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HPC 4 ENERGYINNOVATION

HPC 4 MATERIALS HPC 4 MANUFACTURING HPC 4 MOBILITY

Polyurethane Foam Process Models Using a Population Balance Method

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U.S. DEPARTMENT OF ENERGY Energy Efficiency & Renewable Energy

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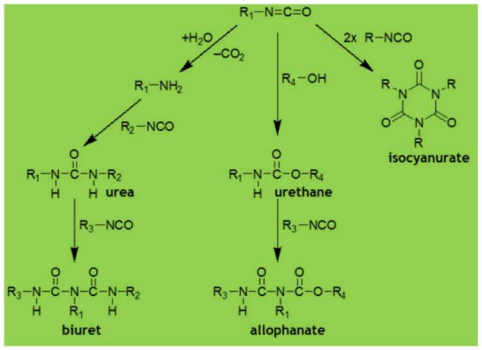
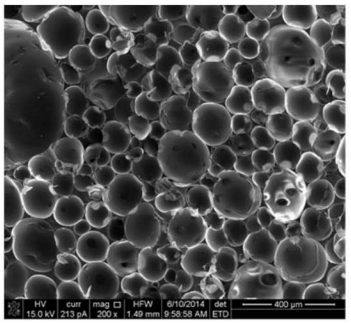
Industry need



- Polyurethane foams are widely used as insulators
- Insulation efficiency is a complex function of gas fraction, solid/gas thermal conductivity, and foam cell size distribution
- A HPC-based polyurethane (PU) foaming model to predict the impact of formulation changes on bubble-scale thermal properties is needed
- A PU model would expedite the timeline for more energy efficient foams and appliances



PMDI-4 RT
4.62 pcf

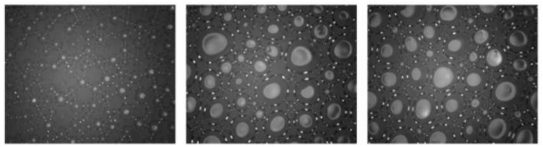
PMDI-4 71°C
6.29 pcf

Computational models can help produce more insulating foam with less waste

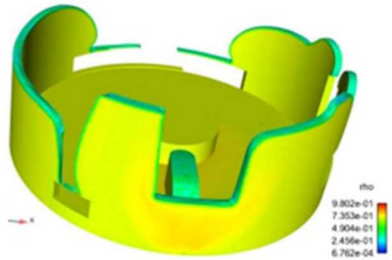
Approach

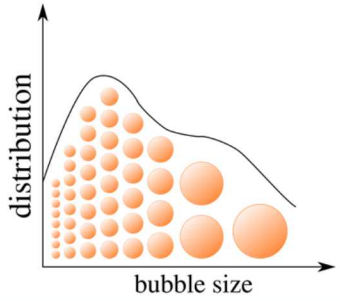
- Implement Sandia foam kinetics into an open source code
- Add population balance equations for bubble size evolution => improve model
- Validate with bubble-scale data

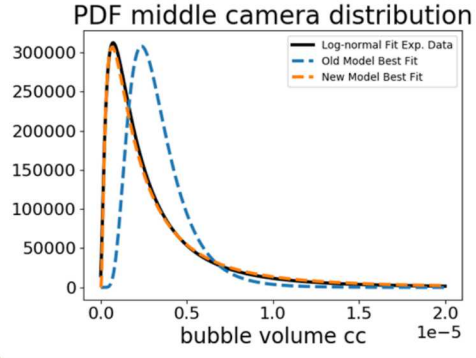
PMDI-4 packed to 8pcf (bottom camera)



	Published Model	New Model
$G(v)$	$G_0\left(\max\left(0,\frac{w-w_{max}}{w_{max}}\right)\right)$	$G_0\frac{\mu_{ref}}{\mu}\left(\max\left(0,\frac{w-w_{max}}{w_{max}}\right)\right)$
$\beta(v',v)$	$\beta_0(v+v')$	$\beta_0\frac{\mu_{ref}}{\mu}(v+v')\max\left(\frac{v}{v'},\frac{v'}{v}\right)$

