Morphological analysis of polyurethane foams

M. Moesen\textsuperscript{1}, K. Verniers\textsuperscript{1}, M. Brennan\textsuperscript{1}, J. Vandenbroeck\textsuperscript{1}

\textsuperscript{1}Huntsman Polyurethanes, Everslaan 45 B-3078 Everberg,

Aims
Polyurethane foams are used in applications ranging from footwear, seating and bedding to acoustic and thermal insulation. In each of these applications, the physical behavior of the foam depends on the material properties of the solid polyurethane and primarily on its three-dimensional cellular morphology. This work presents a microCT analysis methodology for quantifying the structure and geometry of a foam in order to simulate its physical behavior.

Method
Polyurethane (PUR) and polyisocyanurate (PIR) foam blocks were prepared, from which representative samples were collected and scanned using a Bruker Skyscan 1272 microtomograph. The source voltage and power were respectively 30kV and 6.36W. All scans were made in 360° without filter, with frame averaging at least 5 and with voxel size below 6 \(\mu\text{m}\). 3D reconstructions were made using Bruker's NRecon, version 1.6.9.8. 3D volume renderings were created using Bruker's CTvox, version 3.0.0. Image processing and analysis was performed using Bruker's CTan version 1.14.4.1 and using in-house developed methods.

Results
The flexibility of polyurethane chemistry enables a wide variety of foam cell microstructures in polyurethane foams. This is illustrated in figure 1, which shows on the left a PIR foam for insulation applications and on the right a PUR foam for bedding applications. The PIR foam visibly has smaller cells, thinner struts and a lower density than the PUR foam.

Figure 1: 3D volume rendering of a 3 mm x 3 mm x 3mm volume of a ‘rigid’ PIR foam (left) and a ‘flexible’ PUR foam (right).

For a quantitative analysis of the cellular morphology of a foam, an in-house methodology was developed based on the approach of Montminy et al. (2004). As illustrated in figure 2, the methodology starts with image acquisition and 3D reconstruction. The reconstructed image is binarized and consequently thinned. The thinned structure is used to identify the struts and
junctions in the foam. From this data, the windows and individual cells are recovered using a combination of structural and geometrical rules.

The individual cells provide quantitative measures of structure, such as the number of edges per face and faces per cell, as well as of geometry, such as strut length, cell surface and cell volume. Figure 3 shows histograms of these measures for an entire foam.

**Conclusion**

MicroCT imaging is an important tool for the analysis of polyurethane foams. MicroCT enables visualizing and quantifying the structure and geometry of these heterogeneous materials. This provides unambiguous 3D parameters for (1) relations between structure and physical (e.g. mechanical, thermal, acoustic) properties, (2) direct simulation of physical properties based on microCT models and (3) more realistic computer-generated models of foam structures that allow parametric simulation of their physical properties.

**References:**