Energy Absorption

Converting kinetic energy into internal work with MetaCORE

MetaCORE is optimized to absorb energy from all directions. This explainer reviews the advantages of MetaCORE as an energy absorber and explores a case study.

MULTISCALE SYSTEMS

MetaCORE **Explainer**

What is MetaCORE?

MetaCORE is a family of 3D geometric patterns (motifs) designed to promote isotropic energy absorption. The geometry looks different from each direction (Fig. 1), but the various lengths and angles are chosen to ensure the key performance metrics — SEA, CFE, peak stress, and compression distance — perform regardless of impact direction. Engineers work with MetaCORE as if it were a conventional foam, but with much higher performance characteristics.

Why MetaCORE is a good energy absorber

Decades of research from transportation, aerospace, and defense engineers have converged on three performance metrics for characterizing ideal energy absorbers:

Specific Energy Absorption (SEA): A high performing energy absorber needs to be both lightweight and mitigate a large amount of energy. Ideal absorbers, like MetaCORE, have large SEAs.

(I) (II)

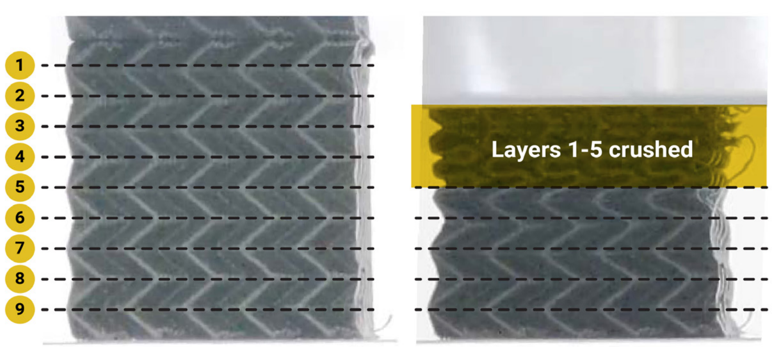

Fig. 1. Crushing mechanics for a representative sample of the MetaCORE [MO] motif. It collapses in a cascade where each cellular layer deforms sequentially. Image (I) shows the layers before deformation, while (II) shows that several of the layers in contact with the compression plate have been crushed, leaving the lower layers unaffected.

Benefits

- Predictable energy absorption from unpredictable impacts
- Low density for lightweight systems
- Fabricated from low cost easily-sourced and processed materials
- Available in polymer, metallic, and fibrous pulp versions

Applications


Transportation


Aerospace


Defense

Terminology

Stress: Applied force per unit area.

Peak Stress: Maximum stress an energy absorber can bear before being crushed.

Crush Stress: The stress that drives energy absorption via internal work.

Crush Force Efficiency (CFE): Ratio of crush stress to peak stress quantifying effect of impact decelerations. An ideal CFE=1.

Crush: Internal work that absorbs energy.

Stroke Distance: The compression cycle primarily responsible for energy absorption.

Compactification: Crushed part that becomes nearly solid.

Specific Energy Absorption (SEA): Energy absorbed per unit mass.

Crush Force Efficiency (CFE): Sudden deceleration can cause injury to people and cargo. Therefore, energy absorbers must do more than just absorb energy, they must mitigate the transmission of force. A CFE of 1 is best, whereas a CFE of 0 is the worst. MetaCORE CFEs are engineered for the highest possible values.

Pro-isotropy: The direction of an impact isn't always predictable. When absorbing energy, it's best to have isotropic protection to ensure the best possible outcomes. MetaCORE is engineered to be pro-isotropic (Fig. 2) and provide full energy absorbing capabilities regardless of the direction of impact.

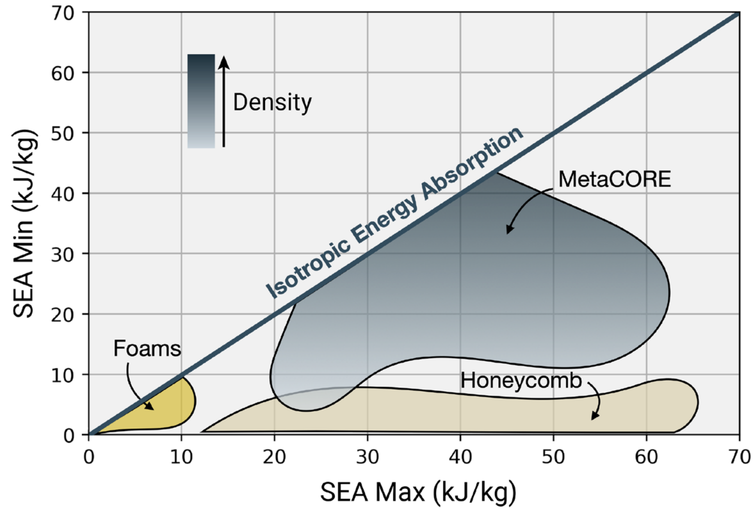

Fig. 2. SEA Min. vs Max. graph comparing energy absorption properties of MetaCORE, foams, and honeycomb.

