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Inverse Mold Design To Accommodate Manufacturing Warpage in Chemically Blown PMDI Foams

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Abstract. We simulate the warpage of chemicaly blow pMDI (polyurethane) foam components (10-40 pounds per cubic foot) from manufacturing processes. We deploy a component-scale "cradle-to-grave" finite element simulation framework (developed in previous work) to consider foaming and filling, secondary cure, vitrification, cool down, demolding, physical aging, and depressurization to predict component warpage from birth to three years. Initially, spatial varyings in density are generated during the filling process and locked in when the polymerization process reaches gelation (captured both by the model and as seen experimentally). Using this as an initial condition, viscoelastic cure and thermal shrinkage are calculated on removal from the mold and cool down. The pore depressurization for a chemically blown foamed is then used to predict aging shrinkage and mass loss over time. Based on this shape change, we then warp the mold by the combined net predicted shrinkage. Components following the same process (but with the new mold) show very little warpage compared with the target shape, which demonstrates that foamed components can be designed through this method with minimal net warpage. Long term measurements show that viscoelastic aging and pore depressurization are not sufficient to describe continued warpage months after our PMDI foam components are made leaving open the discussion for other mechanism (physical and chemical) of warpage during foam aging. We discuss varying levels of model complexity and their associated predicted responses during manufacturing as well as a variety of manufacturing sensitivity studies on the warpage of exemplar components.

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