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# FATIGUE BEHAVIOUR OF DUCTILE CLOSED-CELL ALUMINIUM ALLOY FOAMS

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**Abstract:** This work investigates the fatigue response of a class of ductile closed-cell aluminium alloy foams known by their commercial name Alulight M8. Fatigue tests were performed in uniaxial compression on cylindrical specimens of 25 mm diameter and 25 mm height with an R ratio of 0.1, at a frequency of 10 Hz. The peak stress was varied from 110% to 135% of the yield stress in compression. Tested specimens were cut from the same cylindrical bar and the density of the investigated material was 500 kg/m$^{3\ \pm 20\%}$, a total of 18 specimens being investigated. With the gathered experimental data, S–N curve were generated, the effect of cellular structure (e.g. structure irregularity-as the number and the size of large or small cells) being discussed.

**Keywords:** Fatigue, Closed-cell aluminium foams, Compression-compression cyclic tests, Plastic collapse, Structure irregularity.

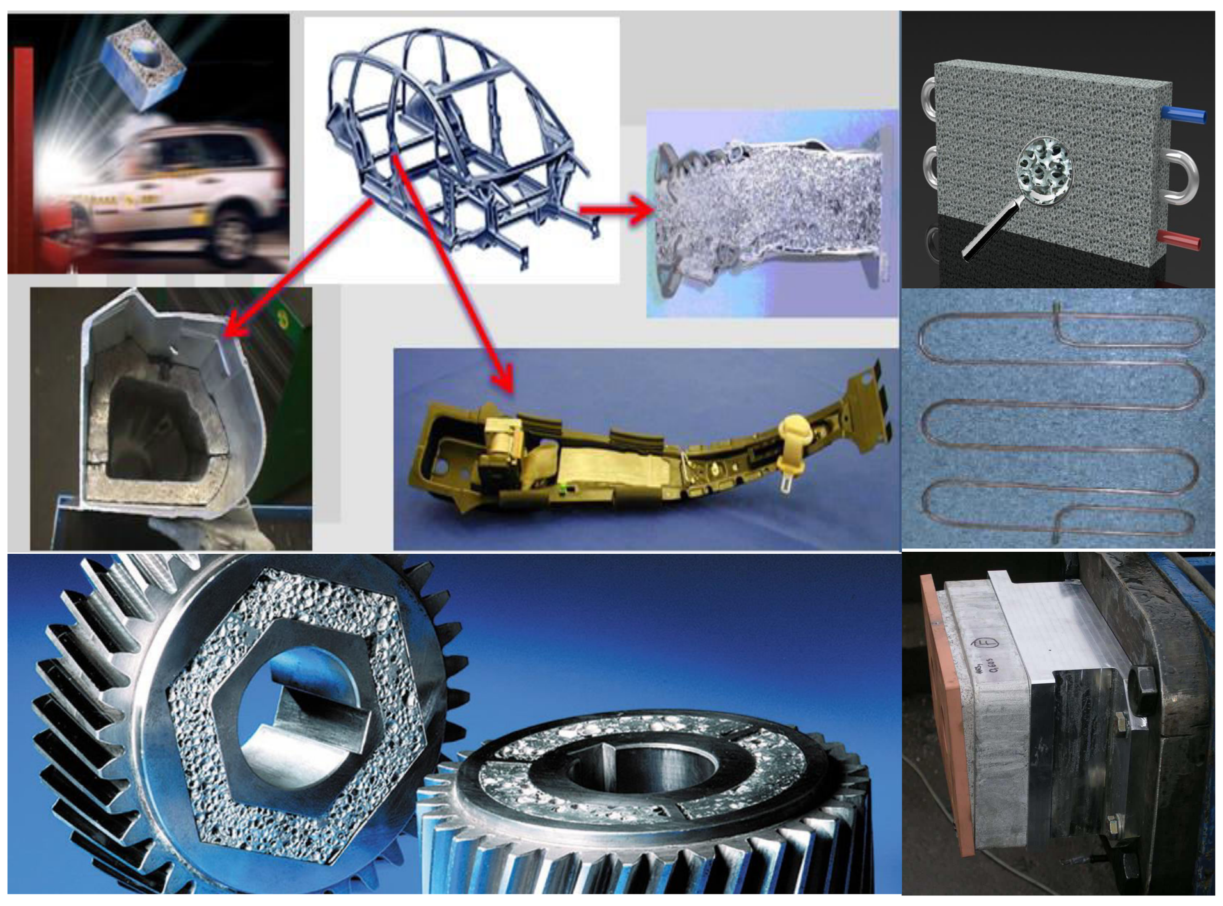

Fig. 1. Main applications of aluminium foams

***Main characteristics of Metallic Foams:***

- high ability to absorb impact energy;
- excellent stiffness-to-weight ratio;
- low density with good shear and fracture strength;
- damping capacity is larger than that of solid metals;
- exceptional heat transfer ability.

