Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Investigation of the Energy Absorption of the Aluminium Foam

To cite this article: József Kertész *et al* 2022 *J. Phys.: Conf. Ser.* **2315** 012026

View the article online for updates and enhancements.

You may also like

- Influence of specimen dimensions on ductile-to-brittle transition temperature in Charpy impact test
S Rzepa, T Bucki, P Konopík et al.

- Impact and hardness optimisation of composite materials inspired by the babassu nut (*Orbignya speciosa*)
Gerrit Staufenberg, Nina Graupner and Jörg Müssig

- Development of advanced high heat flux and plasma-facing materials
Ch. Linsmeier, M. Rieth, J. Aktaa et al.

This content was downloaded from IP address 89.135.109.116 on 30/07/2022 at 11:55

Investigation of the Energy Absorption of the Aluminium Foam

József Kertész[1], Zoltán Nyikes[2], Péter Pinke[3], Tünde Anna Kovács[3*]

[1] Doctoral School on Safety and Security Sciences, Budapest, Hungary
[2]Milton Friedman University, Budapest, Hungary
[3] Óbuda University, Budapest, Hungary

*E-mail: kovacs.tunde@uni-obuda.hu,

Abstract. To assure safe traffic is a goal of the vehicle manufacturers. The car body elements are usually made from high plasticity metals whiches can deform in the case of an accident. By this deformation way, the car body absorbs the collision energy. Aluminium foam is a special material that can absorb impact energy. The authors wanted to find a rapid and simple test method to investigate the dynamic load effect for the aluminium foam. The Charpy impact test is a suitable and standardized impact test to determine the absorbed energy of the material during the fracture. In this research, the aluminium foam was tested by the Charpy impact test and compared the results with literature data to evaluate the used impact test.

1. Introduction

High energy absorption is very important in the collision zone of vehicles, which protects the driver and passengers of the vehicle from harmful dynamic effects [1]. However, several aspects need to be considered in the energy absorption capacity of the collision zone increasing. A collision is a physical process in which two vehicles make contact with each other, the participants in the collision transfer energy to each other and deform depending on the kinetic energy of the vehicles. The collision time is very short and involves many processes. In the event of a vehicle collision, the kinetic energy is absorbed by the permanent deformation of the vehicle equipment. There is no significant difference between a vehicle collision with a stationary vehicle or colliding with an oncoming vehicle. In the case of the material selection, important aspects are the cost and weight.

Figure 1. Open-cell aluminium foam [5]

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

Steel production has developed significantly over the past decade, enabling the automotive industry to use high-strength steels and thin plates [2]. However, this is not enough to provide adequate protection in the event of a collision. The production and distribution of aluminium foams offer new opportunities. It can find different kinds of aluminium, like open cell and closed cell aluminium foams. Aluminium foam is a new kind of structural material with several great properties. On the base of the porosity, it can split the foams into two groups, like open-cell foams and closed cell foams. Open-cell aluminium foam is an aluminium foam with contiguous inner pores with a pore size of 0.5-1.0 mm (Fig.1.) [5]. Due to its porous structure, aluminium foam can be used as a noise-reducing material because of its excellent sound absorption, fire resistance, dust resistance, environmentally friendly and water-resistant.
In the case of closed-cell aluminium foam, the pores are not connected; while in the case of an open cell, the pores are connected.

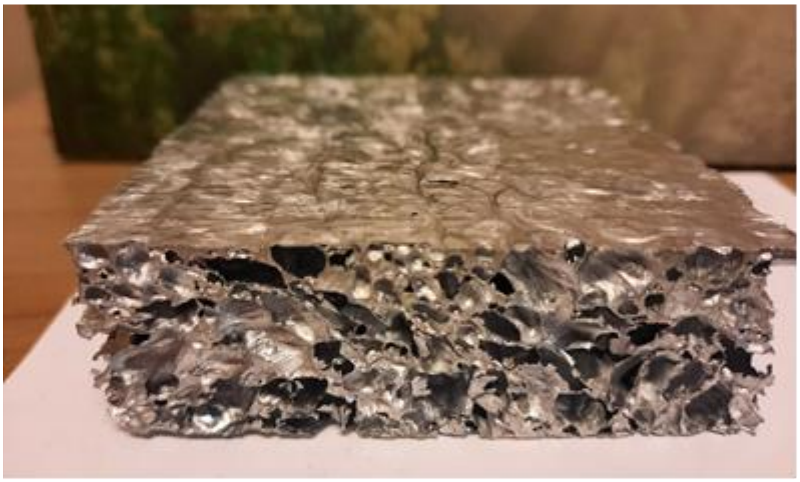

Figure 2. Closed-cell aluminium foam

The porosity is usually 5-10 mm in size and has a density of 0.25-0.85 g/cm^3. Its energy absorption depends on its density [5]. The picture of the used closed-cell aluminium foam can see in Fig. 2. and Fig.3.

