Crash Testing of Aluminum Honeycomb Impact Attenuator for FSAE Car

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Abstract: To meet the requirement of Formula Society of Automotive Engineers (FSAE) 2009 Rules, it is necessary to design an impact attenuator that would give an average deceleration not to exceed 20g, with a peak deceleration less than or equal to 40g, when it mounted on the front of a vehicle with a total mass of 300 kg and run into a rigid wall，with a velocity of impact of 7 m/s. Aluminum honeycomb construction has the advantage of high strength, highly impact resistant and low density. An aluminum honeycomb construction was adopted as the impact attenuator of Xiamen University of Technology (XMUT) FSAE car 2009. The crash testing was carried out for a frontal impact. Deceleration and the energy absorbed were studied. The impact attenuator attached to the front of XMUT FSAE car 2009, complies with the rules and will provide protection in the event of a collision.

Keywords: aluminum honeycomb, impact attenuator, crash testing

1 Introduction

The Formula Society of Automotive Engineers (FSAE) Series competitions challenge teams of university undergraduate and graduate students to conceive, design, fabricate and compete with small, formula style [1].

FSAE rules require attaching an impact attenuator to the front part of a formula car for safety. The function of an impact attenuator is to decelerate the car in a safe way and dissipate as much of the crash energy as possible. The average deceleration is has to be kept under a certain level and it is desirable to keep the maximum deceleration low enough to prevent damage on the structure of the car and the driver. It is important to keep the impact attenuator as light and small as possible [2]. 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 kg and run into a solid, non-yielding impact barrier with a velocity of impact of 7.0 m/s, would give an average deceleration of the vehicle not to exceed 20g, with a peak deceleration less than or equal to 40g[3].

2 Kinetic Energy Calculation

To calculate the amount of energy the impact attenuator will absorb, the total energy absorption needed was calculated using the basic equation:

$$K_E = \tfrac{1}{2} m v^2 \tag{1}$$

Where m is the mass and v is the speed of the car. In SI units, mass is measured in kg, speed in m/s, and the resulting kinetic energy is in J.

Given the requirements of stopping a mass of 300 kg moving at 7 m/s, the kinetic energy absorption is

$$K_E = \tfrac{1}{2} \times 300 \times 7^2 = 7350J \,.$$

In the crash testing, the kinetic energy of a total mass of 400 kg car moving at a velocity of 6.5 m/s is determined. The kinetic energy absorption is

$$K_{E,T} = \tfrac{1}{2} \times 400 \times 6.5^2 = 8450J > K_E = 7350 \,.$$

3 Structure of Impact Attenuator

The performances of the impact attenuator was estimated in terms of the energy absorption, cost and mass regulated in FSAE rules [4]. Research was conducted both through the Internet and through engineering texts [5]. Based on the findings of this research, aluminum honeycomb was determined to construct the impact attenuator for Xiamen University of technology FSAE car, due to its high strength, highly impact resistant and low density [6].

A design of the impact attenuator prototype used for the crash testing is a rectangular prism, with face dimensions of 200 mm and 100 mm, and a length of 200 mm (Fig.1), which are the minimum detentions of impact attenuator given by FSAE 2009 rule. Table 1 shows structure of the aluminum honeycomb core material 3003-h18 which was used in testing. Table 2 shows the mechanical properties of the aluminum honeycomb core material 3003-h18, which was provided by the manufacturer.

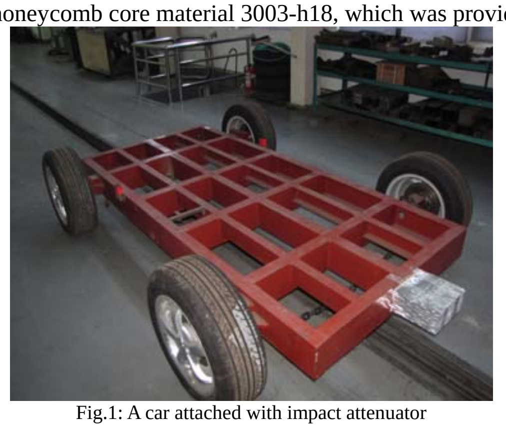

Fig.1: A car attached with impact attenuator

Table 1: Structure of aluminum honeycomb core material 3003-h18

L /mm	H /(mm)	W /(mm)	t /(mm)	α /(°)	d/mm
200	200	100	0.07	120	4

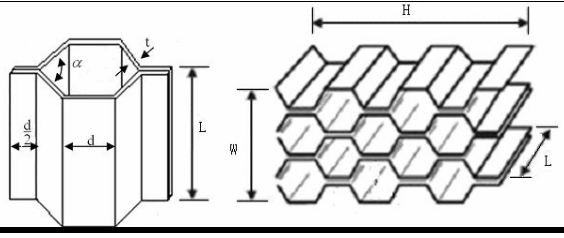

Table 2: Mechanical properties of the aluminum honeycomb core material 3003-h18

Yield stress / (MPa)	Ultimate stress /(MPa)	Young's modulus/ (MPa)	Core density /(kg/m3)	Elongation /(%)	Poiss Ratio
186	200	69000	62.6	1204	0.33

