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CRASH TEST OF THE STUDENT RACING CAR IMPACT ATTENUATOR

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Abstract
The student formula SAE [1] is the international competition for university student design teams. Each team must design and build its own racing car and then participates in international races. Strict rules are set for its design and great emphasis is placed on the safety of the driver. Therefore, every race car must be equipped with an impact attenuator in the front and it must meet the prescribed rules for the energy absorption in the crash event. Testing of the impact attenuator for a racing car that is built by the student team of the Technical University of Liberec is described in this article.

Key words: *crash test; impact attenuator; student racing car; testing device.*

INTRODUCTION

The student formula SAE organization was founded in 1981 in the United States and now brings together around 120 student design teams from universities all around the world. The team of the Technical University in Liberec joined this organization last year. Each team must demonstrate the ability to build a single-seat racing car of its own design, which will be well-handled, efficient, reliable, safe and environmentally friendly. Emphasis is also placed on aesthetic properties and the lowest production cost. Then each team can participate in competitive events all around the world. Races are divided into static and dynamic disciplines, from which the team gets a certain number of points. The winner will be the one who gets the most out of 1,000 possible points. In the first phase of static disciplines, each team presents the engineering design and maturity of the technical side of their design before a professional jury. The second part of the entrance presentation is the successful passing of safety tests, which is a necessary condition for participation in the following dynamic disciplines. The safety of the driver is most important, so every race car must be equipped with an impact attenuator in the front and it must meet the prescribed rules for energy absorption in the crash event. The used impact attenuator functionality has to be verified by a real crash test.

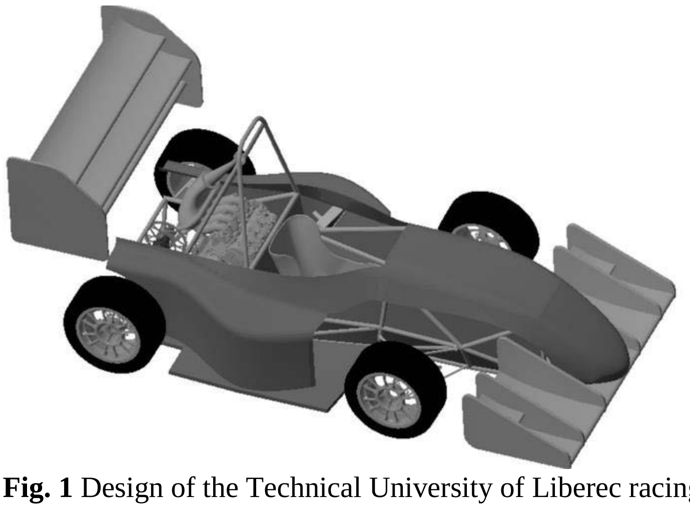

Fig. 1 Design of the Technical University of Liberec racing car

Crash tests are generally very expensive and this is in contrast to the requirement for a minimum price for a racing car. The student team did not first know where such a test could be done. It finally succeeded in Laboratory of Applied Mechanics at the Technical University of Liberec. It was big challenge for a laboratory staff and the student team to carry out this difficult test with minimal resources and moreover in a short term because the first race in Italy was approaching.

MATERIALS AND METHODS

Many parameters determine the impact attenuator dimensions, properties and location in the car. Of course, its dynamic properties are also prescribed and these are shown in the Table 1.