Fig. 2. A 10 kN Zwick/Roell static testing machine

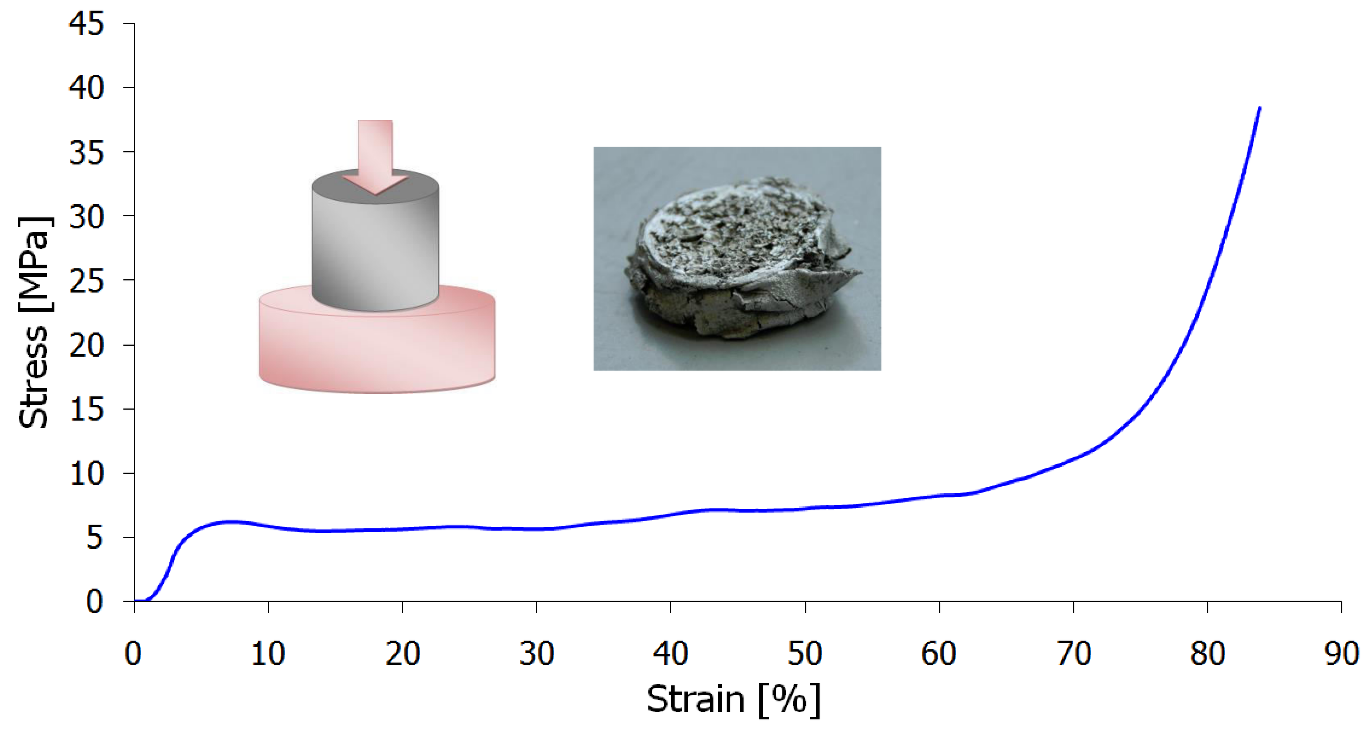


Fig. 3. The quasi-static compressive stress-strain curve of Al foam specimens with different aspect ratios

***Experimental setup:***

- *Quasi-static compression tests* were carried out on a 10 kN Zwick/Roell testing machine on cylindrical specimens of 25 mm diameter and 25 mm height, with a loading speed of 10 mm/min at room temperature (23 °C).
- *Fatigue tests* were carried out in compression on a 10 kN Walter+Bay testing machine on cylindrical specimens of 25 mm diameter and 25 mm height, on load control at a frequency of 10 Hz and an R ratio of 0.1