How MetaCORE compares

MetaCORE vs Honeycomb

- Honeycomb has SEAs ~3,250 to 20,000 ft-lb/lb (~10 to 60 kJ/kg), comparable to MetaCORE.
- Honeycomb typically has CFEs ~0.5 (when pre-crushed, its ability to bear loads decreases by about 50%). MetaCORE outperforms honeycomb with CFEs from 0.85 to 0.99.
- Honeycomb has one functional direction for energy absorption, which covers only 3% of all possible impact directions. MetaCORE is pro-isotropic, giving a 30x larger operational envelope.

MetaCORE vs Foam

- Foams have low SEAs of typically less than 3,250 ft-lb/lb (10 kJ/kg), compared to MetaCORE's large SEA of ~3,250 to 20,000 ft-lb/lb.
- Foams have CFEs approaching 1, which is comparable to MetaCORE.
- Foams are typically isotropic, which is comparable to MetaCORE.

This comparison shows MetaCORE offers a superior package of SEA, CFE, and isotropy when compared to other energy absorbing solutions.

Customization

Depending on the application, MetaCORE can be customized for greater energy absorption and directional sensitivity (Fig. 3). This customization is accomplished by optimizing geometric parameters according to your technical requirements.

Contact us to discuss your requirements:

- 1-855-955-7900
- info@multiscalesystems.com
- multiscalesystems.com

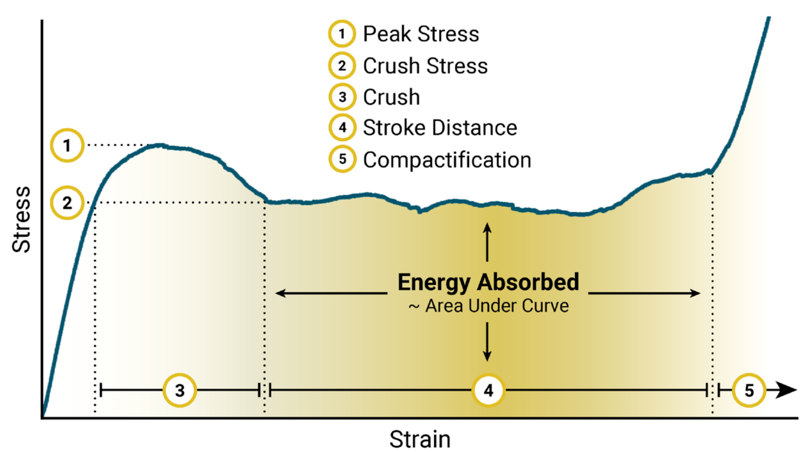

Fig. 3. Stress-strain graph of MetaCORE [MO]. Each of the five labeled parameters can be customized.

Case study: Trailer side impact guards

The problem

Select a MetaCORE product for impact guard panels that keeps total weight and cost to a minimum while satisfying technical requirements.

Known technical requirements	Unknown product specifications
Minimum peak load: 37,250 lbs (166 kN) of force	Crush stress (psf or MPa)
Bumper area: 8 in x 44 in (20.3 cm x 112 cm)	Panel thickness (in or cm)
Impact guard panel size: 20 ft x 8 in (6.1 m x 20.3 cm)	Panel weight per area (lbs/ft^2 or kg/m^2)
Bumper overlap with impact guard: 100%	MetaCORE product selection
Minimum energy absorbed: 7,376 ft-lb (10 kJ)	
Maximum crush distance: 5 in (12.7 cm)	

1 **Determine minimum impact guard crush stress.** The impact guard must be able to support a minimum peak load to activate the car's crumple zone.

(crush stress) = (peak load) / (bumper area)

(37,250 lbs) / (8 in x 44 in) = ***15,240 psf (0.73 MPa)***

2 **Determine the thickness of one panel of impact absorbing material required to absorb the minimum amount of energy.**

(energy absorbed) = (crush stress) x (bumper area) x (panel thickness)

Rearrange and solve for *panel thickness:*

(panel thickness) = (energy absorbed) / [(crush stress) x (bumper area)]

(7,376 ft-lb) / [(15,240 psf) x (8 in x 44 in)] = ***2.4 in (6.0 cm)***

Exceeds requirement: 5 in maximum crush distance

3 **Select material and verify requirement satisfaction.** Using the Multiscale Systems **metamaterial data selector**, technical requirements are satisfied by multiple options. We select a standard MetaCORE [MO] motif fabricated from CF-PLA as it's: i) low cost, ii) low weight at 13.7 lb/ft^3 (220 kg/m^3), and iii) its crush stress is 37,600 psf (1.8 MPa), which allows for the bumper to have as little as 40% overlap with the impact guard.

Exceeds requirement: Bumper overlap

(material weight per sq-ft) = (material density) x (panel thickness)

(13.7 lb/ft^3) x (2.4 in) = ***2.7 lb/ft^2 (13.3 kg/m^2)***

Satisfies requirement: Low weight

Product selected: CF-PLA MetaCORE [MO]	CF-PLA MetaCORE [MO] impact guards on both sides would only add 72 lbs (33 kg) while meeting or exceeding technical requirements.

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