Tab. 1 Basic requirements for the impact attenuator crash test

Minimal impact attenuator absorbed energy	7350 J
Maximum value of the deceleration peak	40 g (392.4 ms^{-2})
Maximum average deceleration value	20 g (196.2 ms^{-2})
Maximum safety zone wall deflection	25 mm

After considering these test parameters and laboratory options, it was decided to carry out a crash test using the mass free fall. It was a very cheap and fast-realizable solution because a 4 m high portal crane is available in the lab. The real free fall height could be about 2.5 m because approximately 1.5 m was considered for the mass, its anchoring and the tested impact attenuator. The theoretical impact velocity v (if friction is neglected) for height h can be calculated using the classic Newtonian mechanics [2] by the next Equation 1.

$$v = \sqrt{2 * g * h} = \sqrt{2 * 9.81 * 2.5} \cong 7 \ [ms^{-1}] \quad (1)$$

The weight of the mass was determined from this velocity and the required impact energy according to Equation 2.

$$m = \frac{2*E}{v^2} = \frac{2*7350}{7^2} = 300 \ [kg] \quad (2)$$

Absolutely free fall of 300 kg mass from 2.5 m height would be very dangerous, because the mass movement after impact would be undefined. Therefore, a simple fall tower was built. The moving table was guided by four guide rods anchored to the base plate. Six 52 kg cast iron weights (which are available in the laboratory) were attached on this table, so the total weight (including the table) of the falling mass was 345 kg (see Fig. 2 left). For this weight the theoretical starting height was recalculated to 2.17 m (Eq. 2). The lower impact velocity due to friction at the guide bars was measured during first functional tests. In order to keep the impact speed, the starting height was gradually increased to 2.4 m. The rapid release of the moving table after its lifting by the crane was finally accomplished by burning the anchor rope with a small gas burner. Due to the small number of tests, it was again a very cheap and efficient solution, no trigger mechanism had to be proposed.

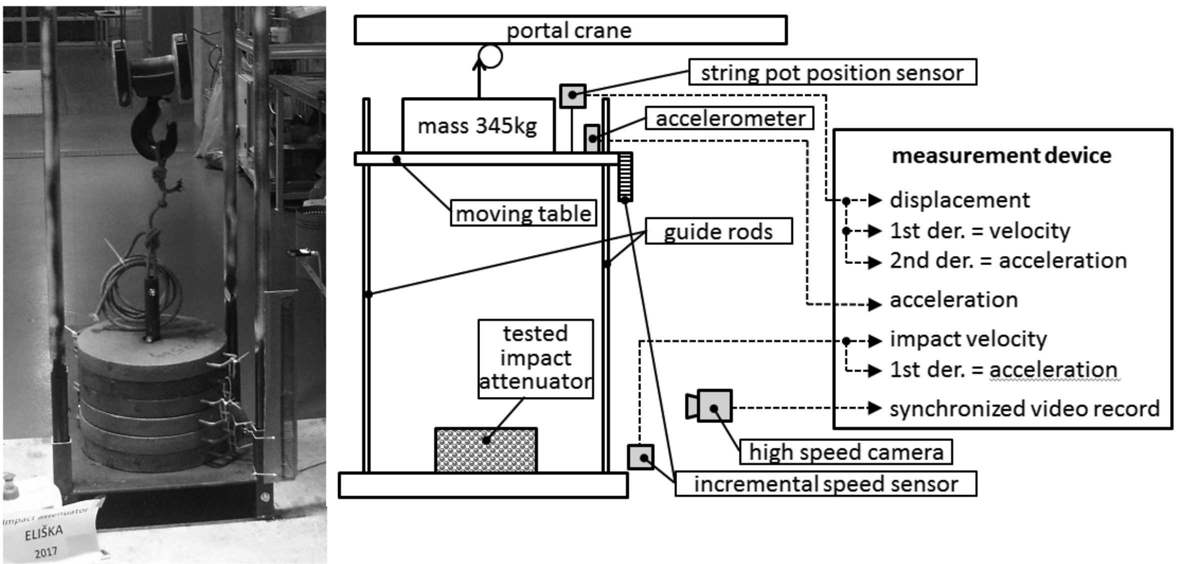

Fig. 2 The testing device real implementation (left) and its block scheme (right)

The moving table displacement was measured by the string pot position sensor, velocity and acceleration were calculated by the first and second derivations of this signal. Acceleration was further measured by a separate accelerometer and the final impact velocity by another incremental speed sensor. Acceleration was again calculated by deriving this signal. So the important signals measurement has been ensured several times. The crash test was also captured by the high speed camera. All sensor signals and the camera were connected to the Dewe5000 measurement device [3], which performed synchronic data and images recording. The sampling frequency was 5 kHz for the sensor signals and 600 Hz for the video.

