FSAE Racecar Crash Protection

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2010

Abstract

Rules for the FSAE Racecar competition require an impact attenuator mounted on the front bulkhead of the vehicle to protect the driver and frame. This project included the design, modeling, fabrication, and testing of two impact attenuator designs. The result was the creation of a single impact attenuator structure which satisfies all FSAE competition rules and regulations.

FSAE Crash Protection Requirements

B3.20.1 The Impact Attenuator must be:

a. Installed forward of the Front Bulkhead.
b. At least 200 mm (7.8 in) long, with its length oriented along the fore/aft axis of the Frame.
c. At least 100 mm (3.9 in) high and 200 mm (7.8 in) wide for a minimum distance of 200 mm (7.8 in) forward of the Front Bulkhead.
d. Such that it cannot penetrate the Front Bulkhead in the event of an impact.
e. Attached securely and directly to the Front Bulkhead and not by being part of nonstructural bodywork.

B3.21.1 The team must submit test data to show that their Impact Attenuator, when mounted on the front of a vehicle with a total mass of 300 kilograms (661 pounds) and run into a solid, non-yielding impact barrier with a velocity of impact of 7.0 meters/second (23.0 feet/second), would give an average deceleration of the vehicle not to exceed 20 g's, with a peak deceleration less than or equal to 40 g's.

Objectives

In order to produce a design which met the requirements, the team accomplished the following:

•Researched rules and previous attenuator designs
•Modeled impact attenuator designs on SolidWorks and performed finite element analysis
•Performed impact tests on two designs to determine deceleration values
•Made recommendations for an optimum impact attenuator design

Materials Selection

Plascore Aluminum Honeycomb Blocks at $100 per 12 X 12 X 10 in. block:
Plascore is a company that produces honeycomb cores and composite panels which exhibit high strength to weight ratios along with high shear strengths. The company donated three aluminum honeycomb blocks which the group modified for both designs.

High-Density Closed Cell Polyethylene Foam at $35 per 54 X 24 X 1 ½ in. sheet:
HDPE foam is specially designed for impacts. Traditionally, the material has been used because it is has high shock absorption, it is shatter proof, and it has a relatively high cost-effectiveness.

4130 Annealed Steel Sheet at $15 per 12 X 12 X 1/16 in. sheet:
The team chose annealed steel sheet for the anti-intrusion plate due to its material properties. This plate is the last material between the attenuator and the frame, and this reliable and non-corrosive steel provides an adequate means to prevent intrusion.

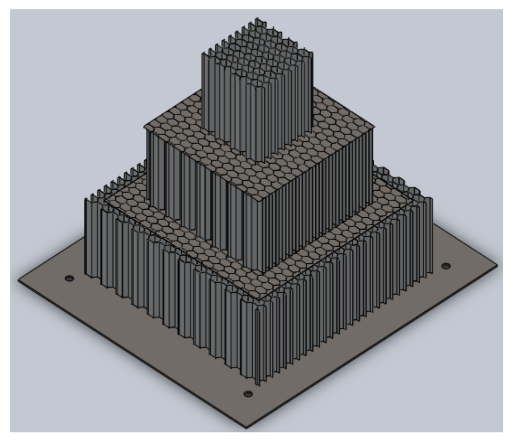
Aluminum T63003 at $25 per 24 X 36 X 1/32 in. sheet:
This aluminum sheet provided protection against penetration in between the layers of the attenuators. The aluminum was used to transfer the force evenly to the next layer. Also, the prototype attenuator would be held together with strapping.

Designs

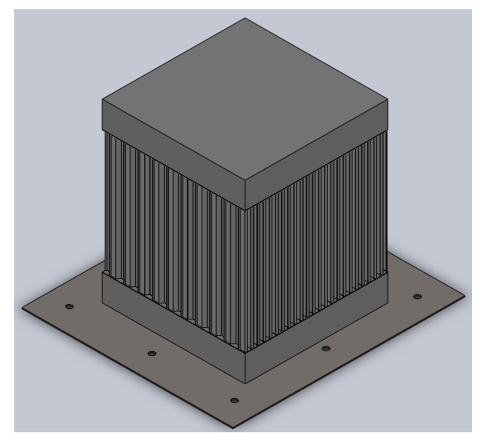
Design Concept	Cost	Weight	Reliability	Safety	Feasibility	Rank
Weighting factor	0.35	0.25	0.20	0.15	0.30	
Airbag	1.0	9.0	8.0	6.0	3.0	6.0
Crimped Metal Lattice	6.0	6.0	5.0	5.0	6.0	7.2
Foam	7.0	8.0	7.0	8.0	8.0	9.5
Honeycomb	8.0	8.0	9.0	8.0	8.0	10.2
Rubber Bumper	7.0	7.0	6.0	7.0	7.0	8.6

