A Study on the Opening Force of a Charging Door

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As electric vehicles require frequent charging, the usability of charging-related exterior features has become increasingly important. Among various opening strategies for electrically actuated charging doors, a push-to-open mechanism is commonly adopted, making the user-applied opening force a key usability factor. In this study, the charging door components contributing to opening force were investigated, and a sealing cross-sectional design was proposed to reduce opening force while maintaining sealing performance.

Opening force originates from reaction forces generated by internal components (e.g., sealing, overslam bumper, and switch) when the outer panel is pressed. These reaction forces depend on component characteristics and the effective overlap (stroke) during pressed. Because the relative locations of some components are strongly constrained by styling and packaging, this study focused on reducing reaction forces through cross-sectional design, especially for the sealing.

To evaluate relative trends among cross-sectional designs, a CATIA-based analysis was performed under contact conditions. A load of 1 N was applied and displacement responses were used as performance indicators. Z-direction displacement under the applied load was used to represent lower opening force. X-direction displacement was used to represent sealing performance based on contact maintenance. Sealing design variables were categorized into angles, inflection-point locations, thickness parameters, and contact-area-related geometry, and were varied across four design cases.

Case studies showed that introducing or relocating an inflection point can reduce opening force by decreasing the contact area and facilitating compression; however, it may degrade sealing performance depending on how the contact condition changes. Reducing sealing thickness generally improved opening force, but manufacturability constraints such as minimum thickness and injection-molding draft-angle requirements limit the applicable design space. A final cross-section achieved opening-force reduction with sealing performance comparable to the baseline. When the proposed geometry is not feasible under manufacturing constraints, increasing the mid-section thickness is recommended rather than modifying the contact area or root-region thickness, because root/contact-adjacent geometries strongly affect opening force. For the overslam bumper, lowering reaction force may further reduce opening force but can worsen vibration near the end of closure; therefore, careful cross-sectional selection is necessary.

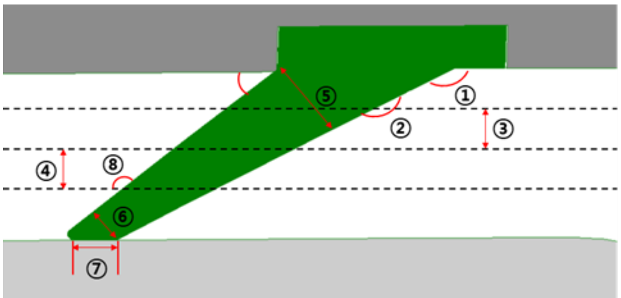

Fig.1 Sealing design parameters

Table.1 Sealing design parameters

Parameter	①	②	③	④
Description	Primary Angle	Inflection Angle 1	Inflection Point 1 Position	Inflection Point 2 Position
Parameter	⑤	⑥	⑦	⑧
Description	Head Thickness	Root Thickness	Matching Area	Inflection Angle 2

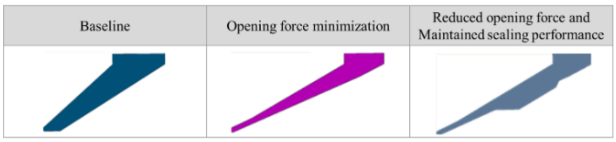

Fig.2 Proposed Sealing Cross-section

Table.2 The Influence of Each Parameter on Performance

Parameter	①	②	③	④
	Angle ↑	Angle ↓	Near root	Near contact area
Opening force	++	+++	++	++
Sealing performance	+	+	+	0
Production RQMT	Injection draft angle			
Parameter	⑤	⑥	⑦	⑧
	Thickness ↑	Thickness ↓	Smaller	Angle ↑
Opening force	+++	+++	++	+
Sealing performance	--	--	--	0
Production RQMT	Minimum thickness	Minimum thickness		