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STUDY OF METALLIC-CERAMIC COMPOSITE FOAMS WITH APPLICATION OF THE COMPUTER TOMOGRAPH

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The paper presents the study of the metallic-ceramic composite foams (the AlSi9 matrix, the SiC reinforcement) with application of the computer microtomograph. The morphology of these materials was also described in the paper, as well as generation of the three-dimensional models of the entire samples of foam. Additionally, quantitative image analysis was performed and the porosity of the test samples (with 3D analysis) and pore size distribution in the tested foams with different densities (with 2D analysis) was determined.

Key words: cast, metalic-ceramic composite, foams, porosity, computer tomography

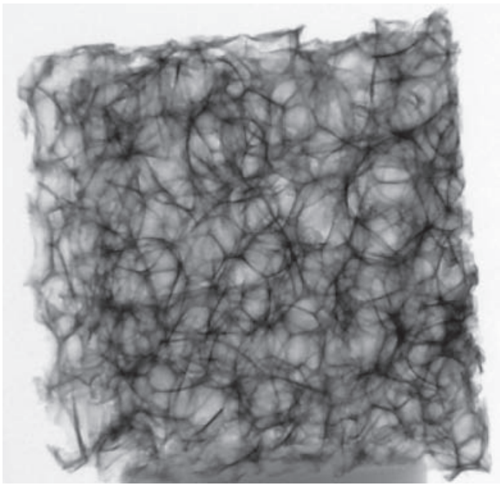
INTRODUCTION

General assessment of quality and structure of the metallic-ceramic composite foams consists of: evaluation of state of the raw surface, the manufacturing accuracy and re-creation of dimensions, detection and location of the internal defects and evaluation of state of the metallographic structure. Application of the non-destructive methods for the assessment understood this way is a very important technical problem, mostly applied for control of stabilization of the manufacturing process and obtaining metal foams of high quality. One of such a methods is the computer tomography. The tomography is one of the most advanced non-destructive methods allowing to assess the real internal structure of a studied material, e.g. porous structures, through analysis of effects of the X-radiation on 2D planes with possibility of joining them in a spatial 3D image [1 – 3]. In the paper, the computer tomography method was used for description of features of the metallic composite foams (of various density), manufactured by a foundry method.

STUDY MATERIAL AND PARAMETERS OF THE TOMOGRAPHIC EXAMINATION

In the presented work, images of structure of the metallic composite foams with the AlSi9 matrix and reinforcement in form of the SiC particles of various density and pore size were analyzed. Selected foam samples represented all groups (of type C, B1 and A) of the studied materials. The foams were manufactured using a foundry method of injection of gas into a liquid composite, according to [1, 4 – 5], at Division of Naval Materials Engineering, Maritime University of Szczecin. Samples of the composite foams were subjected to examination using the XRADIA XCT-400 computer tomograph, at Warsaw University of Technology. Scanning of the samples was performed using the lamp volt-

a)



b)

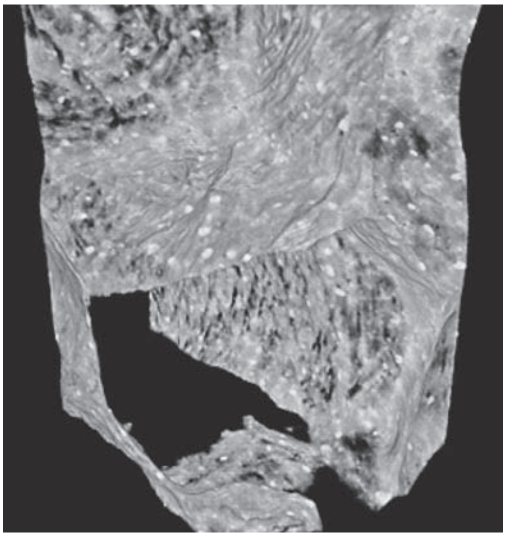


Figure 1 Exemplary projection of the composite foam: a) radiograph, b) fragment of the radiograph

