Acetone Polishing of ABS Test Results

Date: June 16, 2016

Objective: Determine Effect of Acetone on Mechanical Strength of 3D Printed Objects in Different Print Orientations.

Equipment: TestrBot, PrintrBot, Digital Calipers, Digital Scale,

Procedure & Test Method: A total of 12 specimens were tested. (4 conditions were tested with 3 specimens representing each variable.)

- 6 specimens were printed in the 'side' orientation, while the other 6 specimens were printed in the 'vertical' orientation.
- 3 specimens from each orientation were treated with an acetone vapor polishing process and allowed to dry out for 72 hours. (3 hours of this time was spent in a dehydrator.) All other variables were held constant.

Specimens were tested via loading at constant displacement rate in 4 Point Bend configuration until failure occurred.

Conclusions & Discussion: The result of static stress testing to failure has shown that acetone treatment has two measurable effects on ABS 3D printed parts:

1) A chemical weakening of the material structure
2) A mechanical strengthening of layer bonds via the reduction of surface stress concentrations.

This testing has shown that effect #1 outweights effect #2 to decrease the part strength by 9% in all stress conditions other than Z-axis loads, where effect #2 outweights effect #1 to increase the part strength by 31%.

Regarding effect #1, these new results agree with previous testing done (by me) in effect but not in magnitude. My hypothesis is that the additional drying time that I gave the new specimens helped remove all traces of acetone which may have contributed to additional softening of the specimens in the previous testing.

The overall effect of Acetone vapor polishing on ABS effectively makes parts more isotropic. That is, they react more uniformly to applied loads from various directions by sacrificing strength in their strong axis to increase strength in their weak axis.

Photo 1: Test Setup
<table>
<thead>
<tr>
<th></th>
<th>Avg Yield Load (lb)</th>
<th>Avg Yield Stress (psi)</th>
<th>Avg Stiffness (lb/in)</th>
<th>Avg Ult Load (lb)</th>
<th>Avg Ult Stress (psi)</th>
<th>Avg Mass (g)</th>
<th>Avg Ult Stress/Weight (psi/g)</th>
<th>Avg Stiffness per weight,(lb/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal, Horz</strong></td>
<td>101.6</td>
<td>5797.5</td>
<td>469.0</td>
<td>113.7</td>
<td>0.3</td>
<td>6493.7</td>
<td>8.03</td>
<td>808.1</td>
</tr>
<tr>
<td><strong>Treated, Horz</strong></td>
<td>89.7</td>
<td>5077.1</td>
<td>415.9</td>
<td>104.8</td>
<td>0.3</td>
<td>5931.8</td>
<td>8.20</td>
<td>723.4</td>
</tr>
<tr>
<td><strong>Normal, Vert</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>461.4</td>
<td>51.8</td>
<td>0.1</td>
<td>2700.3</td>
<td>11.80</td>
<td>228.9</td>
</tr>
<tr>
<td><strong>Treated, Vert</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>438.5</td>
<td>66.0</td>
<td>0.2</td>
<td>3549.4</td>
<td>11.80</td>
<td>300.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Std Dev 2% Yield (lb)</th>
<th>Std Dev 2% Yield Stress (psi)</th>
<th>Std Dev Stiffness (lb/in)</th>
<th>Std Dev Ult Load (lb)</th>
<th>Std Dev Ult Stress (psi)</th>
<th>Std Dev Mass (g)</th>
<th>Std Dev Ult Stress/Weight (psi/g)</th>
<th>Std Dev Stiffness per weight,(lb/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal, Horz</strong></td>
<td>2.7</td>
<td>282.7</td>
<td>12.0</td>
<td>7.3</td>
<td>0.048</td>
<td>516.6</td>
<td>0.058</td>
<td>60.3</td>
</tr>
<tr>
<td><strong>Treated, Horz</strong></td>
<td>2.5</td>
<td>293.4</td>
<td>18.6</td>
<td>0.1</td>
<td>0.021</td>
<td>170.7</td>
<td>0.000</td>
<td>20.8</td>
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<tr>
<td><strong>Normal, Vert</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>43.5</td>
<td>14.2</td>
<td>0.014</td>
<td>757.3</td>
<td>0.173</td>
<td>64.9</td>
</tr>
<tr>
<td><strong>Treated, Vert</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>2.7</td>
<td>6.9</td>
<td>0.017</td>
<td>327.6</td>
<td>0.000</td>
<td>27.8</td>
</tr>
</tbody>
</table>
### Vapor Polishing Test Results 6-19-16

