

Development of Door Deformation Prediction during the Paint Drying Process

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The exterior quality of an automobile is a crucial factor determining its product value; in particular, fit-and-finish quality—exemplified by the gaps and flushness between the door and the body—serves as a key indicator for customers when evaluating a vehicle. The required level of fit-and-finish precision has become increasingly stringent in recent years, driven by advancements in vehicle design and heightened quality expectations. On the other hand, doors are components prone to shape changes during the manufacturing process, making it difficult to predict their final shape with high precision. Consequently, ensuring quality during mass-production development requires repeated cycles of evaluation and countermeasures using prototype vehicles, which entails significant time and labor.

This paper focuses on the behavior of the hemming section (where the outer and inner door panels are joined) during the paint drying process and presents the development of a technology capable of highly accurate prediction of door deformation before and after this process.

Fig.1 shows an example of door deformation in the vehicle's lateral direction before and after the paint drying process.

During the paint drying process, the vehicle's outer panel heats up first— due to variations in hot-air exposure within the oven and differences in the heat capacity of the steel panels.

—creating a temperature differential between the inner and outer panels. This temperature difference leads to differential thermal expansion, causing sliding at the hemming section; as heating continues, the structural adhesive within the section cures, resulting in warping of the door edge during cooling after the paint drying process. To predict door deformation during the drying process, it is necessary to understand the behavior of the hemming section.

To predict the behavior of the hemming section during the paint drying process, sliding resistance measurement tests were conducted using test specimens. Based on the experimental results, the analytical model shown in Fig.2 was developed to reproduce the sliding behavior of the hemming section during the paint drying process. Fig.3 shows the relationship between the sliding resistance measured in the test-specimen experiments and the hemming-section thickness and corresponding moment required in the analytical model.

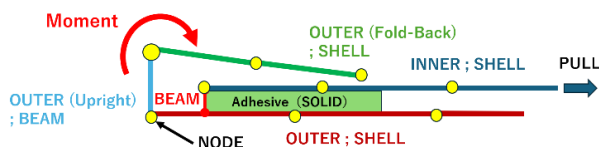


Fig.2 Proposed Analytical Model for the Hemming Section

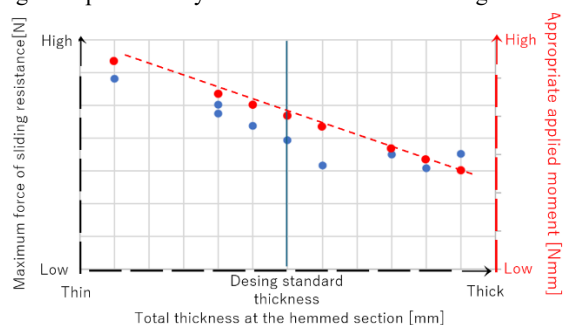


Fig.3 Relationship between Measured Sliding Resistance and Applied Moment

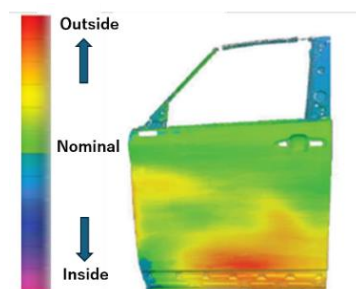


Fig.1 Diagram showing lateral Deformation of the Vehicle Before and After the Paint Drying Process

Fig.4 compares the actual door deformation with the deformation predicted by the developed hemming model before and after the paint drying process. The developed model successfully reproduces both the deformation mode and the magnitude of deformation.

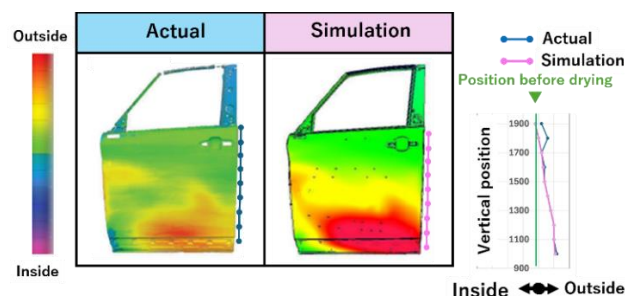


Fig.4 Comparison of Actual and Simulated Deformations