Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 167 (2016) 23 – 29

Procedia Engineering

www.elsevier.com/locate/procedia

International Symposium on Dynamic Response and Failure of Composite Materials, DRAF 2016

# Infrared thermography to an aluminium foam sandwich structure subjected to low velocity impact tests

C. Meola, S. Boccardi, G. Petrone, N.D. Boffa, F. Ricci, G.M. Carlomagno

Department of Industrial Engineering – Aerospace Section,
University of Naples "Federico II", via Claudio 21, 80125 Naples, Italy

**Abstract**

This work is the straightforward continuation of previous ones in which vibro-acoustic characteristics of AFS panels were investigated both numerically and experimentally. Herein, the use of infrared thermography (IRT) is exploited to investigate impact damaging of an aluminium foam sandwich panel by monitoring its surface, opposite to the impact, during a low velocity impact test, which is performed with a modified Charpy pendulum. Thermal images, acquired in time sequence during the impact by the infrared camera, are post-processed to get information useful for understanding absorption capabilities and impact damaging mechanisms of this kind of structure.


Peer-review under responsibility of the Organizing Committee of DRaF2016

*Keywords:* Impact; sandwich structures; metal foam; infrared thermography

## 1. Introduction

Sandwich structures are increasingly used in an a more and more wide number of application fields such as transport industry, civil infrastructures, chemical equipment; this because of their high strength-to-weight ratio, easy formability, and other properties that make them preferable to conventional engineering materials.

Aluminum foam sandwiches (AFS) [1,4], obtained by combining metal face sheets with a lightweight metal foam core, have peculiar properties (low specific weight, efficient capacity of energy dissipation, high impact strength, acoustic and thermal insulation, high damping), that make them interesting for a number of practical applications, such as the realization of lightweight structures with high mechanical strength and good capacity of energy dissipation under impact. In fact, sandwich structures have so far shown good capabilities in absorbing energy in response to collision and crash events, which are very important for high speed terrestrial and marine


Peer-review under responsibility of the Organizing Committee of DRaF2016
doi:10.1016/j.proeng.2016.11.665

vehicles. Then, it is necessary to acquire a better knowledge concerning the impact behavior of structural parts, built up resorting to sandwich technologies.

Core deformation and failure are decisive factors for the energy absorption capabilities of sandwich structures. After the impacting object has fractured the skin, it may penetrate into the core and damage it. With aluminum honeycomb cores, damage consists of crushing or "buckling" of cell walls in a region surrounding the impact point, while, in foam cores, damage looks more like a crack for low-energy impacts [5].

The attention of this work is focused on the use of infrared thermography (IRT) to investigate impact damaging of metal sandwich structures. It has been already demonstrated the usefulness of an infrared camera to monitoring the impact event of structures made of composite material [6,7]. The intention, now, is to apply infrared thermography also to AFS, attempting to gain more information on the role played by metal foam as energy absorber.

## 2. Experimental investigations

The Aluminium Foam Sandwich (AFS) panel under investigation has been manufactured by the Austrian company Mepura Metallpulver GmbH with the commercial name Alulight. As depicted in Fig. 1, the AFS panel consists of a three-layer composite: two external face sheets made of aluminium alloy and an internal core layer made of foamable aluminium alloy sheet (containing TiH2 as a blowing agent) .

The total thickness of AFS panel is 10mm: the foam thickness is 8mm, each of the two external layers is 1mm thick and the average cell size of the foam bubbles is about 2 mm.

**Fig. 1.** Aluminium foam sandwich panel.

Impact tests are carried out at different energies (from 3.6 J up to 39 J) with a modified Charpy pendulum available at the Laboratory of the Department of Industrial Engineering of the University of Naples Federico II. The pendulum consists of a hammer, which has hemispherical nose 12.7 mm in diameter and a specimen lodge with a window 12.5 cm x 7.5 cm to allow for the contact with the hammer from one side and optical view (by the infrared camera) from the other one. Therefore, the infrared camera views the surface opposite to impact and acquires thermal images in time sequence at frame rate fr = 960 Hz.