RESULTS AND DISCUSSION

The impact attenuator is composed from two parts, the absorption and safety zones, their minimum dimensions are again given by the SAE. The absorption zone is deformed during the impact, absorbs the impact energy and reduces the deceleration peak. The safety zone must not be broken in the crash event (it protects the driver's legs), only its wall below the deformation zone may have a small deflection.

The student team designed the absorption zone from three layers of aluminium honeycomb panels [4] in two variants of their composition – cubic and pyramidal (see Fig. 3). They preferred the second solution because it was more convenient for installation to the car.

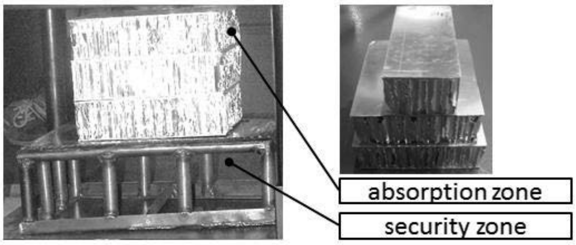

Fig. 3 The impact attenuator design, cubic composition left and pyramidal right

Because only one security zone part was made, two variations of the absorption zone without the security zone were first tested to verify their properties. So, security zone remained intact for the final test. These two measurement results are summarized in the Figure 4.

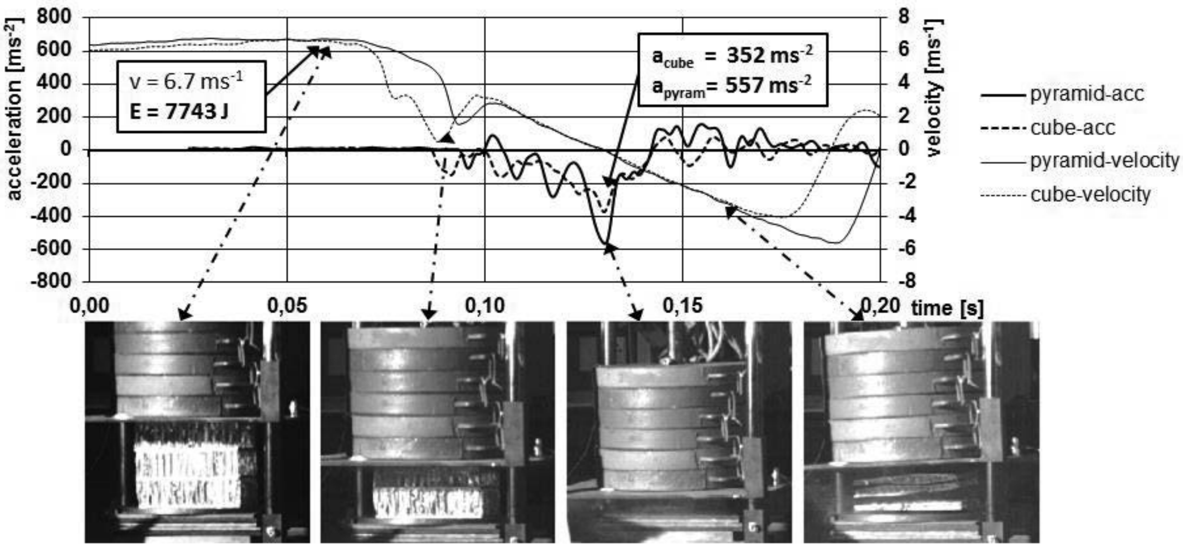

Fig. 4 Comparison of the cubic and pyramidal absorption zone

The impact velocity was 6.7 ms^{-1}, the impact energy 7743 J. The acceleration waveforms show that the pyramidal composition did not meet the requirement because its deceleration peak was 557 ms^{-2} (56.7 g). The area of the pyramid top part was too small. In contrast, the cubic composition meets the SAE requirement, the deceleration peak was less than 40 g.

