# Modelling of the mechanical properties of metallic foams based on x-ray analysis

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## Abstract

The aim of this work is the evaluation of a modelling method used for predicting the mechanical properties of metallic foams. This model is based on an x-ray analysis of the cellular structure and provides a simple method for estimating the compressive stress-stain curve and the mechanical properties of metallic cellular structures.

## 1. Introduction

Metallic foams are suitable for the production of lightweight composite structures for use in the automotive and aircraft industries, as their high specific stiffness and energy absorption abilities make them suitable for these applications. One of the main issues limiting their use in industrial applications is the lack of simple routine methods for qualifying the mechanical properties of foams. The presented technique is based on existing models and requires the use of an on-line x-ray analysis of the samples that characterises the pore size distribution of the cellular structure for use in the modelling of the compressive stress-strain curve.

## 2. Modelling method and characterisation

The modelling method is based on the assumption that areas of lowest density within the cellular structure are the first regions to deform plastically under uniaxial stress. Furthermore it is assumed that the cellular structure deforms graduall with increasing density. Figure 1 shows an x-rayed aluminium foam sample with an artificial area of lowest density (drilled hole in the sample), the gradually deformation of foam adjacent to this hole and the transition of the deformation to areas with the next lowest density.

J. Banhart, M.F. Ashby, N.A. Fleck: *Metal Foams and Porous Metal Structures.* © MIT Verlag (1999)

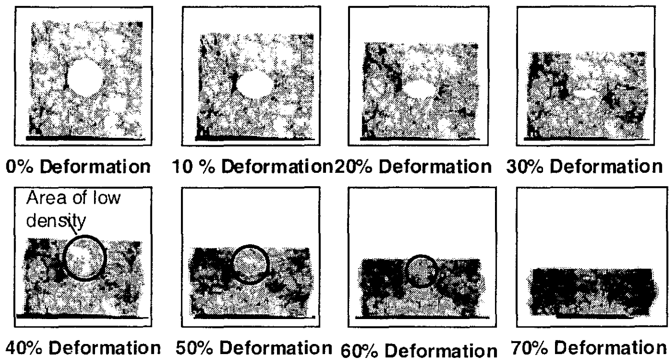


Fig. 1: Gradual deformation of a cellular structure

If this mechanism were applicable on the microstructural level, then the deformation of the foam body could be modelled as a serial connection of the deformation of pores with different sizes. In consequence, a knowledge of the pore size distribution can lead to the prediction of the compressive stress-strain curve of the foams, provided

- a cell-geometry dependent deformation model and
- an analysis method for the pore size distribution exists.

In the past years various researchers have concentrated on developing a deformation model of cellular structures. The present work is based on a tetrakaidecahedron model presented by Huschka [1]. For the investigation of the pore-size (resp. density) distribution, an on-line x-ray analysis is used, because of its higher applicability compared to other analysis methods, e.g. computer tomography. The density distribution of the foam sample is obtained by recording an x-ray image of the sample and creating a gray-value histogramm of this image. The gray-values are transferred to density-values according to chapter 3.

The compression-densification curve is modelled separately for the three deformation regimes suggested by Gibson and Ashby [2]. The equations used for calculating the stress and densification values can be found in [1] and [2]. Figure 2 shows a schematic compression curve and its characteristics.

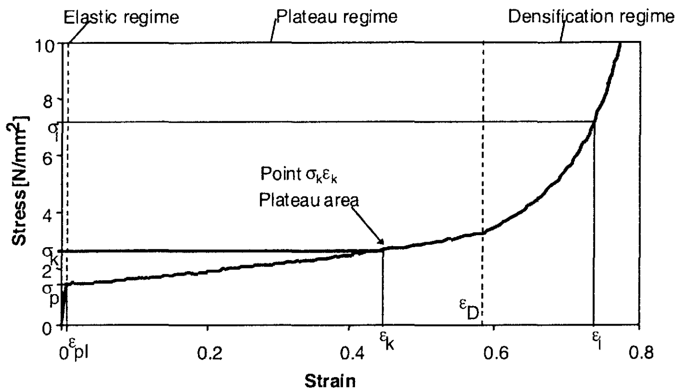


Fig. 2: Schematic compression curve of a foamed structure

## 3. Results

The pore size distributions of the foam structures have been analysed with a 225kV x-ray tube and an on-line image processing system. The data obtained are the basis of the modelling process and the prediction of the compressive stress-strain curve. These results are compared with the real stress-strain curves recorded in compression tests of the x-rayed foam. The investigated material was a AlSi7Mg alloy foam with SiC particles produced by the continuous casting process [3]. The samples were x-rayed in two directions, perpendicular to the compression direction. An overall density distribution was obtained by calculating a mean grey-value distribution for four x-ray pictures. The grey-values were transformed to density values by calibrating the x-ray and image-processing system with samples of known densities as shown in Figure 3.