The first image (t = 0) of the sequence, i.e. the specimen surface at ambient temperature before impact, is subtracted to each subsequent image so as to generate a map of temperature difference ΔT:

$$\Delta T(i,j,t) = T(i,j,t) - T(i,j,0) \quad (1)$$

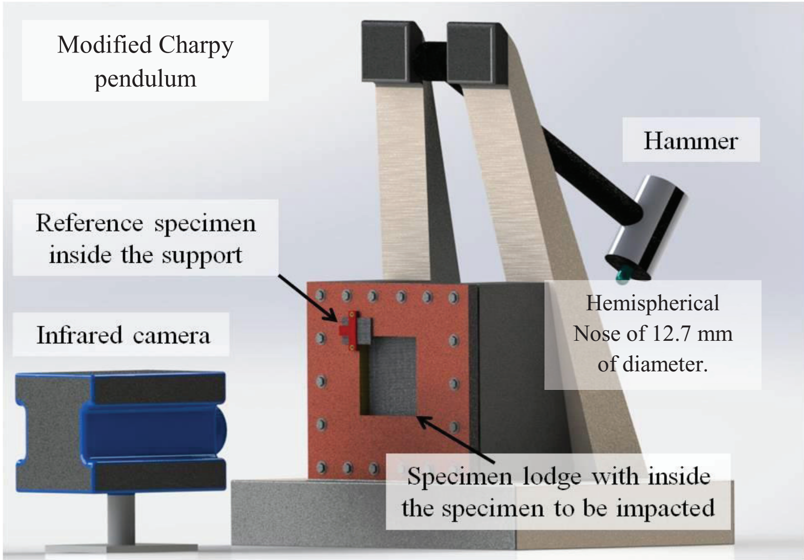



**Fig. 2.** Test set-up: Charpy pendulum and position of the infrared camera.

## 3. Results and Discussion

Some ΔT images, at different times, of the AFS specimen impacted at E = 3.6 J are shown in Fig. 3. As it can be seen, before impact (t = 0 s), ΔT attains an almost uniform zero value while a dark (cool) zone appears soon after wnich is followed later by the appearance of some light (hot) spots/areas. It is worth remembering that dark tones mean cooling down linked to thermo-elastic effects, while light tones mean heating up linked to thermo-plastic effects [6,7]. On the whole, the behavior under impact of this type of material for the two energy levels is similar, showing first cooling down and appearance of hot spots/areas after. However, to a deeper view, some differences can be recognized, which mainly regard the importance of the occurred damage. To this end, some ΔT images are compared in Fig. 4 for the two above mentioned impact energies. As it can be seen, both the darker stain at t = 0.003 s and the hotter one at t = 0.055 s widen and strengthen up for increasing the impact energy meaning that the material is undergoing larger bending with most important damage. For more details, a visible image and a thermal one with ΔT profiles along x and y directions are supplied in Fig. 5 for E = 3.6 j and in Fig. 6 for E = 39 J. It is possible to see the higher ΔT value attained for E = 39 J as consequence of dissipation of the higher absorbed energy which, on the other hand, caused the material deformation that is clearly distinguishable in the visible image.