The above table shows that honeycomb and foam are the two highest ranking designs. The team used combinations of the materials and altered the geometries. Several initial solid models were created and tested using SimulationXpress, a basic simulation test in SolidWorks 2009. The following models showed the most promise of the final four designs, and they were chosen for finite element analysis.

Honeycomb Pyramid



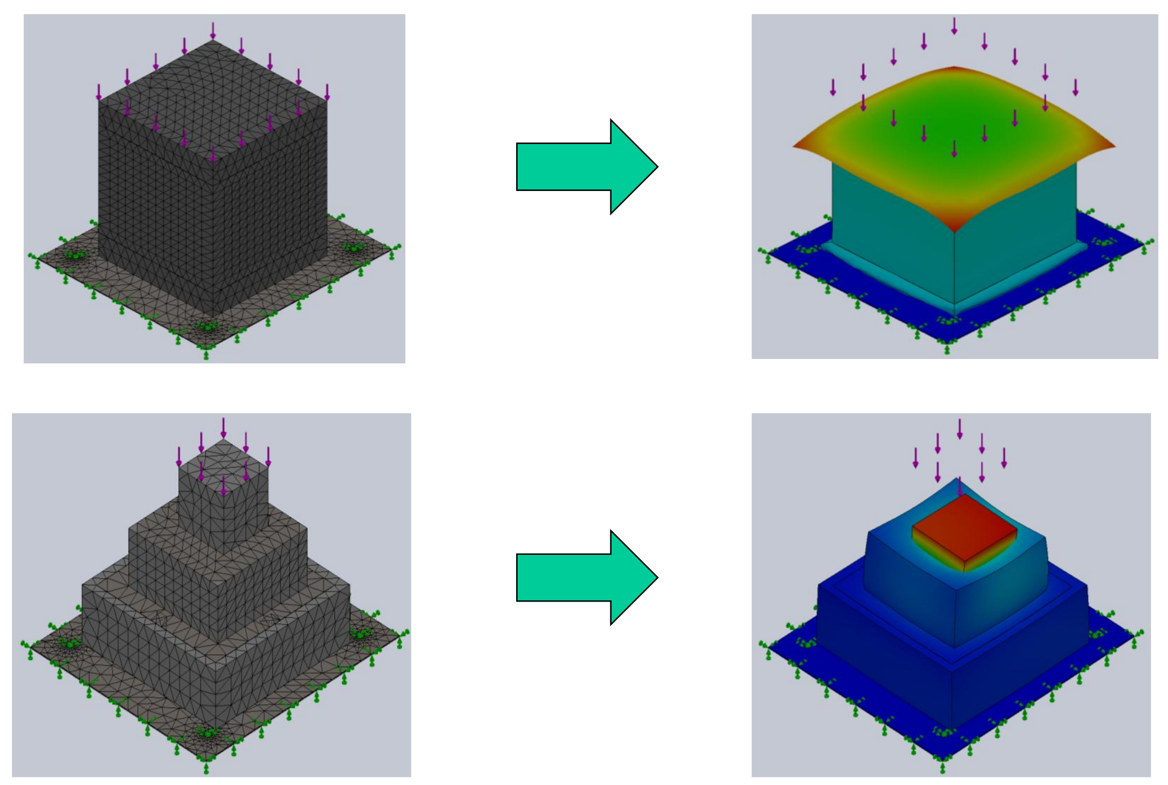
Honeycomb and Foam



Finite Element Analysis

The complex honeycomb structures were modeled as blocks with the same physical properties, and a finite element analysis was performed on each to determine impact patterns.

