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MULTIPHYSICS MODELING OF COUPLED CHEMICAL-THERMAL-MECHANICAL PHENOMENA IN POLYURETHANE FOAMS DURING MANUFACTURING

Kevin N. Long[1], Judith A. Brown[1], Christine C. Roberts[1], and Rekha R. Rao[1]

[1] Engineering Sciences Center, Sandia National Laboratories*, PO Box 5800, Albuquerque, NM, USA 87185, rrrao@sandia.gov

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PMDI (polymeric methylene diphenyl diisocyanate or polyurethane) foams encapsulate and protect fragile components from stray voltage and mechanical shock and vibration. Complex chemical and physical processes occur within PMDI foams during manufacturing and in service (aging) that can cause foam parts to warp out of shape. A good understanding of what drives these deformations and the ability to model foam behavior is essential to enable production of parts with tight dimensional tolerances that remain acceptable over time.

Here, we present our multi-physics theoretical and computational model that describes each step of the manufacturing procedure and furnishes a residual stress state and warpage response due to the manufacturing conditions [1]. The model involves four coupled conservation equations: energy (for the temperature field), momentum (for the foam velocity field), water concentration (for the blowing reaction), and polyol concentration (for the extent of polymerization). We implement the solution to these field equations in a loosely coupled finite element framework in which the computation is divided into three stages: 1) the fluid, foaming resin fills the mold in an Eulerian description of the foam matrix pre-gelation [2]; 2) the now solid, post-gel solid curing and vitrification behavior of the foam subject to manufacturing thermal conditions and mold constraints is presented in a mixed Lagrangian and ALE framework in which the momentum balance is Lagrangian (poromechanics description) and the species balances are in an Arbitrary Eulerian Lagrangian (ALE) description; and 3) a Lagrangian cool down and demolding stage. The computational framework is exercised against experimental measurements on PMDI foam parts during manufacturing. Results are favorable in predicting temperature variation throughout the part, density variation, and warpage immediately following the release of the part from the mold (demolding).

REFERENCES

[1] K.N. Long, K.L. Troyer, C.C. Roberts, M. Soehnel, K. Johnson, R.R. Rao, Manufacturing Induced Residual Stress Development and Deformation in PMDI-10 Structural Foam, SAND2018-9096, Sandia National Laboratories, 2018.

[2] Rao, R. R., Mondy, L. A., Noble, D.R., Long, K. N., Celina, M. C., Wyatt, N., Roberts, C. C., Soehnel, M. M., Tinsley, J., Thompson, K., Brunini, V. E., “A finite element/level set model of polyurethane foam expansion and polymerization,” *Computers & Fluids*, *175*, 20-35 (2018)

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