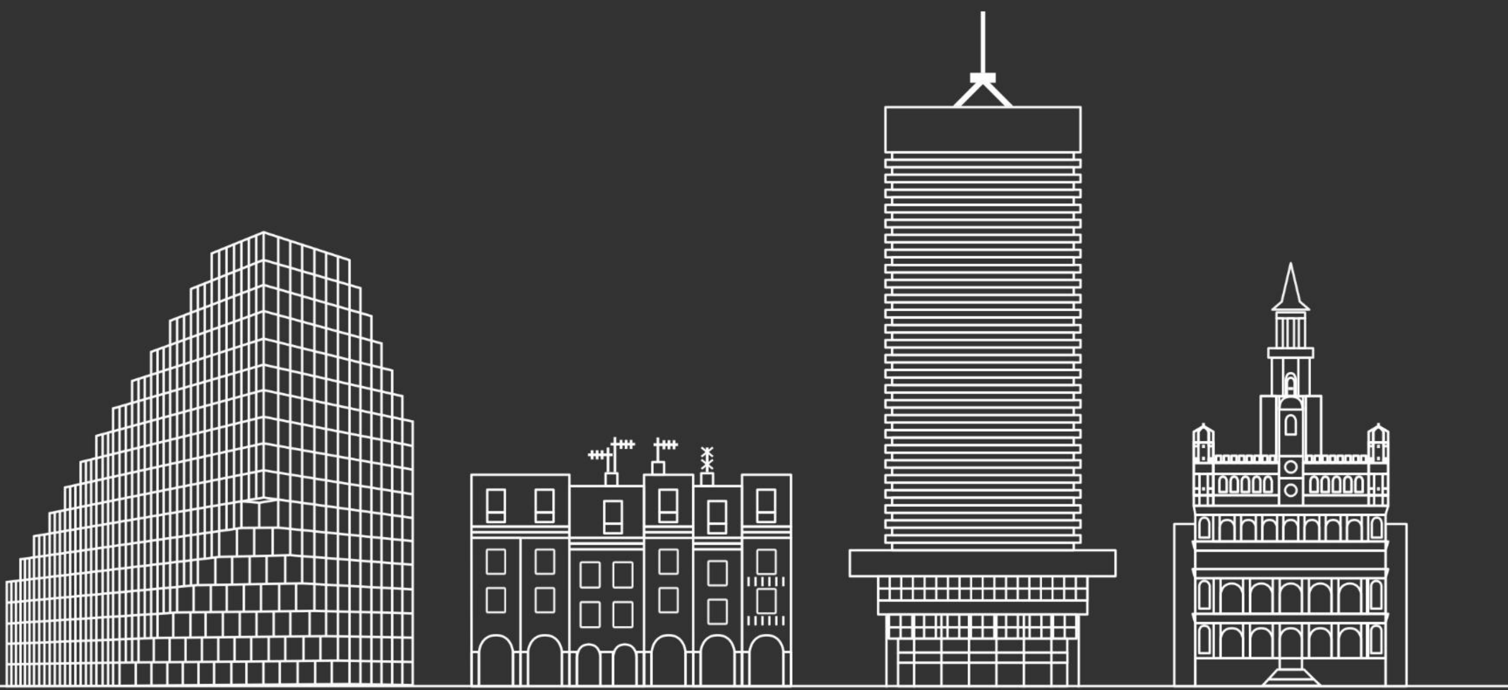
ICPS5

Design, Experiment and Analysis of Protective Structures

Proceedings of the 5th International Conference on Protective Structures | ICPS5
19-23 August 2018, Poznan, Poland



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The concept of virtual cellular material in peridynamic modelling of deformation processes

Ryszard B. Pęcherski, Zdzisław Nowak, Eligiusz Postek

Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawinskiego 5B, 02-106 Warsaw, Poland
rpecher@ippt.pan.pl

1 Introduction

The study of modern cellular materials due to complexity of their internal structure requires the application of efficient computational methods. One of such methods developed in the last 10 years is peridynamics [1], [2]. This approach resulted in the parallelized code [3] that is used in presented analysis.

The subject of the study are alumina foams produced by gelcasting method and metallic cellular materials that can be produced in the process of additive manufacturing. The results of microtomography of alumina foams are used to create the numerical model reconstructing the structure of foam skeleton. In this way an example of virtual cellular material is reconstructed, [4], [5], [6]. The other example of virtual material with topology generated by tomograms obtained for polyurethane foams [7] and [8] is studied as well. The skeleton material of such a virtual cellular structure is assumed as OFHC copper. The oxygen-free high conductivity (OFHC) copper powder can be used in additive manufacturing to produce the open-cell multifunctional structures, e.g., crush-resistant heat exchangers, heat capacitors, etc.

The numerical simulations of failure strength under compression for the 3D virtual alumina foams are performed. The calculations with use of the numerical model are time consuming. Therefore, the simplified method of the assessment of failure strength is proposed. We attempt to present the mechanism of damaging of a crushable foam under impact. Also preliminary results of virtual cellular material with the OFHC copper skeleton are discussed

2 Material model of solid alumina

The deformation and progressive damage of the skeleton of alumina foam body that impacts a stiff wall with velocities 50 m/s and 100 m/s, Figure 1 and Figure 2, respectively is analysed. The velocities are directed downwards along the Figures. One of the most important aspects in numerical simulation of the material is to formulate constitutive material model. The elastic part of deformation for solid alumina describes isotropic Hooke's law. Assuming that the damage of the skeleton is isotropic, the maximum reduced stress can be expressed as follows, [9].

$$\sigma_{max}^{D} = \sigma_{max}(1 - D) \tag{1}$$

where the reduced stress is related to the non-dimensional damage variable D=A/A_0 where A is the damaged area, and A_0 is the initial area. The variable D varies between 0 and 1.