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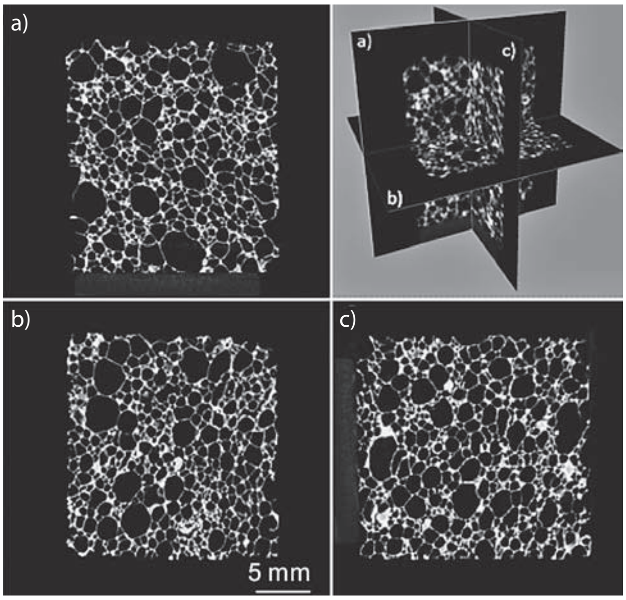

Figure 2 The metallic-ceramic composite foam: three perpendicular cross-sections and their spatial representation

age of 50 kV and the current intensity of 200 μA. Time of examination of one sample was approximately 1 hour. Out of each measurement, 900 projections were obtained. Each projection was created for a given angular position of a sample in range of 0 – 180°. Time of exposure of a single projection was 2 seconds. The Figure 1 presents one projection for the reference sample of the composite foam.

ASSESSMENT OF STRUCTURE OF THE COMPOSITE FOAMS USING THE COMPUTER TOMOGRAPHY

On the basis of the obtained projections, reconstructions of the object cross-sections were prepared, using modified Feldkamp algorithm [2, 6]. Resolution of the reconstructed cross-sections was 33,7 μm (pixel size). One of the methods of exploring the internal structure of the examined foams using the computer tomography is reviewing them in form of three views on perpendicular planes. This method allows to quickly search through the three-dimensional image, by watching single or

