Energy Absorption

A guide to kinetic energy management systems
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- Energy Absorption Terminology
- Types of Plascore Energy Absorbers
- Example: Drop Protection
- Example: Damping

Applications

- Crash Test Dummy Calibration
- Impact Protection
- Large Mass Drop Protection
- Overrun Protection
- Nuclear Industry Compliance
- Aerospace
- Automotive
- Blast Mitigation
What is an Energy Absorber?

“The basic concept of energy absorption is to take a moving object’s kinetic energy and convert it into internal work.”

When a load is applied to the honeycomb it exhibits plastic deformation, in the form of crushing.

This deformation results in a constant force through the crushed thickness.

The work (Force x Distance) done by the energy absorber defines how much kinetic energy the system has absorbed.


Before and after crushlite and AlTuCore assembly crushing
Energy Absorption Terminology

Below is a sample graph (using data from pre-crushed 320 PSI Crush Core) that explains the basic terminology of Plascore’s energy absorbers.

1. **Kinetic Energy Absorbed**: Defined as the work (force x distance) done.

2. **Crush Strength Tolerance**: The acceptable range the average crush strength can be.

3. **Crush Strength**: Defined in accordance to ASTM D7336 as the average compressive stress during the core’s stable crush strength region.

4. **Crush Stroke**: The length a part is crushed.

5. **Densification**: Occurs when all material has been fully crushed. Compressive stress will increase exponentially from that point forward.

6. **Pre-crush**: A procedure to eliminate peak bare compressive loading by initiating the crushing process on one side of the core.
Types of Plascore Energy Absorbers

Plascore manufactures two different materials that are ideal for energy absorption applications. The first of these is CrushLite, a lower density expanded aluminum honeycomb. The second is AlTuCore, a high-density corrugated material.

**CrushLite**

- Typically manufactured in 4’ x 8’ sheets
- Customer specified thicknesses
- Crush strengths ranging from 7.5 - 750 psi
- Tested per ASTM D7336
- Can be provided with or without pre-crush
- Typical thickness range: 1” - 30”
- Minimum stroke of 70% of part thickness.

<table>
<thead>
<tr>
<th>Density</th>
<th>1.0</th>
<th>1.6</th>
<th>1.6</th>
<th>2.0</th>
<th>2.3</th>
<th>2.3</th>
<th>3.4</th>
<th>3.1</th>
<th>3.7</th>
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<td>Foil Gauge</td>
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<td>0.001</td>
<td>0.0007</td>
<td>0.0007</td>
<td>0.001</td>
<td>0.001</td>
<td>0.0015</td>
<td>0.0007</td>
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<td>0.003</td>
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<tr>
<td>Foil Alloy</td>
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<td>5052</td>
<td>5056</td>
<td>5056</td>
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<td>5056</td>
<td>5052</td>
<td>5056</td>
<td>5052</td>
<td>5052</td>
</tr>
<tr>
<td>Crush Strength (psi)</td>
<td>30</td>
<td>45</td>
<td>50</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td>140</td>
<td>170</td>
<td>180</td>
<td>210</td>
</tr>
</tbody>
</table>

**AlTuCore**

- Cylindrical built to order energy absorber
- Customized ID and OD, based on customer’s needs
- Test method similar to ASTM D7336
- Can be provided with or without pre-crush
- Typical thickness range: 0.30” - 20”
- Custom crush strength ranges from ~1,000 psi to 8,000 psi
- Typical Stroke between 55% and 70% of part length, depending on density

<table>
<thead>
<tr>
<th>Density</th>
<th>5.2</th>
<th>4.5</th>
<th>4.5</th>
<th>5.4</th>
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<th>8.1</th>
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<td>Cell Size</td>
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<td>1/8</td>
<td>3/8</td>
<td>3/16</td>
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<td>3/16</td>
<td>1/8</td>
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<tr>
<td>Foil Gauge</td>
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<td>0.002</td>
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<td>0.002</td>
<td>0.0015</td>
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<tr>
<td>Foil Alloy</td>
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<td>5056</td>
<td>5052</td>
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<td>5052</td>
</tr>
<tr>
<td>Crush Strength (psi)</td>
<td>245</td>
<td>275</td>
<td>320</td>
<td>350</td>
<td>380</td>
<td>420</td>
<td>440</td>
<td>535</td>
<td>700</td>
<td>750</td>
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</tbody>
</table>

*Alternative crush strengths available on our Crush Lite data sheet. Minimum order quantity may apply.*
The Problem: An engineer has been tasked with arresting a large tensioning weight used on an industrial conveyor belt. The tensioning weight poses a significant risk to equipment if it is allowed to plunge to the ground.

