

Study on the Prediction Technology of Outer Panel Distortion Caused by Bead-Applied Stiffeners

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Bead-applied stiffeners are being investigated as an alternative to conventional sheet-type stiffeners for improving the stiffness of automotive outer panels. Compared with bonded sheet stiffeners, bead-applied systems offer better workability, greater flexibility in application location, and improved conformity to complex panel geometries. However, because the material foams and cures during the paint baking process, shrinkage-induced panel distortion may occur, potentially deteriorating surface appearance.

This study investigated the distortion behavior of automotive door outer panels with bead-applied stiffeners and evaluated the accuracy of a CAE-based prediction method.

Prototype front door outer panels manufactured from 0.75 mm thick GA steel sheets (270 MPa grade) were prepared. Bead-applied stiffeners were deposited in two parallel rows on the inner surface of the door(Fig.1). The bead width was fixed at 75 mm, while the thickness was varied at 1, 3, and 4 mm. After application, the panels were subjected to a thermal curing process simulating an automotive paint bake cycle (170°C for 40 min).

Panel distortion was evaluated using the surface quality measurement system surfTRiDY. The second derivative amplitude, $\Delta Y''$, which is known to correlate well with visual appearance evaluations, was used as the distortion index.

Thermo-elastic finite element analysis was conducted using the static implicit solver of LS-DYNA. Shell elements were employed for the outer panel and five-layer solid elements were used for the bead region. The thermal cycle was simulated by heating from 20°C to 170°C followed by cooling back to 20°C. Material properties reflecting thermal curing behavior of the bead-applied stiffener were incorporated into the analysis model.

Experimental results showed that distortion occurred mainly near the bead edges after the baking process(Fig.2). The distortion index $\Delta Y''$ increased with increasing bead thickness, and the increase became more pronounced when the bead thickness exceeded 3 mm(Fig.3). These results indicate that bead thickness is a critical design parameter affecting panel surface quality.

Comparison of measured and simulated distortion at representative bead-edge locations demonstrated good agreement across all test conditions(Fig.4). The results confirmed that incorporating temperature-dependent material property changes during curing significantly improves prediction accuracy.

In conclusion, the proposed CAE approach successfully predicted panel distortion caused by bead-applied stiffeners in automotive outer panels. The developed methodology can be used to determine appropriate bead dimensions that achieve stiffness improvements while maintaining surface appearance quality.

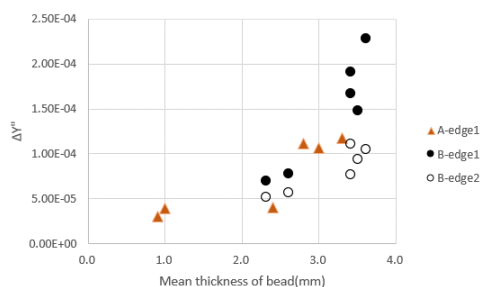


Fig. 3 Influence of bead mean thickness on $\Delta Y''$



Fig. 1 Appearance of the bead-applied stiffener area (Inner surface of the door outer panel)

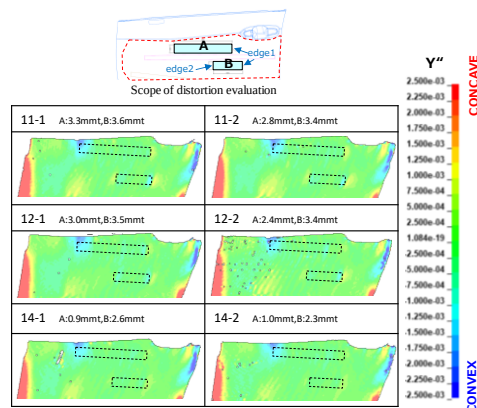


Fig. 2 Measurement results of panel distortion in the prototype door (second derivative)

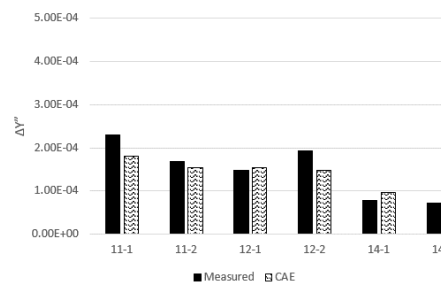


Fig.4 Comparison of $\Delta Y''$ at edge1 of bead B (Measured vs. CAE results)