3 Numerical results

The Young modulus is assumed 370 GPa and Poisson's ratio 0.22 and density 3.92g/cm^3, cf. [6]. The virtual foam skeleton is discretized with 585897 points. The critical strain is assumed 0.0005. Let us note the gradual damage in the samples shown in the both Figures 1 and 2.

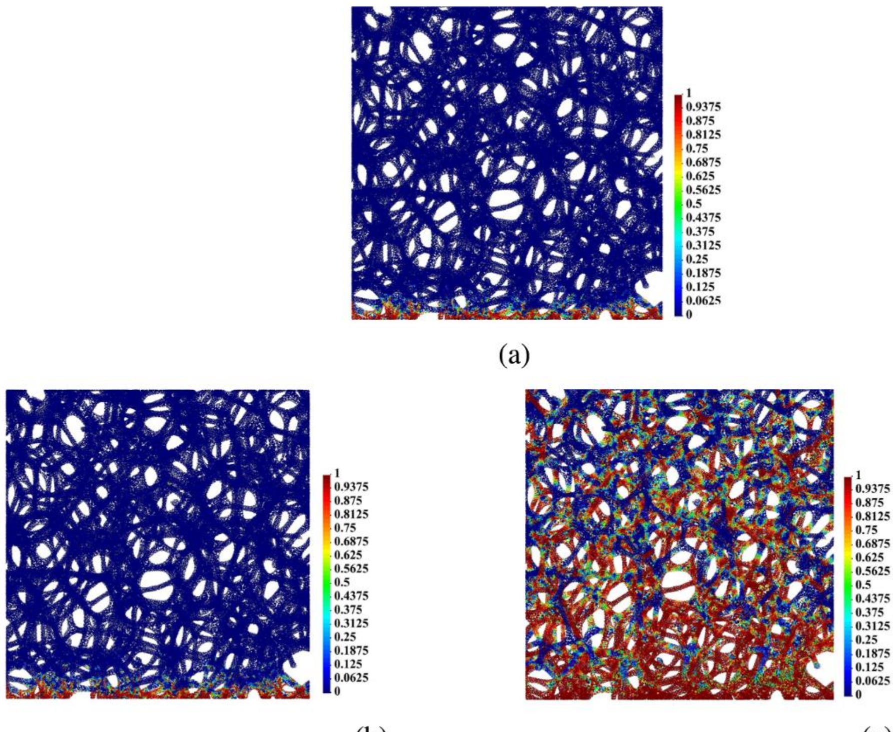

Figure 1: Damage advancement, impact velocity 50 m/s: (a) time instant 7.7E-08 s; (b) time instant 15.5E-08 s; (c) time instant 23.3E-08 s

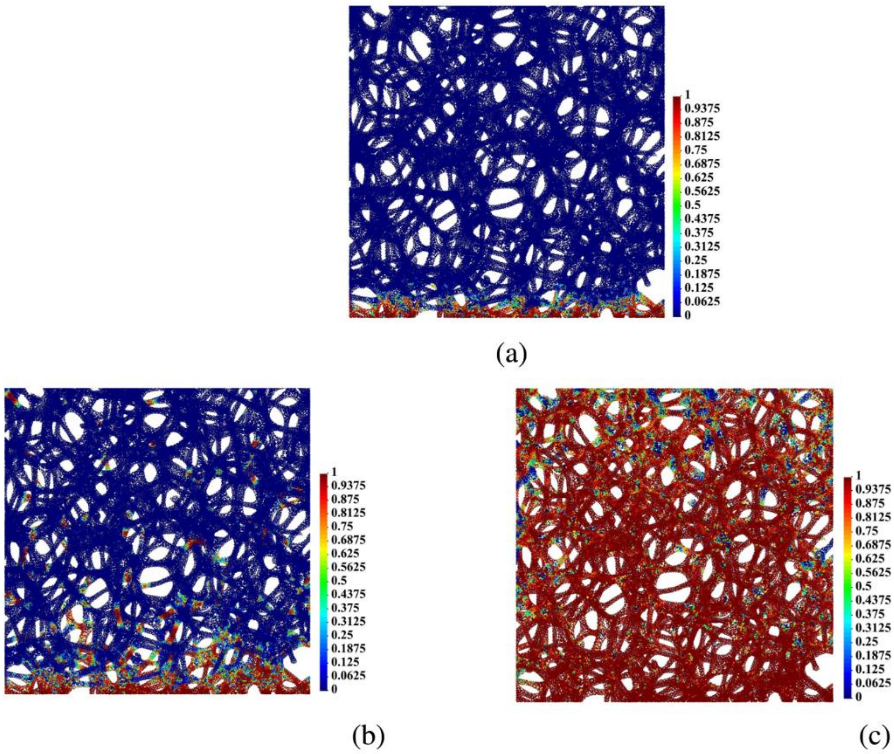

Figure 2: Damage advancement, impact velocity 100 m/s: (a) time instant 7.7E-08 s; (b) time instant 15.5E-08 s; (c) time instant 23.3E-08 s

An interesting observation is done in Figures 1(b) and 2(b). We find that the maximum values of damage variable that are close to 1, form islands in the entire structure, far from the attacking edge. It can be interpreted that stress wave phenomena play a role during this kind of process.

4 Final Remarks

A numerical model for the open-cell ceramic foam structures is presented. The increase of localized stresses and the brittle nature of ceramics cause the failure of some struts of ceramic foam. For this reason the understanding of stress state in ceramic foam is necessary. Several numerical simulations have been performed to analyze the influence of applied velocity on the compressive strength of the considered alumina foam. The peridynamic modelling is applied to investigate its dynamic damage process under axial compression.

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