Knowns

<table>
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<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Maximum Load on Support Structure</td>
<td>345,000 Kn</td>
</tr>
<tr>
<td>Usable Support Structure Width</td>
<td>1 meter</td>
</tr>
<tr>
<td>Usable Support Structure Length</td>
<td>1.1 meters</td>
</tr>
<tr>
<td>Maximum Drop Height</td>
<td>3 meters</td>
</tr>
<tr>
<td>Mass of Tension Weight</td>
<td>9,100</td>
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</table>

Unknowns

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Crush Strength</td>
<td>TBD psi or MPa</td>
</tr>
<tr>
<td>Required Material</td>
<td>TBD CrushLite</td>
</tr>
<tr>
<td>Required Part Thickness</td>
<td>TBD in or m</td>
</tr>
</tbody>
</table>

Step 1:
Determine required crush strength to maximize load distribution.

Maximum Crush Strength = Maximum Load / CrushLite Area
Crush Strength = 0.38 MPa, or 56 psi

Step 2:
Select a material.

Referencing Plascore’s CrushLite data sheet:
PACL - 1.6 - 1/4 - 0.0007 - 5056 with a Crush Strength of 50 psi +/-10% would be a perfect fit.

Step 3:
Determine required part thickness:

Governing equation
Potential Energy (PE) = Work (W)
In this case:
PE = Mass x Gravity x (Drop Height + Stroke)
And
Work = Crush Strength x Area x Stroke
This results in the following equation:
Mass x Gravity x (Drop Height + Stroke) = Crush Strength x Area x Stroke
Solving the above equation for stroke:
Stroke = 0.92 m
Using this information and Plascore’s advertised minimum stroke of 70%:
Part thickness = Stroke / Minimum Percent Stroke
Part thickness = 1.314 m of honeycomb

Step 4:
Request a quote from Plascore.
The Problem: An engineer is designing an amusement park ride and has the responsibly of ensuring the safety of the occupants. In this case the engineer is designing for a catastrophic cart-to-cart impact, and needs to ensure that the occupants are able to safely walk away. Based upon the usable area, the AlTuCore OD and ID have been predefined.

### Knowns

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Maximum Allowed “G” Load</td>
<td>3 Gs</td>
</tr>
<tr>
<td>Cart Mass</td>
<td>2,000 Kg</td>
</tr>
<tr>
<td>AlTuCore Outside Diameter</td>
<td>0.1 meters</td>
</tr>
<tr>
<td>AlTuCore Inside Diameter</td>
<td>0.025 meters</td>
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<tr>
<td>Worst-Case Cart Velocity</td>
<td>4 m/s</td>
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### Unknowns

<table>
<thead>
<tr>
<th></th>
<th>TBD</th>
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<tbody>
<tr>
<td>Required Stroke</td>
<td>inches or meters</td>
</tr>
<tr>
<td>Part Length Required for Safe Deceleration</td>
<td></td>
</tr>
<tr>
<td>Required Part Thickness</td>
<td>TBD</td>
</tr>
<tr>
<td>Crush Strength</td>
<td>TBD</td>
</tr>
<tr>
<td></td>
<td>psi</td>
</tr>
</tbody>
</table>

### Step 1:

Determine the required part length to achieve safe deceleration. First, we have to determine the required stroke.

\[ G \text{ Load} = \frac{(\text{Velocity})^2}{2 \times \text{Gravity} \times \text{Stroke}} \]

Solving for stroke

\[ \text{Stroke} = 0.272 \text{ meters or 10.70 inches} \]

Now we can use this information along with minimum available stroke of 55% to determine the required part length.

\[ \text{Part length} = \frac{\text{Stroke}}{\text{Expected Percent Stroke}} \]

\[ \text{Part length} = 0.494 \text{ meters or 19.458 inches} \]

### Example: Damping

**Step 2:**

Determine the required crush strength.

Governing equation

\[ \text{Kinetic Energy} = \text{Work} \]

in this case:

\[ \text{Kinetic Energy} = \frac{1}{2} \times \text{Mass} \times \text{Velocity}^2 \]

And

\[ \text{Work} = \text{Crush Strength} \times \text{Area} \times \text{Stroke} \]

We arrive at the equation:

\[ \frac{1}{2} \times \text{Mass} \times \text{Velocity}^2 = \text{Crush Strength} \times \text{Area} \times \text{Stroke} \]

Solving for crush strength:

\[ \text{Crush Strength} = 8.0 \text{ MPa or 1159 psi} \]

**Step 3:**

Request a quote for AlTuCore from Plascore.

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