So, the pyramidal solution was abandoned and the final impact attenuator was assembled with the cubic absorber. Its test is shown in the Figure 5. The impact velocity was 6.9 ms^{-1} and the impact energy 7743 J. The impact attenuator met all the requirements. The safety zone was not broken and its wall deflection measured after the test was only 15 mm. The maximal deceleration peak was 276 ms^{-2} and it is less than in the only deformation zone test because the peak size was reduced by the small deflection of the safety zone wall. All test results are summarized in the Table 2.

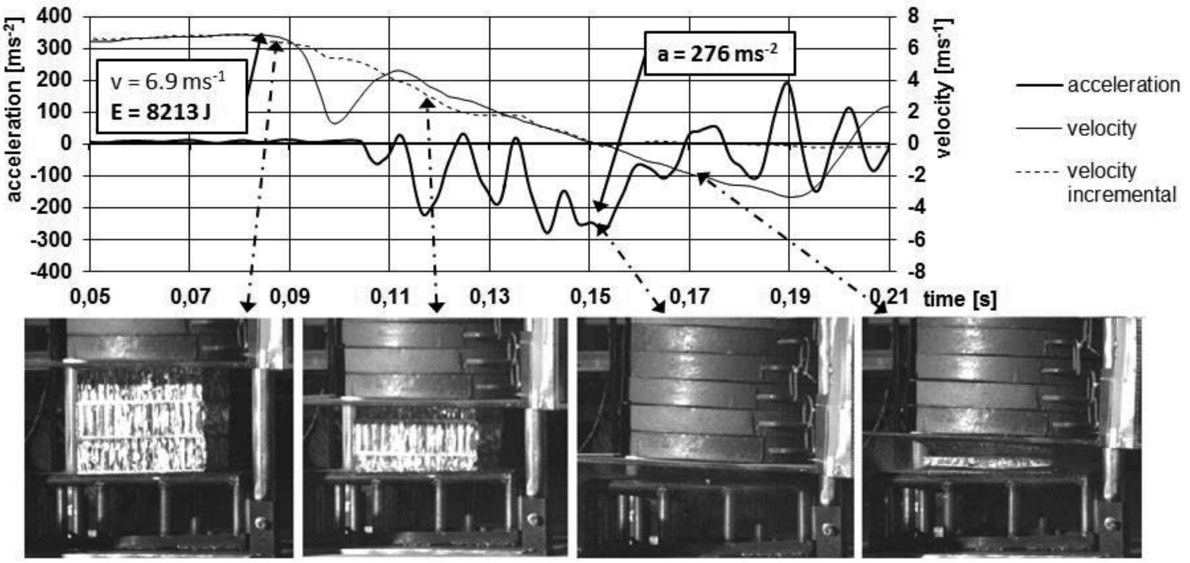

Fig. 5 The impact attenuator test

Tab. 2 The impact attenuator crash test results

Requirement	Criterion	Measured value	Status
Impact attenuator absorbed energy [J]	7350	8213	Passed
Value of the deceleration peak [ms^{-2}]	392.4	276	Passed
Average deceleration value [ms^{-2}]	196.2	115.8	Passed
Safety zone wall deflection [mm]	25	15	Passed

CONCLUSIONS

The team of students and laboratory staff of the Technical University of Liberec managed to design and manufacture test equipment and implement the required impact attenuator crash test in a very short time (only five days from the first idea to the final test). Also the price was minimal, only the material for the guide rods had to be bought. Everything else, including sensors and measuring device, was available in the lab.

The impact attenuator final version with the cubic absorber met all SAE requirements and it was built into the student racing car that was then entered into the race. So good luck!

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