*The main mechanical properties of investigated foams were determined according to International Standard for Compression Test of Porous and Cellular Metals*

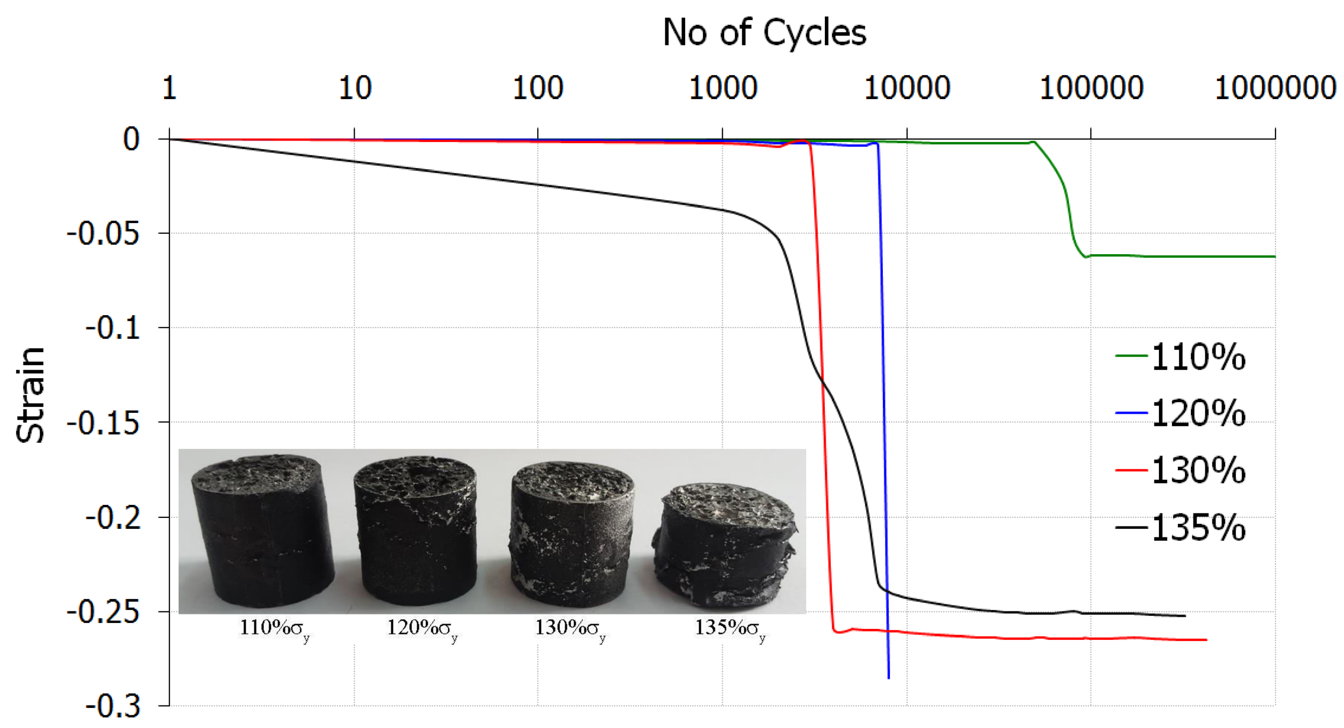


Fig. 4. Strain degradation with the Number of Cycles at different $\%\sigma_y$ for the investigated foams

