

TuffFoam Density Variation through Radiography

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Introduction

TuffFoam is low density, high impact tolerant polyurethane foam with good high voltage breakdown developed at the Sandia National Laboratories. Identically shaped samples have been fabricated with various formulations and production conditions.

Goal

- Compare the density variation of samples that are produced under different conditions.

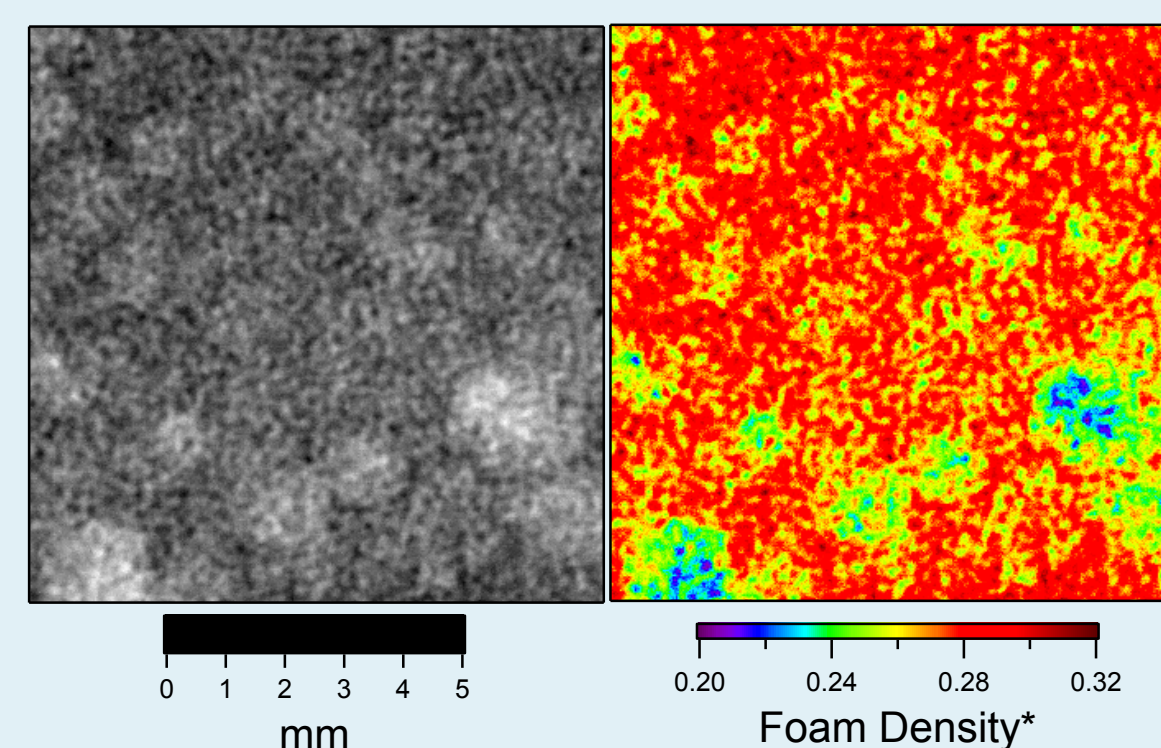
Variables

Molding Direction	Horizontal (H)	Vertical (V)	MD
Molding Temperature	68°F (20°C)	140°F (60°C)	MT
Foam Density g/cc	35%	80%	D
Packing Factor	Free (F)	2	P
Skin/No Skin	Molded (Mo)	Machined (Ma)	S
Post Cure Time	2 h	16 h	PC
Post Cure Temperature	80°F	145°F	PC
Isocyanate Index	105	125	I