4 Testing Methodology

In order to prove compliance with FSAE2009 rule, test had to be performed on the aluminum honeycomb impact attenuator. The crash test was undertaken in State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body of Hunan University. A total mass of 400 kg car mounted with impact attenuator run into a rigid wall with a velocity of 6.5 m/s (Fig 2).

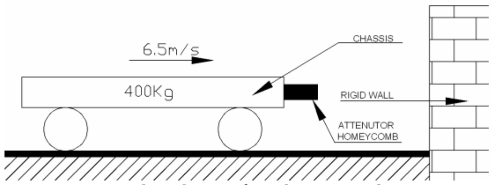

Figure 2: The scheme of crash test in L-direction

5 Results

A computer operated data acquisition system was used to monitor the deceleration and time during the crash testing. The sampling frequency of data acquisition system is 10000Hz. The total energy absorbed by the full-scale mockup was 8450, well above the required 7350 J. Figure 3 shows the structure of aluminum honeycomb impact attenuator after crash testing.

Figure 3: The structure of impact attenuator after crash testing

According to the FSAE Rules, when using acceleration data, the average deceleration must be calculated based on the raw data. The peak deceleration can be assessed based on the raw data, and if peaks above the 40g limit are apparent in the data, it can then be filtered with a 100 Hz, 3rd order, lowpass Butterworth (-3dB at 100 Hz) filter.

The results of raw data of the crash testing can be seen in Figure 4. The average deceleration calculated based on the raw data is 11.79g, so it satisfies the requirement of 20 g.

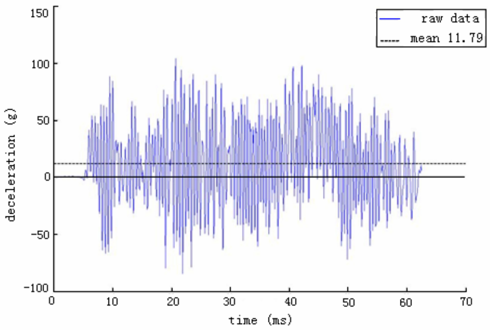

Figure 4: Deceleration versus time (raw data)

The results of raw data filtered with a lowpass Butterworth (-3dB at 100 Hz) filter can be seen in Figure 5. The maximum deceleration is 39.24g, so it meets the requirement of 40 g.

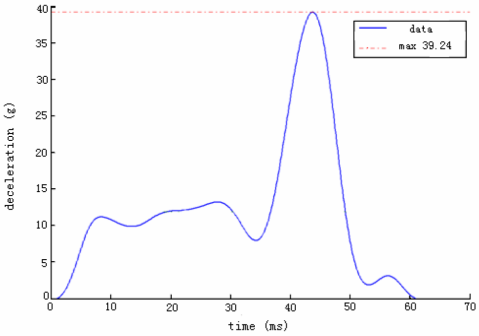

Figure 5: Deceleration versus time.

Based on the results of the crash testing, it was determined that an aluminum honeycomb impact attenuator, with a width of 200 mm, a height of 200 mm and a length of 200 mm was attached to the front of XMUT FSAE car 2009(Fig 6). This complies with the 2009 FSAE Rules and will ensure adequate energy absorption and provide protection in the event of a collision.

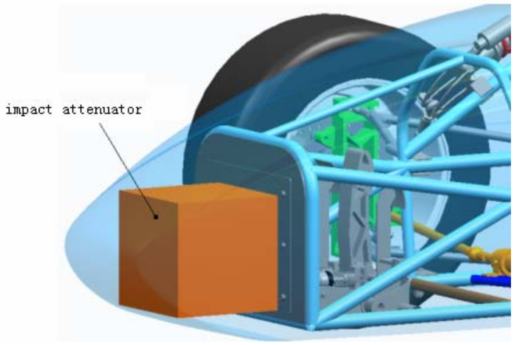

Figure 6: Impact attenuator CAD model

6 Conclusion

The present paper describes an experimental investigation of aluminum honeycomb impact attenuator. The crash testing is performed measuring the deceleration and the energy absorbed by the structure. Based on the results of the crash testing, the final design of impact attenuator was determined. The impact attenuator installed forward of XMUT FSAE car 2009 complies with the rules. XMUT formula team has successfully scored in all events of FSAE California 2009 and achieved 23rd in the overall results.

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Reference

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