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Compression and Shear Response of 3D Printed Foam Pads

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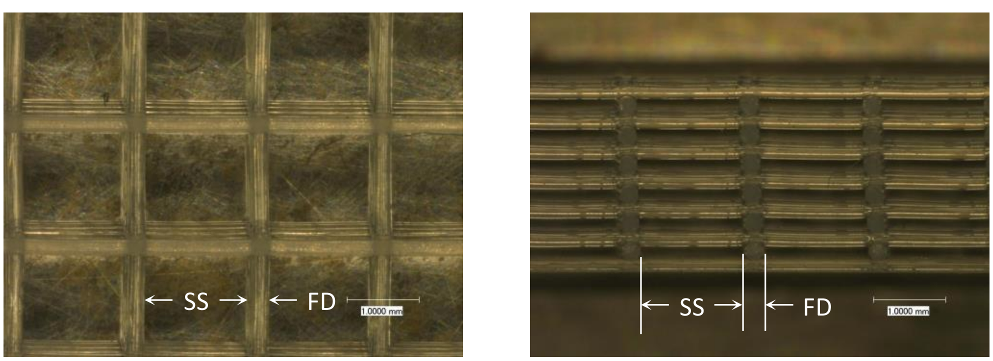
ABSTRACT

Polymeric porous materials have a wide range of applications. An important one in structural engineering is to use foams for cushioning or absorbing the kinetic energy from impact. Conventional foaming processes produce polymeric foams with disordered three-dimensional networks, which are dispersion in cell shape, size, etc. Since mechanical properties depend on the shape and structure of the cell, these foams are difficult to characterize and predict due to complexity and variation of cells. The new 3D printing fabrication method can now prepare components of foams with perfect regular array of cells. The printed foams potentially could be tuned or designed for application. In this study, foam pads of various porosities were printed using the same polymer. They all have a Body Centered Cubic (BCC) cell structured but with different span sizes. Experiments were conducted to characterize these foam pads in compression and shear, including off-axis loadings. The property of printing polymer was also characterized for analyzing the behaviors of these foam pads. Results are compared.

Keywords: additive manufacture, silicone foam, compression pad, shear characterization

INTRODUCTION

In 3D printing polymers, such as silicone, can be heated and deposited layer by layer under computer control to build 3D foam objects. Instead of random cell shape and size, the 3D printed foams can have perfect array of cells. The mechanical properties of a printed foam would be easier to predict if the cell parameters are known. This study concentrates on characterizing the mechanical behaviors of foams with BCC cell structure. The BCC cell foam is defined by two printing parameters: span size (SS) and filament diameter (FD) as shown in Figure 1. For various foam pads considered here, the constitutive polymer was SE1700 and FD was kept constant at 0.25 mm; SS was the only variable, its value ranged from 0 to 2.0 mm. The figure shows the foam pad with SS = 1.50 mm.

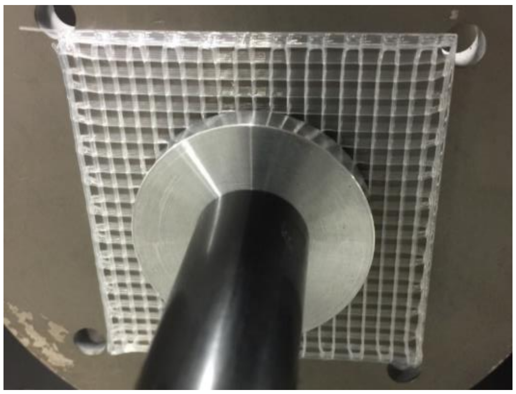


(a) Top view (b) Side view

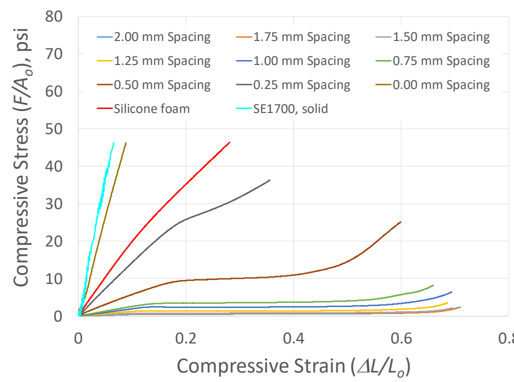
Fig. 1 3D printed foam pad with BCC cell structure.

COMPRESSION CHARACTERIZATION

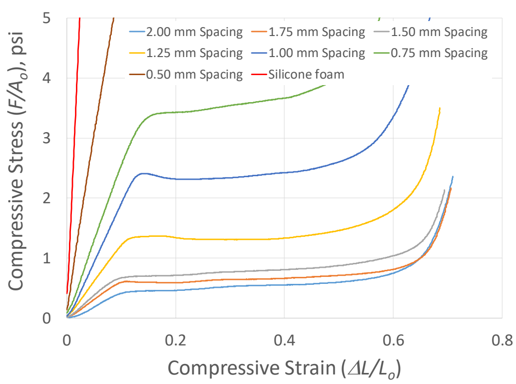
Punch compression test was performed as shown in Figure 2(a), where the platen was smaller than the pad sample. The platen diameter was about 31.56 mm; the nominal pad size was 50 mm x 50 mm x 3 mm. The loading was quasi-static, about 0.001 s^{-1}. The normalized load-displacement curves are plotted in Figure 2(b)-(d); (b) and (c) are the same plot but with different scales, so the responses of lower density pads are distinguishable; (d) displays the loading-unloading hysteresis. In addition to printed foam pads, solid SE1700 and a conventional silicone foam are also included in the plots for comparison. Notice that the pad that SS = 0 mm and solid SE1700 are not the same.