Density Measurements

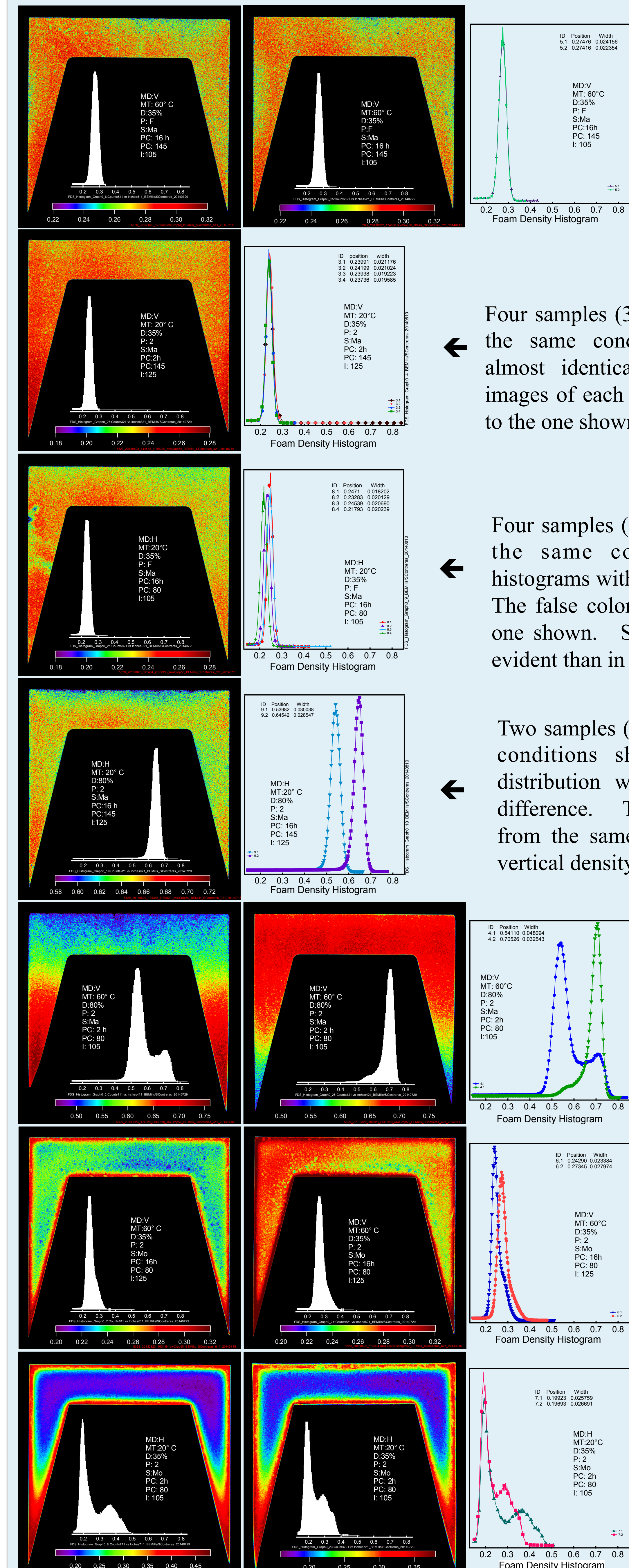
- Machined parts were made from pre-poured billets:
 - Vertical parts were machined from 5.12" cylinders 5.8" high.
 - Horizontal parts were machined 6" cylinders 3" high.
- A total of 28 samples with an overall sample dimension of 4x4 inches were studied. They are 1 inch thick.
- The radiographs were taken with a 25 micro pixel size at 53 inches from the source to the sample.
- The radiographic density is converted to sample density by fitting the radiographic density of each step in a plastic step wedge with 10 steps from 0.1 to 1.0 inches and applying the resulting equation to the sample data.
- The resulting inch-scaled data sets were converted to the false color images scaled to show the range of thickness in each sample.
- The number of pixels at each density level is shown in the accompanying histograms. The x-axis is scaled to the range of the entire sample set.
- The shape of the histogram reflects the homogeneity of each sample's density.

A portion of the raw image and the associated false color image from sample 6.2, showing pores within the sample.



*based on a plastic standard

Results and Discussions



Two samples (5.1, 5.2) produced under the same conditions show symmetrical distributions with almost identical histograms.

Four samples (3.1, 3.2, 3.3, 3.4) produced under the same conditions show symmetrical and almost identical histograms. The false color images of each of the samples look very similar to the one shown.