Applied Loads Deformed Models



Impact Test Calculation

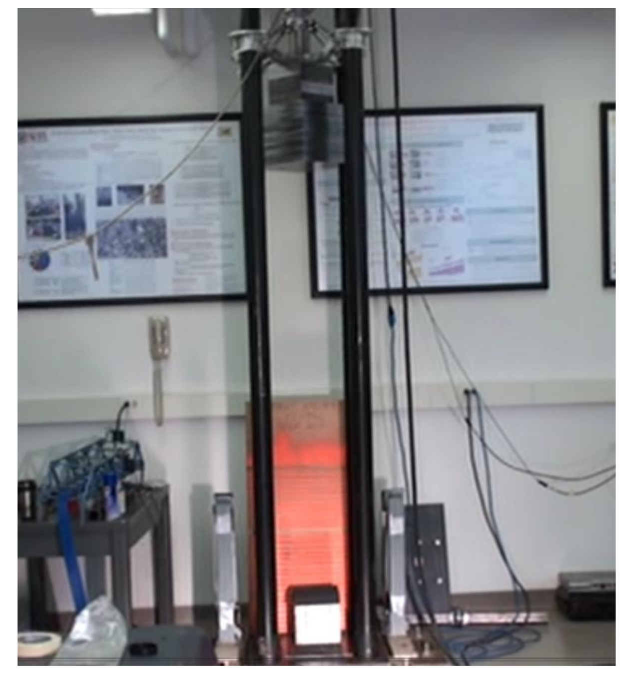
A key calculation had to be made to find the necessary drop test mass, m_2.

Given impact mass= m_1 = 661 lbs
Given impact velocity= v_1 = 23 ft/s
Maximum testing apparatus height= h = 7.5 ft

Energy at Impact= Kinetic Energy= $(0.5)*m_1*v_1^2 = m_2*g*h$

The necessary mass for a drop height of 7.5 ft was calculated to be 721 lbs. A mass of 732 pounds was used to compensate for the friction factor during the drop.

Drop Test Procedure



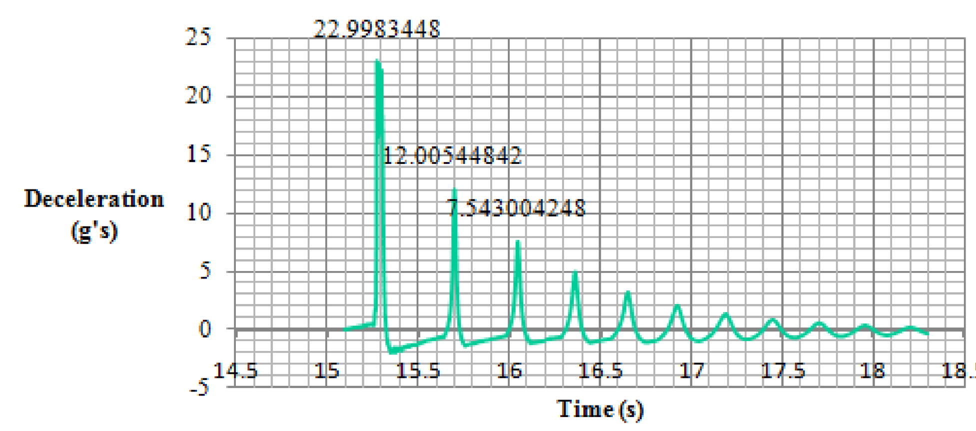
•Attached 50g and 500g accelerometers to drop tester to retrieve deceleration data

•Focused high-speed camera on impact for visible deformation observations

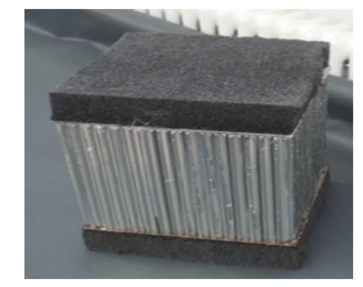
•Dropped 732 lbs from a distance of 7.5 feet from the center of gravity onto attenuator designs