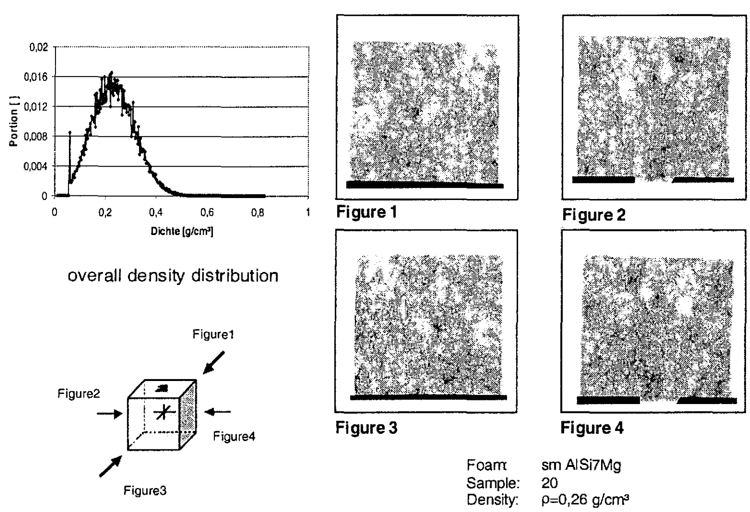


Figure 4: X-ray images of foam sample and density distribution

The compression curve is modelled by assigning a certain density to a stress-value calculated by the mentioned equations in [1]. For example, a stress value $\sigma_k$ in the plateau area of the compression curve and the corresponding strain value $\varepsilon_k$ (compare Fig. 2) can be calculated as a function of a certain density class $\rho_k$, where all $\rho_k$´s are sorted by increasing density. According to the 256 grey values of the image processing system and the calibration of the grey-values to density values, 256 density classes exist for calculating the compression curve. Figure 4 shows the modelled curve compared with an experimental stress-strain curve attained for the sample in a compression test. During modelling it is assumed, that each element of a certain density is subjected to the same stress.

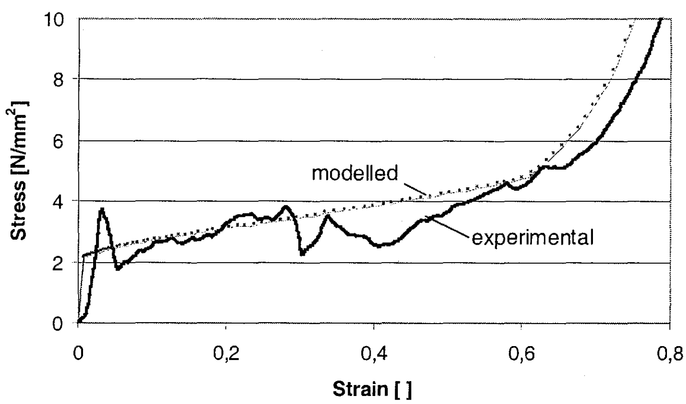


Fig. 4: Recorded and modelled compression curve

The experimental and modelled curve correspond quite well. The local stress maxima and minima cannot be calculated by the model and the density characterisation method. For modelling the discontinuities in the curve, the location and geometry of the cell-walls and struts has to be known. This is not possible by an on-line-x-ray characterisation-technique. Furthermore the deformation model has to be extended.

## 4. Conclusions

An on-line x-ray analysis of the pore structure of metallic foams can be used to model the stress-strain curve of the cellular structure. The calculation of the curve is based on a density distribution of the metallic foam which is obtained by transferring the analysed grey-values into density-classes. A certain stress $\sigma_k$ and strain $\varepsilon_k$ can be assigned to every density-class. The comparison of experimental and modelled compression curves show satisfactory suitability of the method for characterising aluminium foams produced by the continuous casting process. The experiments will be extended to other materials in the future.

## 5. References

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