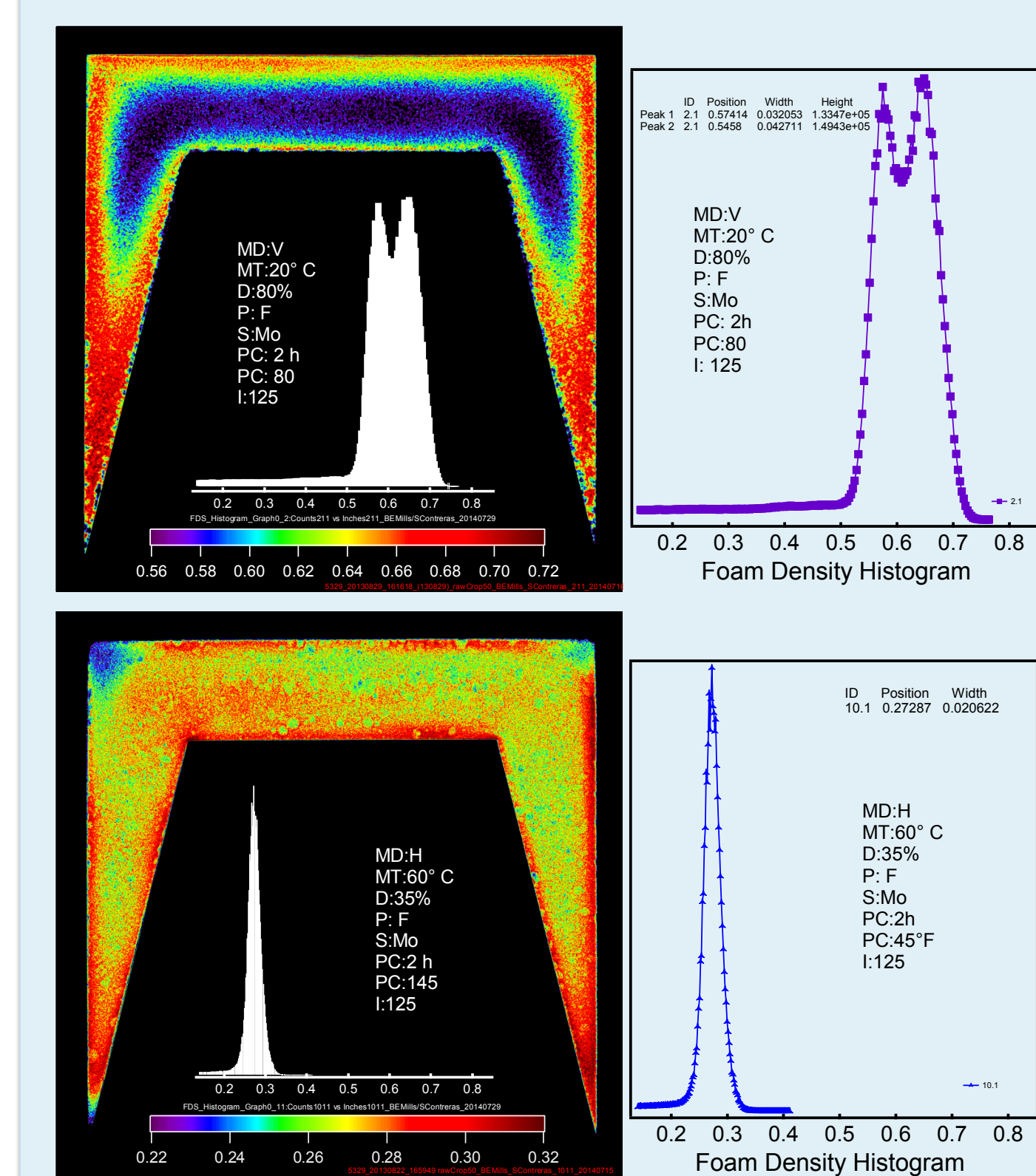
Four samples (8.1, 8.2, 8.3, 8.4) produced under the same conditions show symmetrical histograms with a small overall density variation. The false color images look very similar to the one shown. Small density variations are more evident than in the previous samples.

Two samples (9.1, 9.2) produced under the same conditions show a symmetrical density distribution with a significant overall density difference. They were machined horizontally from the same billet and show the effect of a vertical density variation in that billet.