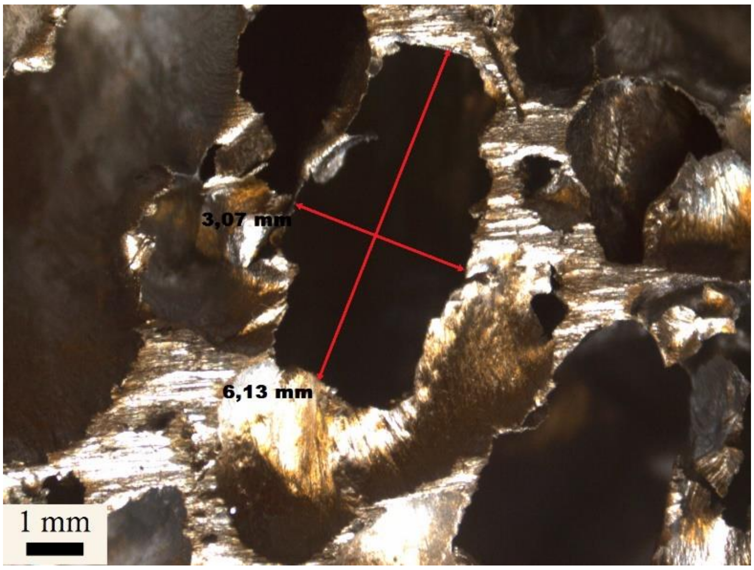

Figure 3. Closed-cell aluminium foam porosity sizes (example)

Some of the closed-cell aluminium foam mechanical properties as a function of the density can see in Tab.1. [5].

Table 1. Some of the closed-cell aluminium foam mechanical properties [5]

Density (g/cm^3)	Pressure strength (MPa)	Bending strength (MPa)	Energy absorption ability (kJ/m^3)
0.25~0.30	3.0~4.0	3.0~5.0	1000~2000
0.30~0.40	4.0~7.0	5.0~9.0	2000~3000
0.40~0.50	7.0~11.5	9.0~13.5	3000~5000

The energy absorption ability determination method is not defined in the referred literature. Several experimental results can find, that the energy absorption increases with the density increasing [6-8]. The energy absorption ability depends on the density but also depends on the porosity parameters, like porous sizes and the porous wall thickness [9-12].

2. Materials and experiments

The density of the used aluminium foam was calculated from the aluminium foam weight m=70,4023g, and volume V=8,7x8x2,57= 178,872cm^3 (1):

$$\rho = m/V = 0{,}394\ (g/cm^3) \tag{1}$$

The used aluminium foam energy absorption ability (from Tab.1.) is about the literature data 3000kJ/m^3 [5]. The Charpy impact test is suitable to determine the energy absorption of the materials.

2.1. Modified Charpy test

The used aluminium foam test sample size 10x25,7x55 mm, the used Charpy impact test machine was a (see Fig.4.) 4J impact energy tester. The mass of the hammer was m=1kg and its start position high was h=40 cm. The collision rate is determined by the next equations E kinetic energy (2), velocity of the hammer (3);

Figure 4. The used Charpy impact tester

$$Ec = mgh = \frac{mv^2}{2} = 4\text{ J} \quad (2)$$

$$v = \sqrt{2gh} = \sqrt{2 * 9.807\frac{m}{s^2} * 0.4m} = 2.8\frac{m}{s} \quad (3)$$

In the case of the metal foams, this process with the standard test sample (10x10x55 mm) can't give useful results. It was made some tests with the standard size of the foam test sample, but the results were unmeasurable. These experimental results show that it can find a minimal thickness whiches is useful for the impact test.

It was modified the test samples size to earn valuable results. The amount of absorbed energy by the aluminium foam during fracture is determinable from the used hammer parameters and the test sample geometry. The modified test sample size was 10x25,7x55 mm.

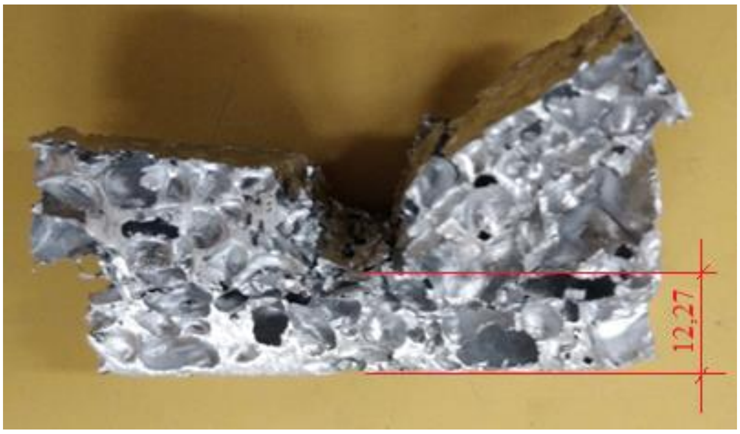

Figure 5. The modified test sample after the Charpy test

The base of the modified test sample design was the standard test sample sizes and the literature suggestion about the energy absorption ability results [9-12]. The Charpy test, was made on 5 equal geometry test sample. The used test samples did not fracture. The used test samples showed plastic deformation under the test load.