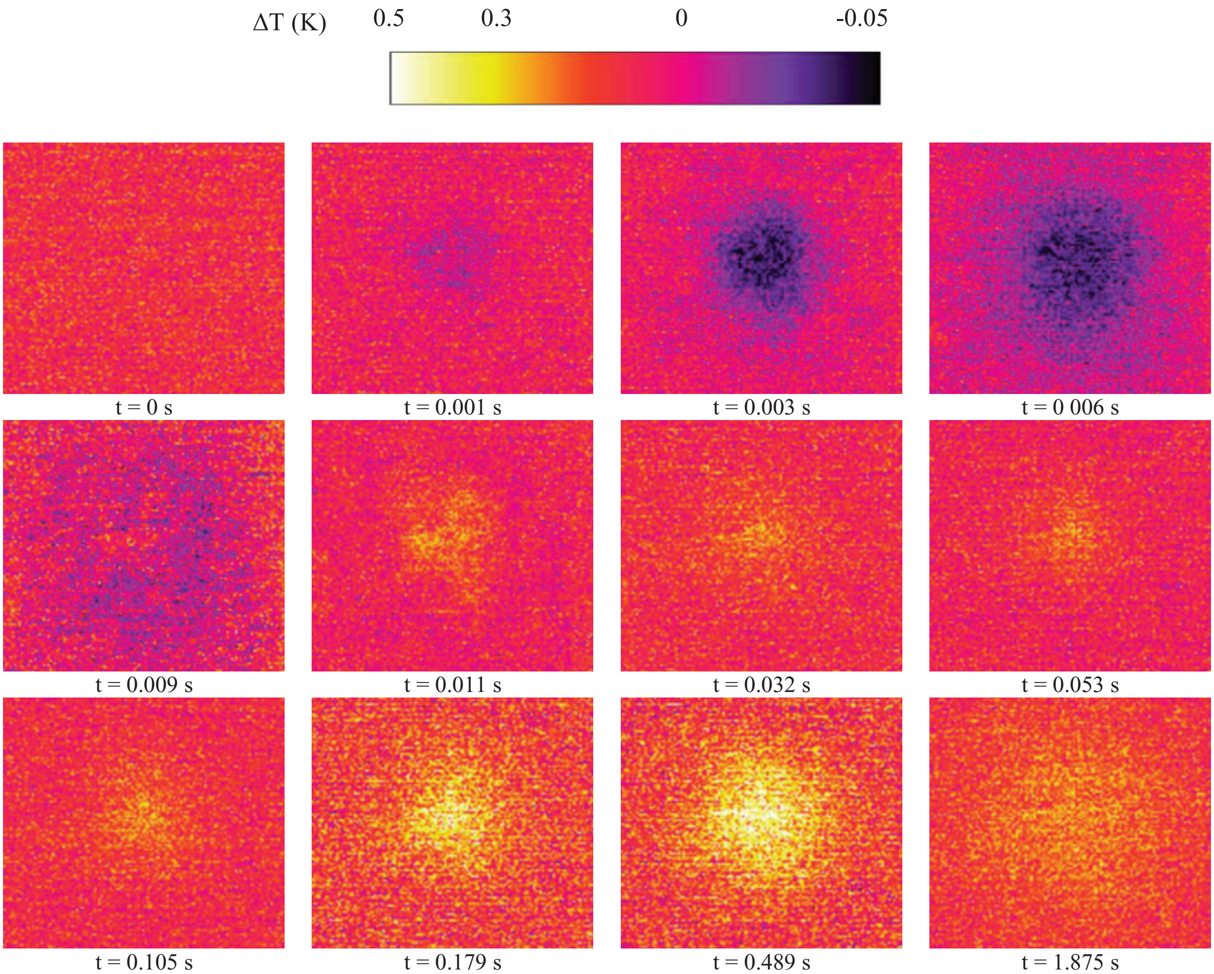
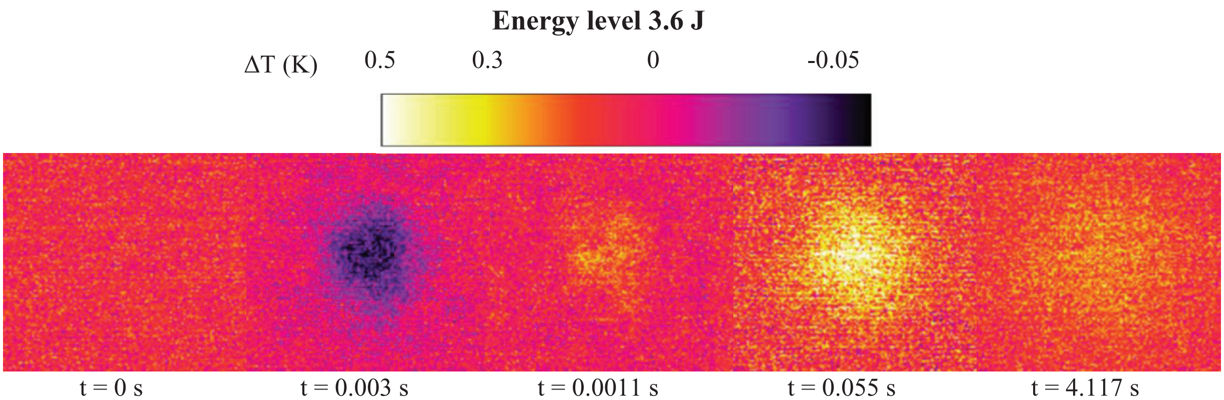