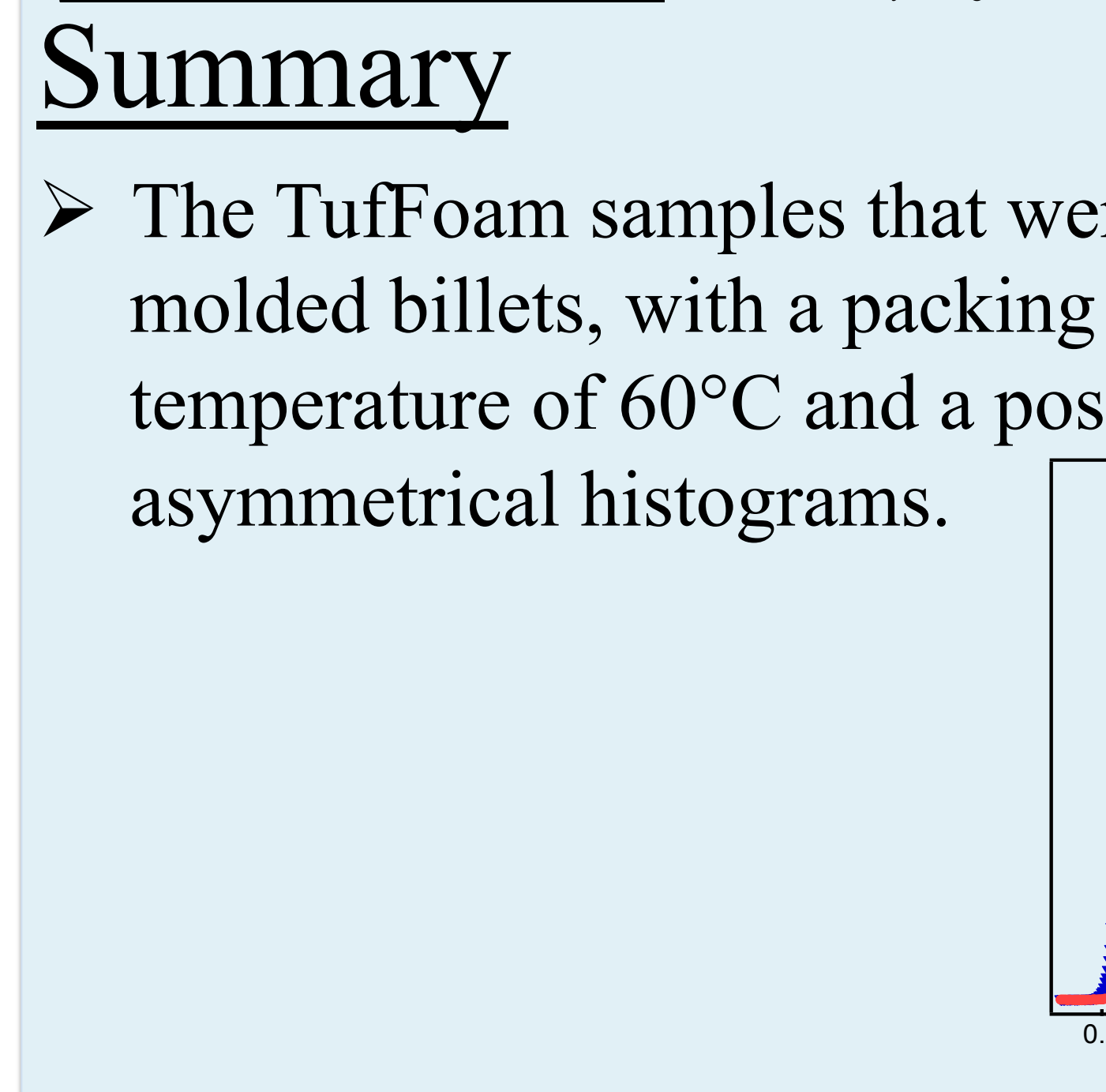
Two samples (4.1, 4.2) produced under the same conditions show different density gradations. They were machined in different vertical orientations from the same billet. Note the short arm seen on the left of 4.1.

Two molded samples (6.1, 6.2) were produced under the same conditions. They display a dense outer skin around a less dense core. This is an example of sample-to-sample variation.

Two molded samples (7.1, 7.2) produced under the same conditions. The density variation between the skin and the interior is greater than in the previous example.



