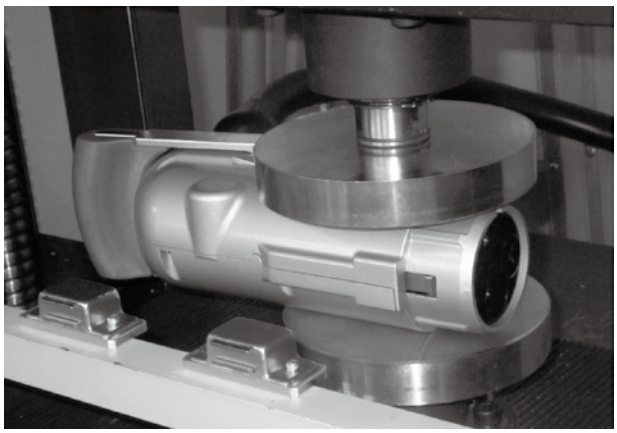


Fig. 10. Withstand load test (crash test:20kN)

ance and Material Safety Law, the mechanical evaluation test as shown in Table 1 is also carried out, supposing various use environments.

6. Final evaluation

The required performance of a connector with lead cable for quick charger is specified by Japan Electric Vehicle Association standard JEVS G 105. The result of evaluation test of finished products confirmed that all items satisfy their performance standards, as shown in Table 2. In addition, a test supposing a special environment was carried out, as shown in Table 3.

7. Conclusion

We developed a connector with a lead cable for a quick charger, aiming for a connector that can be easily operated without wavering, and started sales from October, 2010. Electric vehicles are considered to take a more and more important position in society in the future, and infrastructure improvement accompanying it is also considered to be an important issue.

The “easy-to-use for everyone” connector with lead cable for quick charger, which we aim for, is expected to stimulate use of electric vehicles, and contribute to the global environment indirectly.

References

1) “Guide for installation and operation of quick charger for electric vehicles” pp 6, edited by CHAdeMO Association
2) National Institute of Technology and Evaluation “human database”
3) Japan Electric Vehicle Association Standard JEVS G 105