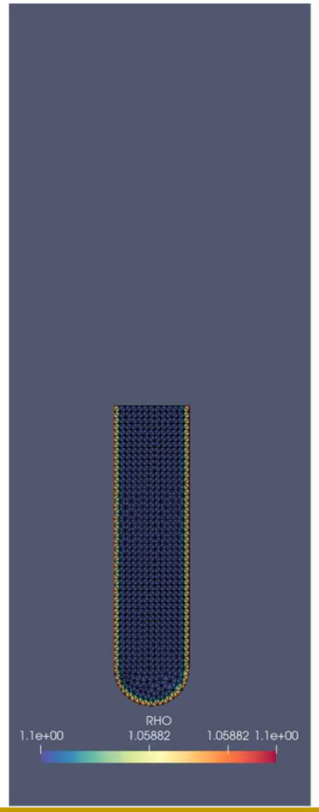






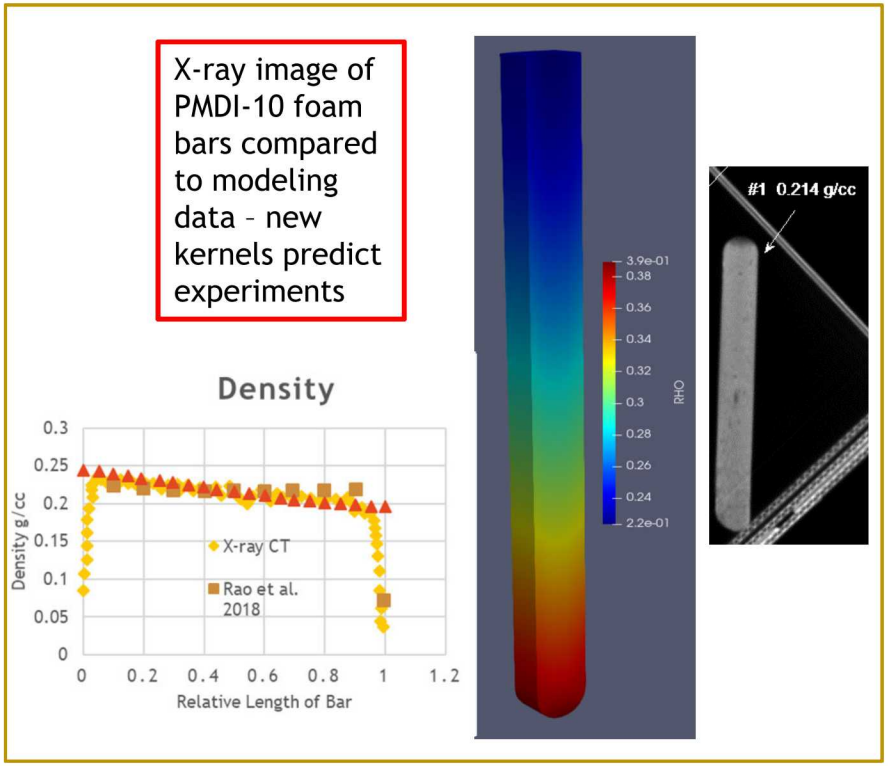
Coupled CFD-PBE for polyurethane process model and property predictions

Results



- New model can predict density gradients seen in X-ray CT experiments for the first time
- Predicts density and thermal conductivity based on bubble size
- Python version of model released to Dow for simple “numerical” foam rise experiments
- PBE equations poorly behaved with level set
- Numerical improvements underway for PBE in complex molds including adaptivity, tetrahedral elements, and upwinding

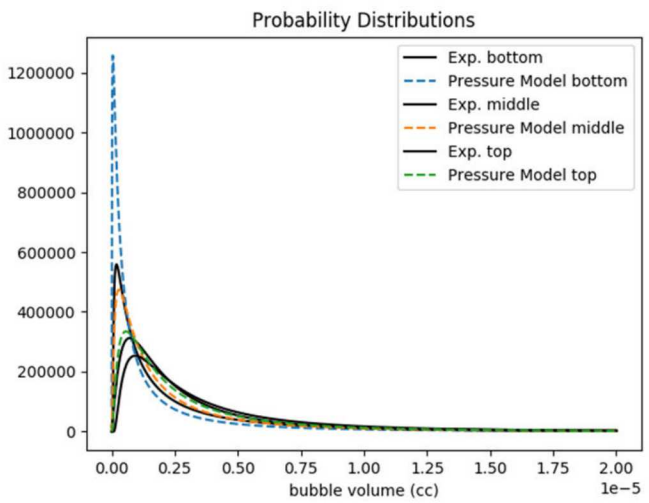
X-ray image of PMDI-10 foam bars compared to modeling data – new kernels predict experiments



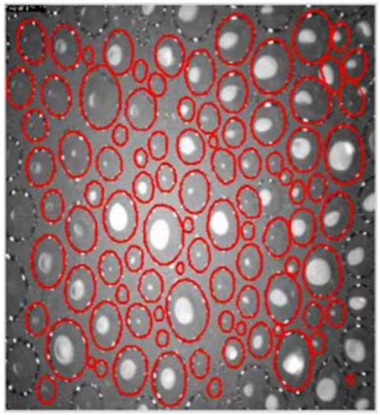
Model can now predict foam filling, curing, and bubble-size distribution for thermal conductivity

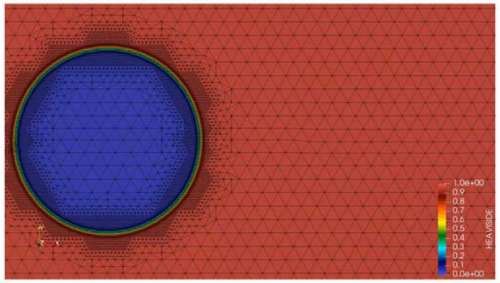
Benefits

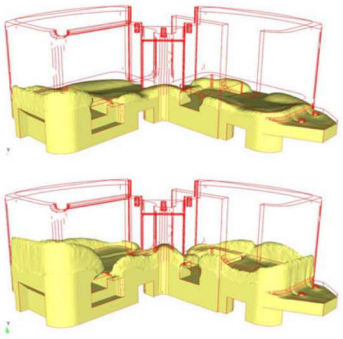
- New bubble-scale model can help improve insulation efficiency while reducing precursor waste
- Energy savings expected once Dow starts using the code to help customers with mold and process design
- Dow currently using Python model
- Working on a paper: CFD-PBE model compared to Sandia experimental results

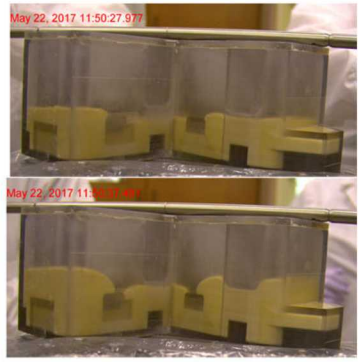


MATLAB script counts bubble-size evolution over time creating bubble volume data









Goma 7.0 release with full model expected October 2020

https://www.buildinggreen.com/blog/epa-raises-health-concerns-spray-foam-insulation

US Korea Hotlink
PU Vacuum Foaming Molds | Refrigerator Door, Cabinet

https://github.com/goma/goma

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