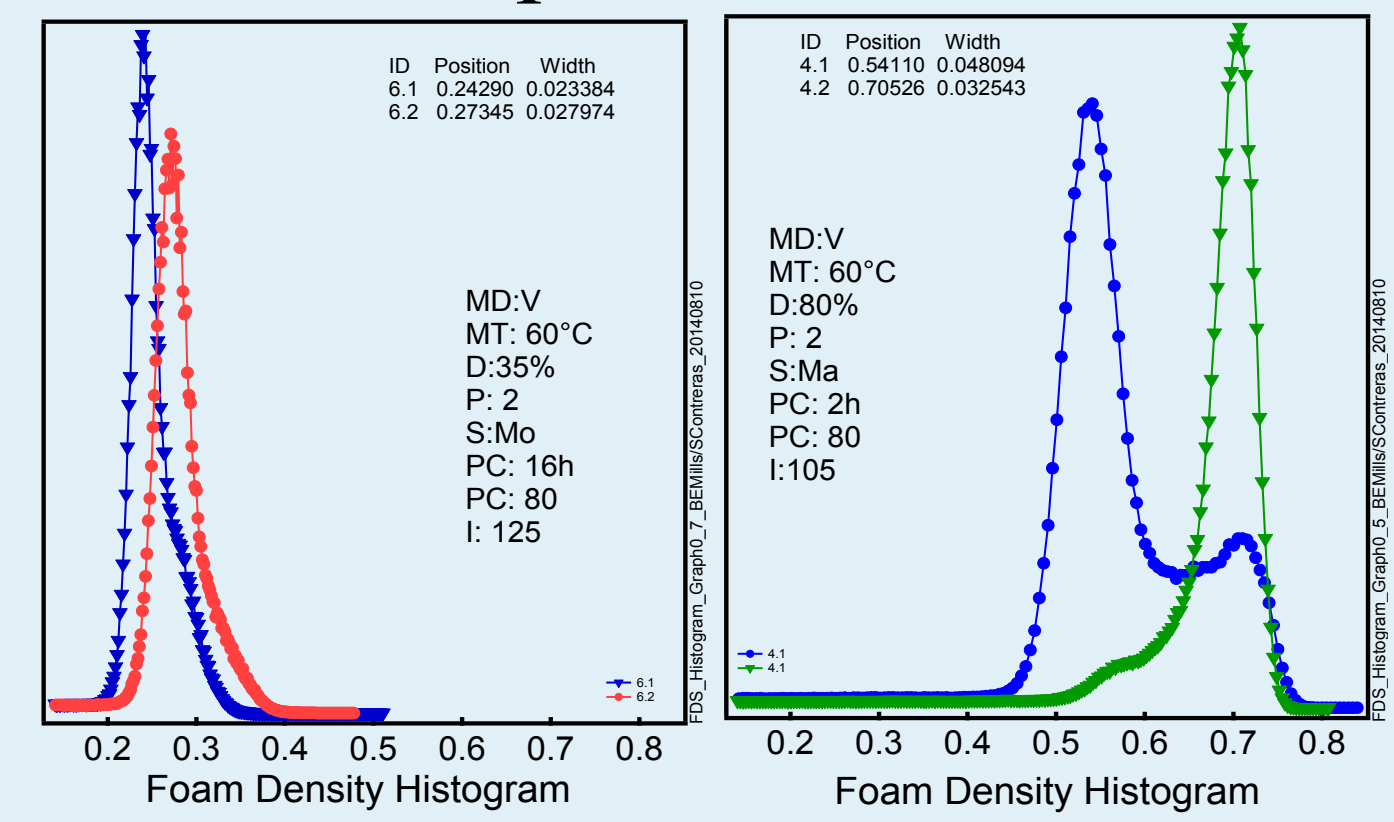
Sample 2.1 is molded. Compared to the 6.x and 7.x samples, 2.1 shows a distinct and thicker skin layer, comprising approximately half of the total sample volume as seen by the two peaks in the histogram.