**Fig. 3.** ΔT images at different times for impact energy E = 3.6 J.



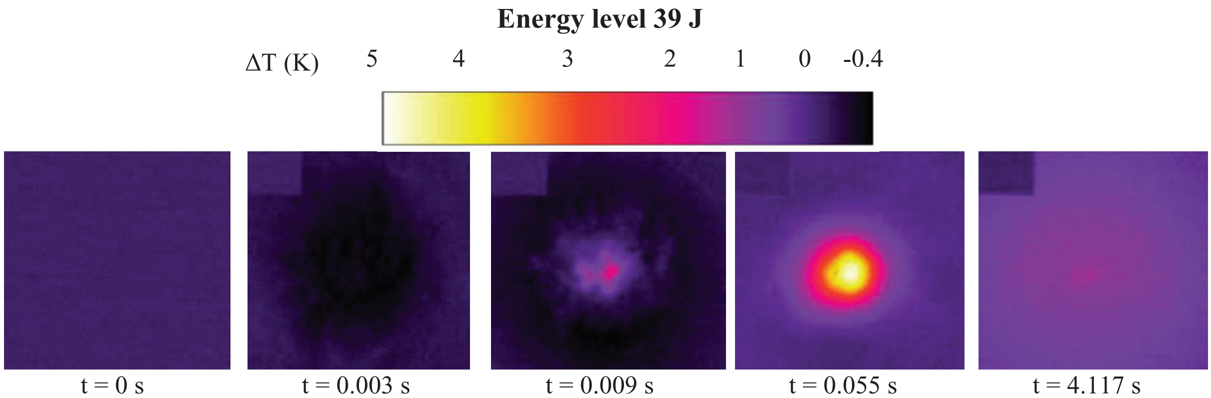