Impact Test Results

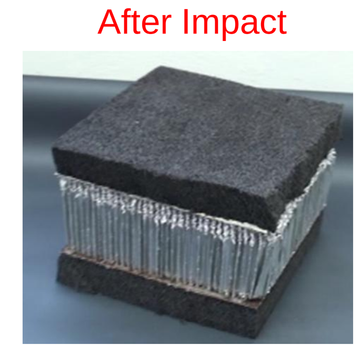
Honeycomb and Foam Data



Before Impact

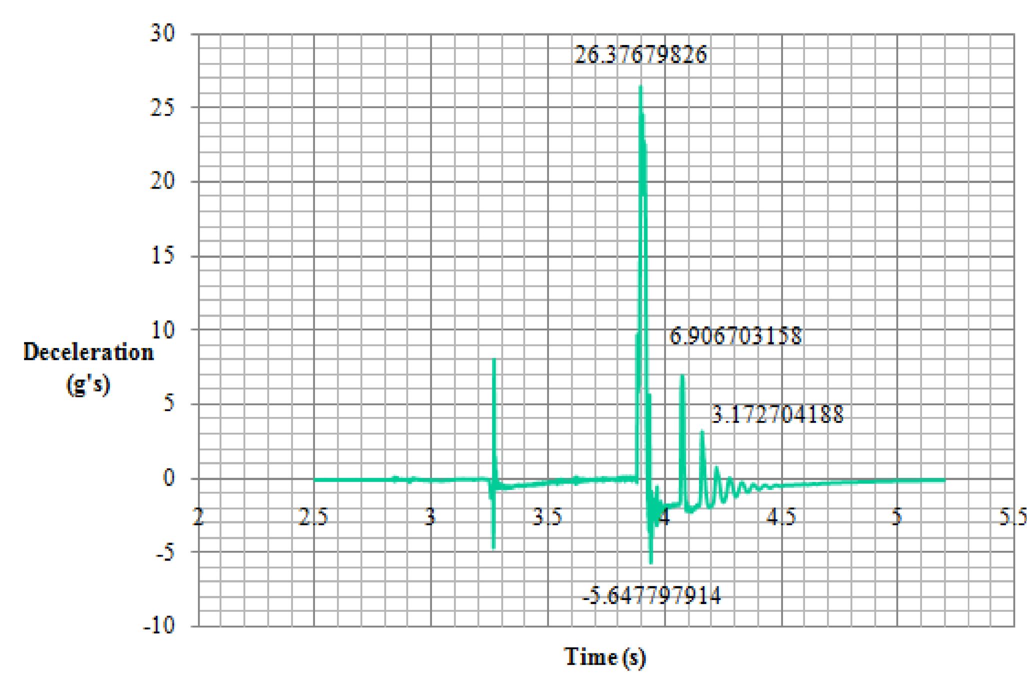


After Impact

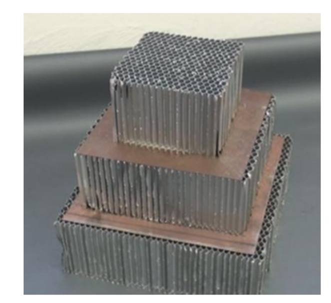


•Impact Period: 0.06 seconds
•Peak Deceleration Value: 23 g's
•Average Deceleration: 12.48 g's

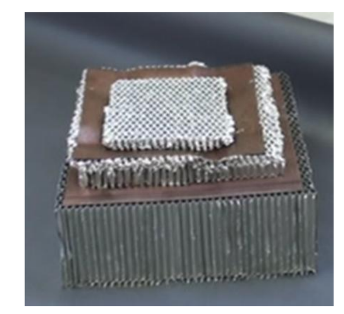
Honeycomb Pyramid Data



Before Impact



After Impact



•Impact Period: 0.04 seconds
•Peak Deceleration Value: 26.38 g's
•Average Deceleration: 14.75 g's

Conclusions and Recommendations

We have concluded that the design that best meets all the requirements is the aluminum honeycomb and foam design. Our group has made several recommendations for further attenuator design improvements:

•Use a different modeling software with dynamic impact testing.
•Use a less dense honeycomb in both designs to increase impact time and absorb more energy.
•Use a less dense foam to avoid the spring effect.
•Modify pyramid design by resizing layers to meet attenuator volume requirements.
•Perform a rolling cart impact test to better simulate an actual crash.