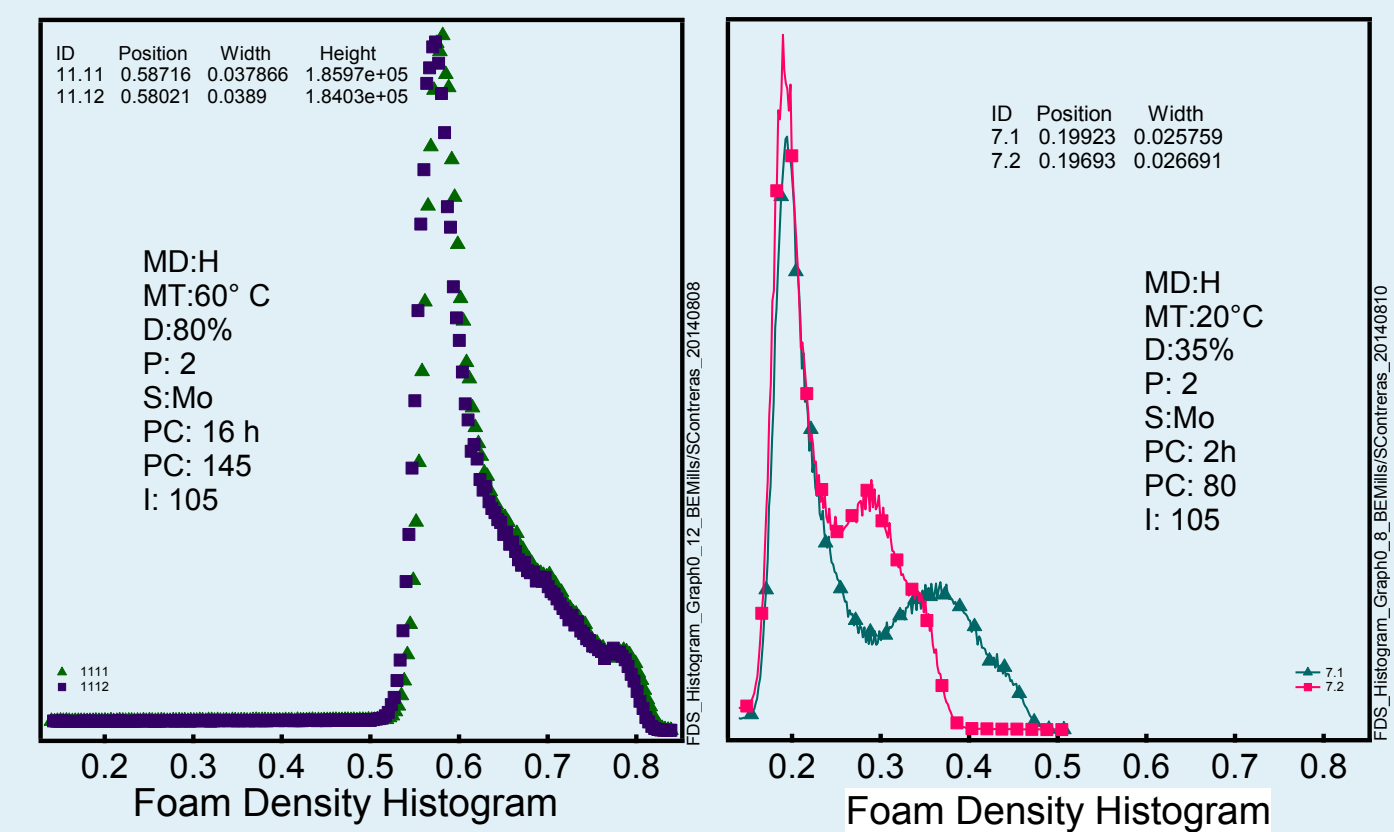
Sample 10.1, also molded, shows a uniform distribution in the histogram but small areas of low density as seen in the image. This may indicate that the mold was not well filed.

Summary

- The TuffFoam samples that were machined out of vertically molded billets, with a packing factor of 2, a molding temperature of 60°C and a post cure temperature of 80 show asymmetrical histograms.



- The TuffFoam samples that were molded out of a horizontal billet, with a packing factor of 2 display asymmetrical histograms.



Conclusion

- Every sample with a packing factor "free" is uniform, except when it is produced out of a vertically molded billet, 80% density, post cure time of 2 hours, post cure temperature of 80°F, Isocyanate index of 125 and molded.
- Otherwise, a packing factor of 2 guarantees a asymmetrical histogram.

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