**4 Point Bend Specimen ID: 2001**

**ABS, Horizontal, Untreated**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2% Yield</td>
<td>99.81 lb</td>
</tr>
<tr>
<td>2% Yield Stress</td>
<td>5633.5 psi</td>
</tr>
<tr>
<td>Stiffness</td>
<td>459.8 lb/in</td>
</tr>
<tr>
<td>Ultimate Load</td>
<td>117.59 lb</td>
</tr>
<tr>
<td>Displacement at Ultimate</td>
<td>0.3532 in</td>
</tr>
<tr>
<td>Ultimate Bending Stress</td>
<td>6636.7 psi</td>
</tr>
</tbody>
</table>

**4 Point Bend Specimen ID: 2002**

**ABS, Horizontal, Untreated**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2% Yield</td>
<td>104.70 lb</td>
</tr>
<tr>
<td>2% Yield Stress</td>
<td>6123.9 psi</td>
</tr>
<tr>
<td>Stiffness</td>
<td>482.6 lb/in</td>
</tr>
<tr>
<td>Ultimate Load</td>
<td>118.37 lb</td>
</tr>
<tr>
<td>Displacement at Ultimate</td>
<td>0.3151 in</td>
</tr>
<tr>
<td>Ultimate Bending Stress</td>
<td>6923.7 psi</td>
</tr>
</tbody>
</table>
4 Point Bend Specimen ID: 2003
ABS, Horizontal, Untreated

2% Yield: 100.20 lb
2% Yield Stress: 5635.0 psi
Stiffness: 464.6 lb/in
Ultimate Load: 105.28 lb
Displacement at Ultimate: 0.2571 in
Ultimate Bending Stress: 5920.6 psi

4 Point Bend Specimen ID: 2004
ABS, Vertical, Untreated

2% Yield: N/A lb
2% Yield Stress: N/A psi
Stiffness: 423.1 lb/in
Ultimate Load: 52.35 lb
Displacement at Ultimate: 0.1190 in
Ultimate Bending Stress: 2675.9 psi
4 Point Bend Specimen ID: 2005
ABS, Vertical, Untreated

2% Yield: N/A lb
2% Yield Stress: N/A psi
Stiffness: 452.4 lb/in
Ultimate Load: 37.31 lb
Displacement at Ultimate: 0.0825 in
Ultimate Bending Stress: 1955.4 psi

4 Point Bend Specimen ID: 2006
ABS, Vertical, Untreated

2% Yield: N/A lb
2% Yield Stress: N/A psi
Stiffness: 508.8 lb/in
Ultimate Load: 65.63 lb
Displacement at Ultimate: 0.1296 in
Ultimate Bending Stress: 3469.5 psi
Vapor Polishing Test Results 6-19-16

4 Point Bend Specimen ID: 2007
ABS, Horizontal, Treated

- 2% Yield: 91.41 lb
- 2% Yield Stress: 5284.6 psi
- Stiffness: 429.1 lb/in
- Ultimate Load: 104.70 lb
- Displacement at Ultimate: 0.3211 in
- Ultimate Bending Stress: 6052.5 psi

4 Point Bend Specimen ID: 2008
ABS, Horizontal, Treated

- 2% Yield: 87.90 lb
- 2% Yield Stress: 4869.7 psi
- Stiffness: 402.8 lb/in
- Ultimate Load: 104.89 lb
- Displacement at Ultimate: 0.3503 in
- Ultimate Bending Stress: 5811.1 psi
Vapor Polishing Test Results 6-19-16

4 Point Bend Specimen ID: 2009
ABS, Horizontal, Treated

- 2% Yield: 83.01 lb
- 2% Yield Stress: 4406.7 psi
- Stiffness: 390.1 lb/in
- Ultimate Load: 86.92 lb
- Displacement at Ultimate: 0.2486 in
- Ultimate Bending Stress: 4614.0 psi

SPECIMEN 2009 NOT ADDED TO AVERAGE DATA BECAUSE IT DID NOT ACTUALLY FAIL. THE SPECIMEN ENDED UP FALLING OVER BUT DID NOT BREAK.

4 Point Bend Specimen ID: 2010
ABS, Vertical, Treated

- 2% Yield: N/A lb
- 2% Yield Stress: N/A psi
- Stiffness: 440.5 lb/in
- Ultimate Load: 71.69 lb
- Displacement at Ultimate: 0.1669 in
- Ultimate Bending Stress: 3833.5 psi
2% Yield: N/A lb
2% Yield Stress: N/A psi
Stiffness: 435.5 lb/in
Ultimate Load: 58.40 lb
Displacement at Ultimate: 0.1340 in
Ultimate Bending Stress: 3191.0 psi

4 Point Bend Specimen ID: 2012
ABS, Vertical, Treated

2% Yield: N/A lb
2% Yield Stress: N/A psi
Stiffness: 439.6 lb/in
Ultimate Load: 67.97 lb
Displacement at Ultimate: 0.1600 in
Ultimate Bending Stress: 3623.6 psi