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Design Quality Assessment Using Forming Deformation Prediction for Automotive Interior Decorative Films

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Decorative films for automotive interiors are applied to complex three-dimensional surfaces. During forming, in-plane deformation changes pattern spacing and direction and causes appearance distortion. Such issues often appear only after prototype forming, leading to late design changes and reduced design freedom.

Forming CAE is used to identify thinning and failure risks, but its outputs are often interpreted only as physical strain maps. These indicators are not directly linked to appearance evaluation, and discussions between designers and analysts may become inefficient. To address this, a framework is proposed that connects deformation prediction with appearance-oriented visualization to support early-stage design decisions.

In forming analysis, the film is modeled with membrane elements under representative forming conditions. The simulation provides in-plane stretch and shear. Stretching affects pattern spacing and density, while shear influences pattern direction and flow. These quantities indicate regions where appearance distortion may occur.

The framework maps these deformation fields onto the decorative pattern and generates simplified visualization showing changes in spacing, direction, and continuity. This supports early-stage appearance evaluation and enables comparison with design intent without requiring detailed rendering procedures. The shared visualization improves communication among designers, analysts, and manufacturing engineers.

Figure 1 summarizes the design-support loop. Forming analysis indicates regions of relatively high deformation. Visualization then presents possible appearance distortion under assumed viewing conditions. Based on this information, designers consider shape relaxation, pattern layout modification, or forming condition adjustment. Re-analysis and visualization allow comparison of alternatives and support design decision-making.

A non-confidential sample geometry was used to illustrate the process. For a single part, deformation distribution was checked to determine whether high-stretch regions overlap visually important zones. Visualization helped designers judge whether appearance changes remain acceptable. For adjacent components, pattern continuity across boundary areas was reviewed, enabling collaborative evaluation and alignment with OEMs.

The method provides comparative trend information, as results depend on material models, forming settings, and observation assumptions. It does not replace physical assessment but supports earlier prototype preparation and more focused trials. Shared visual information also promotes smoother OEM collaboration by clarifying acceptable appearance ranges at the design stage.

This demonstrates that linking in-plane deformation prediction with appearance visualization provides a practical framework for early-stage design decision support.

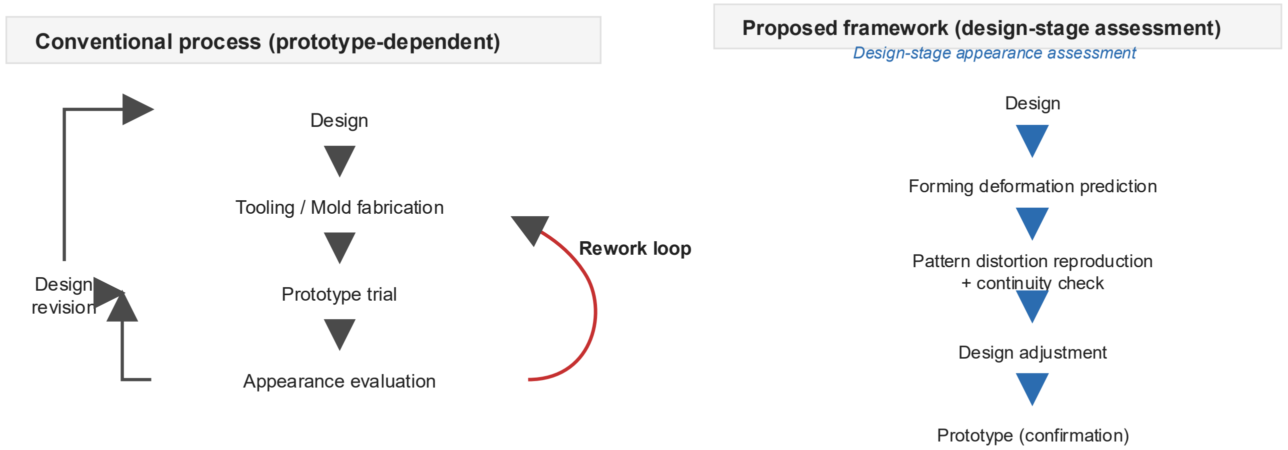

Fig.1 Feedback loop integrating forming analysis, appearance visualization, and design decision-making