Table 2. Charpy test results

Test number	**Deformation deepth**
1	13,40 mm
2	13,42 mm
3	13,45 mm
4	13,49 mm
5	13,41 mm
Average	13,434 mm

The average deformation depth was 13,43mm and the average residual undeformed thickness was 12,27mm (Fig.5.). The absorbed energy is calculated from the deformed volume of the foam. The deformed volume (V) was determined from the geometry of the deformation (Fig.6.) and the thickness (S=10 mm) of the tested sample (4).

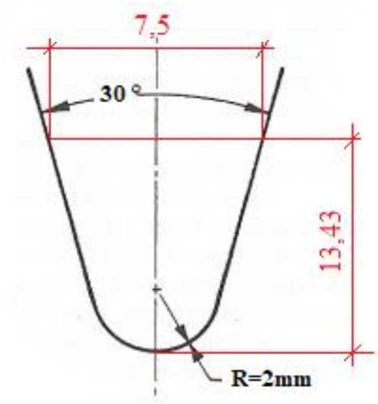

Figure 6. The deformed area front view

The deformed volume, where A is the penetration area (Fig.6.) and s is the test sample thickness:

$$V = A \cdot s = 695 mm^3 \quad (4)$$

The maximal energy of the used Charpy is E_c=4J, because the hammer was stopped by the test sample. The energy absorption ability E_a (kJ/m^3) of the tested aluminium foam can determine by equation (4):

$$E_a = \frac{Ec}{V} = \frac{4J}{695\ mm^3} = 5755\,\frac{kJ}{m3} \quad (5)$$

The tests resulted absorbed energy E_a of the used aluminium foam calculated by the equation (5) is 1,91 times bigger than the literature suggested results energy absorption ability for the used aluminium foam.

3. Results and discussions

It was concluded that the aluminium foam deformation was limited under the impact load, only an average half of the foam thickness deformed. The test result of the standard Charpy test sample was unmeasurable because the test sample didn't show any deformation. The modified test sample showed high energy absorption and deformation in the limited thickness of the test sample. The tested aluminium foam density 0,394 (g/cm^3) and the calculated energy absorption was 5755 kJ/m^3. It can conclude that in the case of the used Charpy method can be useful for the determination of the metal foam energy absorption ability determination, but it needs to define a suitable geometry because the result depends on the thickness of the test sample. Also, it needs to define a correction coefficient because the density of the aluminium foam is not enough to determine the energy absorption ability, the porosity size and the wall thickness of the porous are also important. To determine a suitable equation for the energy absorption ability it needs to determine the suitable test sample and the correction coefficient as a function of the aluminium foam structure by several experimental tests.

Acknowledgement

The authors would like to thank the Hungarian State, National Research, Development and Innovation Office for their support in project No. 2020-1.1.2-PIACI-KFI-2020-00081. The authors also want to tell thanks to Andor János Kovács BSc student who participated in the research project and shared his investigation results.

References

[1] Paul D B et al Vehicle 2004 Crashworthiness and Occupant Protection, *American Iron and Steel Institut 2000 Town Center Southfield*, Michigan 48075 USA. www.autosteel.org

[2] The Aluminium Automotive Manual Version 2013 *European Aluminium Association* https://www.european-aluminium.eu/resource-hub/aluminium-automotive-manual/
[3] Kajtár L 2004 Autóiparban felhasznált nagyszilárdságú acélok *Nagyszilárdságú acélok melegalakítása* Miskolci Egyetem Gépészmérnöki és Informatikai Kar (in Hungarian)
[4] Miller W S et al 2000 *Materials Science and Engineering* **280** (1). 37-49 ISSN 0921-5093 doi: 10.1016/S0921-5093(99)00653-X.
[5] https://www.metalfoamweb.com/aluminum-foam/open-cell-aluminum-foam
[6] Ashby M F 2000 Metal Foams: A Design Guide *Elsevier* US,Oxford
[7] Gibson L J and Ashby M F 1997 Cellular Solids: Structure and Properties *Cambridge University Press* Cambridge New York
[8] Mukai T et al 1999 *Scripta Materialia*, **40** (8), 921–927. doi:10.1016/s1359-6462(99)00038-x
[9] Yu H et al 2007 *Materials Science and Engineering: A* 454-455, 542–546. doi:10.1016/j.msea.2006.11.091
[10] Damghani M Gonabadi M 2016 Investigation of Energy Absorption in Aluminum Foam Sandwich Panels By Drop Hammer Test: *Experimental Results, Mechanics, Materials Science & Engineering* https://hal.archives-ouvertes.fr/hal-01508653
[11] Hassanli F Paydar M H 2021 *Journal of Materials Research and Technology* **14** 609–619 doi:10.1016/j.jmrt.2021.06.073