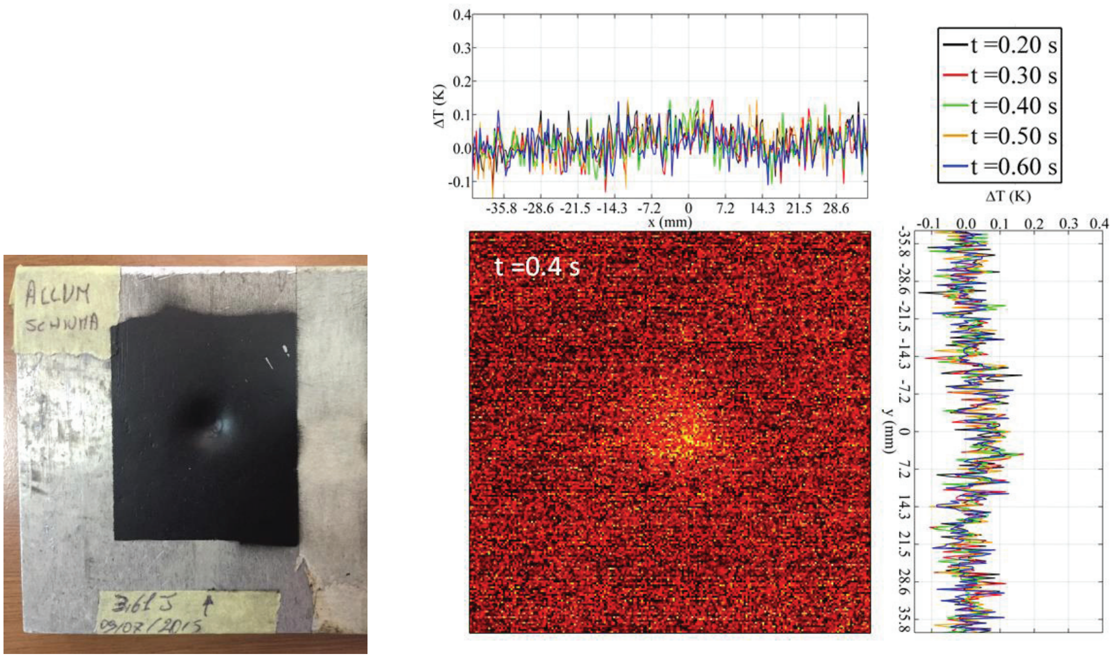
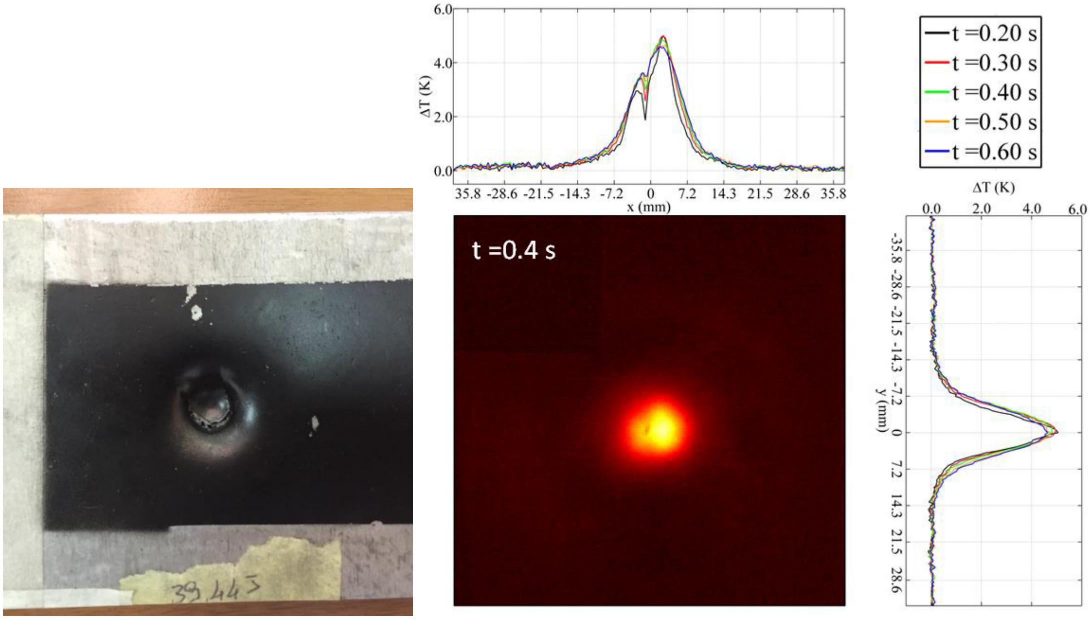