Fig. 5. A 10 kN Walter+Bay fatigue testing machine

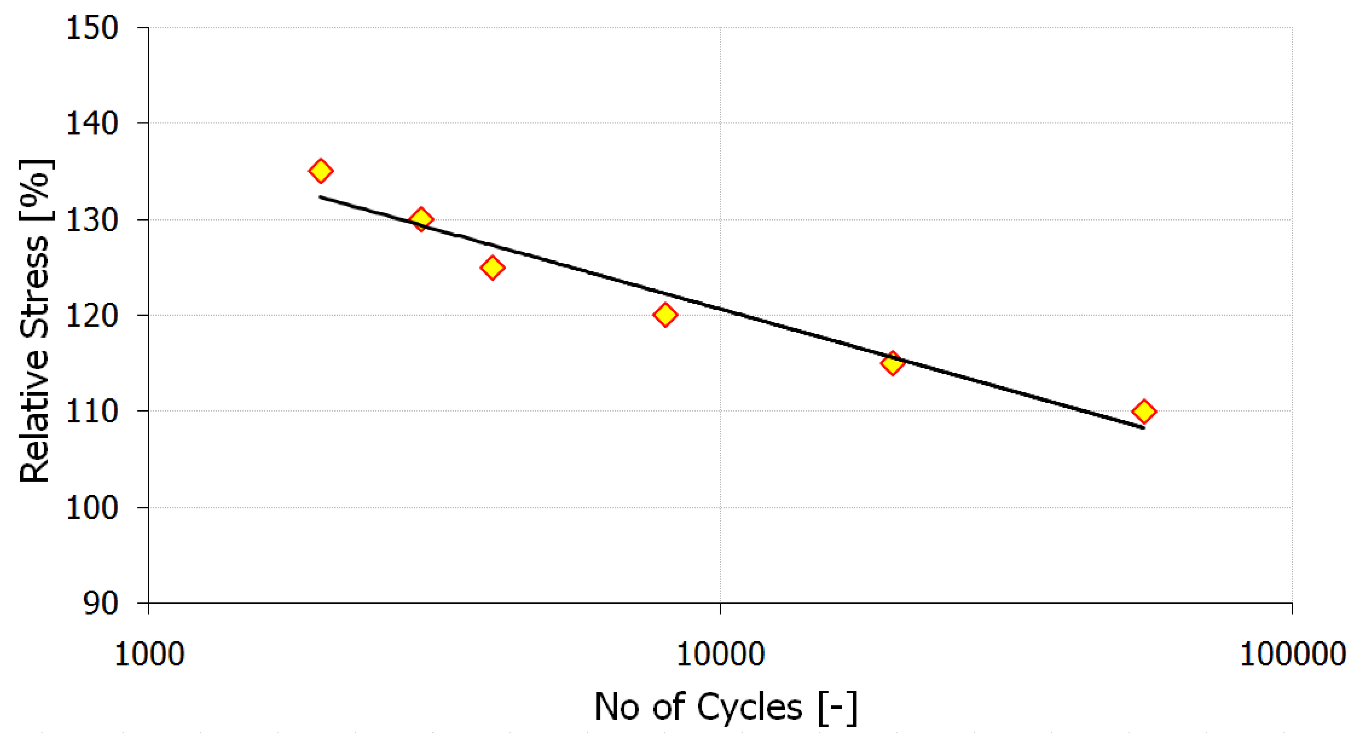


Fig. 6. The S-N curves of ductile closed-cell aluminium alloy foams with an R ratio of 0.1 at a frequency of 10 Hz in case of compressive fatigue test.

**Conclusions:**

*This work investigates the fatigue behaviour of ductile closed-cell aluminium foams*. Due to the large dimensions and random scattering of the cells, each specimen had a different value for the density. After measurement and weighing, the average density resulted to be 500 kg/m$^3$, specimens with density variation above or below 20% being excluded. A total number of 18 specimens were investigated.

The following conclusions can be drawn from this study:

- At a macro-scale (after quasi-static compression tests), degradation occurs through a local densification of the specimen (see Fig. 3).
- The aluminium foams exhibit a stress-strain behaviour characteristic to cellular materials, having three regions of deformation: a linear elastic-region, a plateau region and a densification region.
- It was observed that *the fatigue-induced damage in the studied material was caused by the occurrence of degradation bands* in the region of the specimen that exhibited the lowest density. In order to highlight this phenomenon, a layer of black paint was applied on the specimens prior to testing, the local failure determining white shades on the surface (Fig. 5). This mechanism can be further observed by analyzing the compressive strain variation with the number of cycles as it produces a significant increase in deformation (Fig. 4).
- Considering the sudden increase in strain as the failure point of the specimen, *the stress-life ($\sigma$–N) curve of the Al foams is obtained experimentally* (Fig. 6).
- It was observed that *the presence of large cells had a significant influence on the fatigue life of the foam*, generating a large scatter of results for some loading levels. The scatter of fatigue life increases as the irregularity of cell structure is higher.
- *The fatigue life decreases* as the number and the size of large cells increase.

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