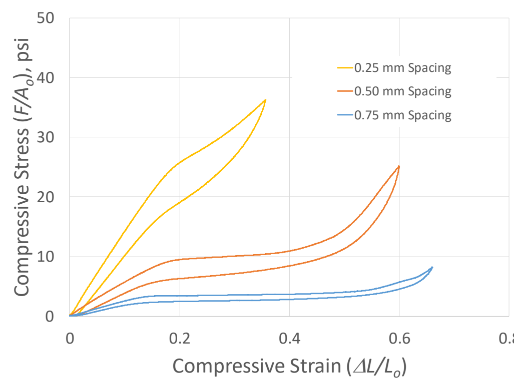
(a) Compression setup



(b) $\sigma - \varepsilon$ curves



(c) $\sigma - \varepsilon$ curves



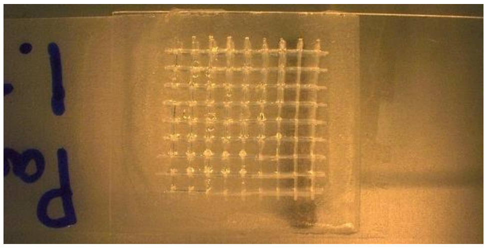
(d) Hysteresis curves

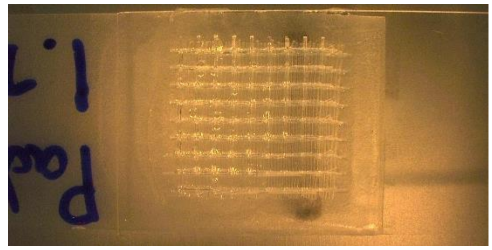
Fig. 2 Compression of 3D printed foam pad.

SHEAR CHARACTERIZATION

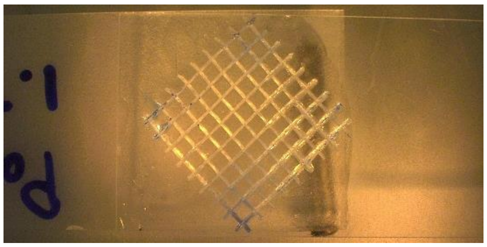
Printed foam pad was cut to about 18 mm x 18 mm x 3 mm size and bonded to plates for lap shear test. Transparent plates, such as glass or Plexiglas, were used, so the integrity of bonding interfaces and the uniformity of foam cell deformation could be observed and assured. Since the pad was orthotropic, the shear was done in two orientations: one was the filament either parallel or perpendicular to the shear loading direction; the other was off-axis, which had an angle of 45 degree between filament and loading directions. These configurations were termed as 90 and 45, respectively, shown in Figure 3. The figure also shows top views of un-deformed and shear deformed foam specimens, where SS = 1.75 mm. On shear deformed specimens, Figure 3(b) and (d), filaments from lower layers become visible.

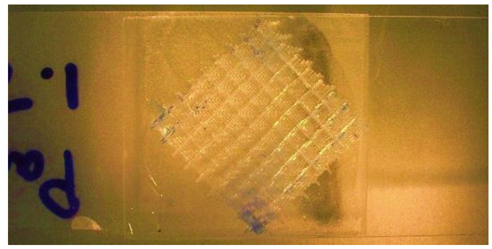
Shear stress-strain curves are shown in Figure 4. Figure 4(b) indicates that configuration 45 is softer than 90. Other pads, i.e. those with different SS values, also show the same trend.





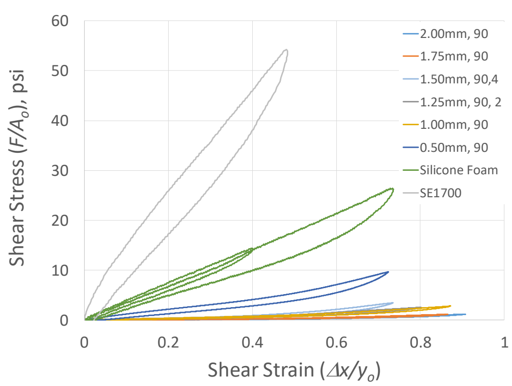
(a) 90, un-deformed (b) 90, deformed



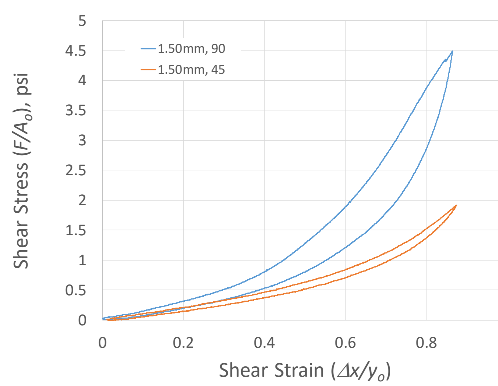


(c) 45, un-deformed (d) 45, deformed

Fig. 3 Shear specimens and deformation, SS = 1.75 mm.



(a) 90, $\tau - \gamma$ curves



(b) 90 and 45 comparison

Fig. 4 Shear stress-strain curves.

SUMMARY AND CONCLUSION

The compression and shear properties of various 3D printed foam pads were characterized. Only considering one cell shape and one cell variable, span size, a wide range of mechanical properties of printed foam pads, from compliant to stiff, can already be achieved by additive manufacturing process.

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