**Fig. 4.** Comparison of ΔT images for lowest ($E$=3.6J) and highest ($E$=39J) impact energy levels




a) visible image b) thermal image

**Fig. 5.** Visible (a) and ΔT image (b) with plots along x and y directions for impact (E) pairs to 3.6 J.



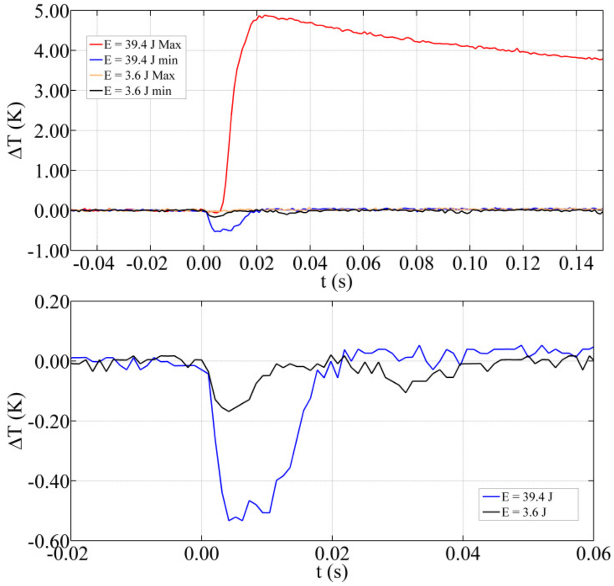

a) visible image b) thermal image

**Fig. 6.** Visible (a) and ΔT image (b) with plots along x and y directions for impact (E) pairs to 39 J.

Apart from the description till now done, it is possible to gain more useful information through post-processing and further analysis of the thermal images acquired during impact,. As a main feature, the temperature rise under impact can be regarded as a key parameter to understand what is happening to the material, in terms of cracks formation, buckling, debonding, etc, on the side opposite to the impacted one.

In Fig. 7, time plots of maxima and minima ΔT appearing on the AFS panel for two different impact energy levels are reported. As it can be seen, the trend of the two minima curves is the same with a peak at minimum temperature, occurring during the contact between impactor and sample (in this phase the impacted sample reaches its maximum deflection). After this phase, the ΔT decreases, the sample going towards the ambient temperature value. The minimum ΔT profile (Fig. 7b) takes a higher tip and a larger concavity for E = 39 J at which the material undergoes larger bending [7].

On the contrary, the maximum ΔT profiles (Fig. 7a) have different trends for the two E values. In fact, for E = 39 J, the maximum ΔT starts to rise with a certain delay with respect to the minimum ΔT descent side [7] and reaches a value of about 5 °C; instead, for E = 3.6 J, the ΔT distribution remains almost unchanged with respect to the initial tract before impact, meaning that practically no material damage occurred apart from a slight elastic deformation accounted for by the minimum ΔT profile (Fig. 7b). During heating, there is dissipation of energy and a plastic deformation occurs in the sample. Naturally, these results do not consider what happens on the impacted side which is not monitored and nothing can be said there.




a) maxima and minima ΔT distributions b) minima ΔT distributions (enlarged)

**Fig. 7.** ΔT variations during impact tests at E=3.6 J and 39 J.

## 4. Conclusion

The impact behavior of aluminum foam sandwiches has been experimentally investigated with infrared thermography. The AFS structure remained relatively intact compared to polymeric sandwiches that generally show more catastrophic and localized fracture; this bears witness for their use in the realization of progressive energy absorbers.

The obtained results show also that through the visualization of thermo-elastic/plastic effects developing under impact, it is possible to gain useful information for the comprehension of the impact damaging mechanisms of sandwich structures made of aluminium foam. Furthermore, these results have particular importance for applications that require lightweight structures with a high capacity of energy dissipation, such as the transport industry, where problems of collision and crash have increased in the last years.

## References


[1] M. Ashby, A. Evans, N. Fleck, L. Gibson, J. Hutchinson, H. Wadley, Metal foams: a design guide, referex engineering. Butterworth-Heinemann, 2000.

[2] G. Petrone, V. D'Alessandro, F. Franco, S. De Rosa, Numerical and Experimental investigations on the acoustic power radiated by Aluminium Foam Sandwich panels, Composite Structure, 118, 2014, 170-177.

[3] V. D'Alessandro, G. Petrone, S. De Rosa, F. Franco, Modelling of aluminium foam sandwich panels, Smart Struct Syst, 13(4), 2014, 615–636.

[4] L.J. Gibson; M.F. Ashby, Cellular Solids, 2nd ed.; Cambridge University Press: Cambridge, UK, 1997.

[5] Abrate, S. Impact on Composite Structures; Cambridge University Press: Cambridge, UK, 2005.

[6] C. Meola, G.M. Carlomagno, Impact damage in GFRP: new insights with Infrared Thermography, Composites Part A, vol.41 (12), 1839-1847, 2010.

[7] C. Meola, S. Boccardi, N.D. Boffa, F. Ricci, G. Simeoli, P. Russo, G.M. Carlomagno, New perspectives on impact damaging of thermoset- and thermoplastic-matrix composites from thermographic images, Composite Structures, vol. 152, pp. 746-754, 2016.