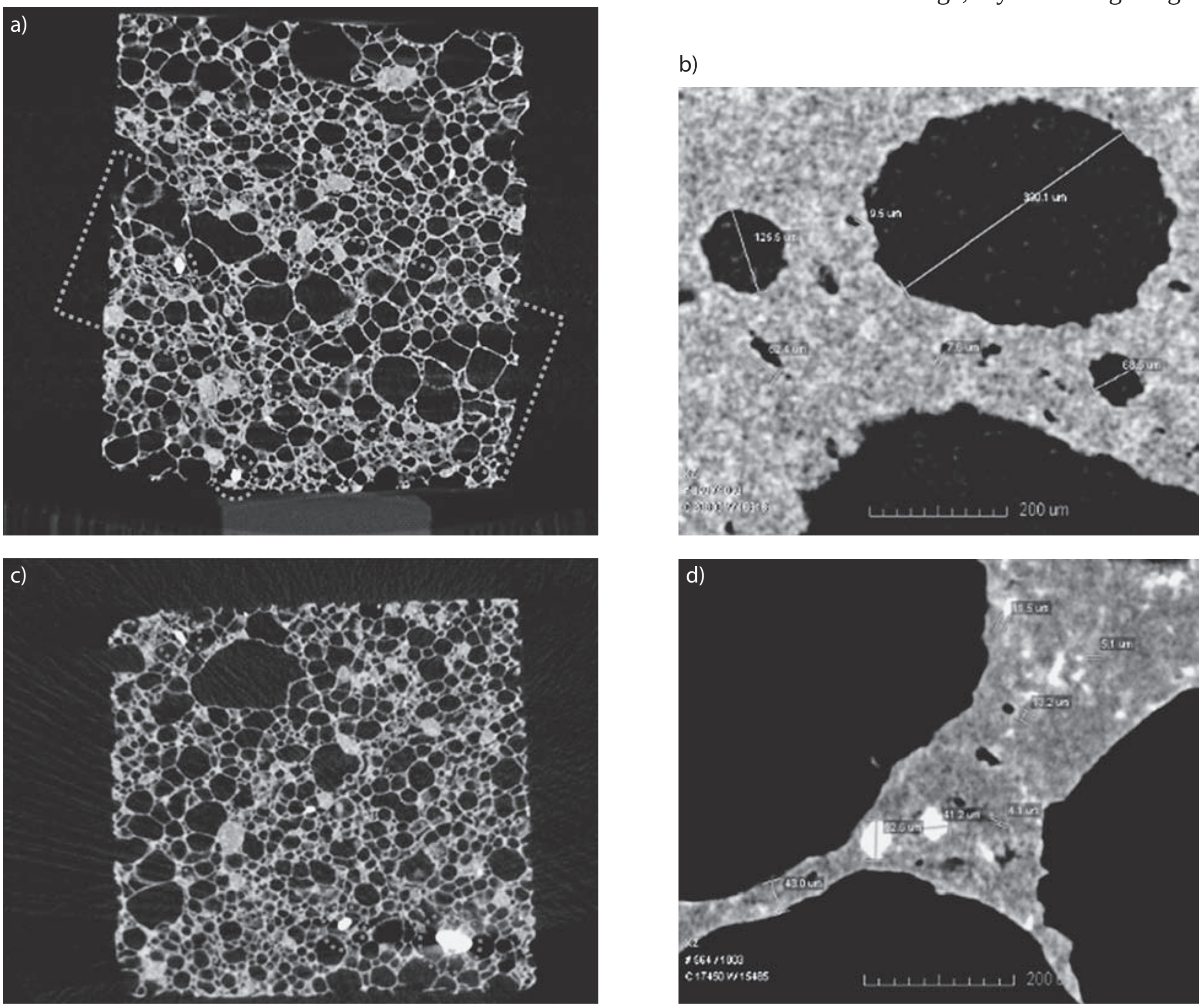

Figure 3 Two perpendicular cross-sections – radiographs, illustrating characteristic features of morphology of the composite foam; a. The rectangle marks a zone of changed pore structure – inhomogeneity of size and shape of the pores in the foam; b. slice of the section – visible pores in walls of the foam of various size; c. the circle marks elements of high level of absorption of the X-radiation, being a particles of the reinforcing phase SiC; d. slice of the section – visible elements of the SiC reinforcement in the foam walls

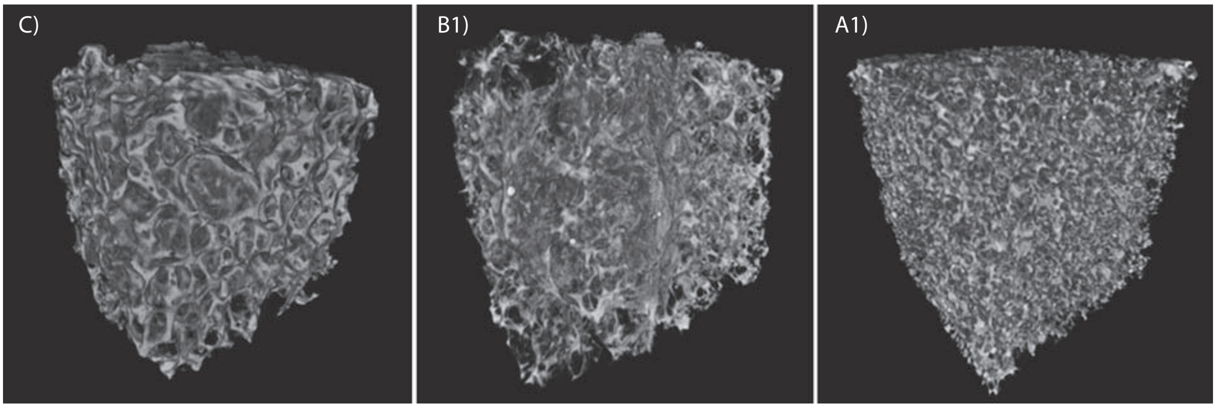

Figure 4 Visualization of the porous structure, 3D models of the entire samples of the selected foams of various density

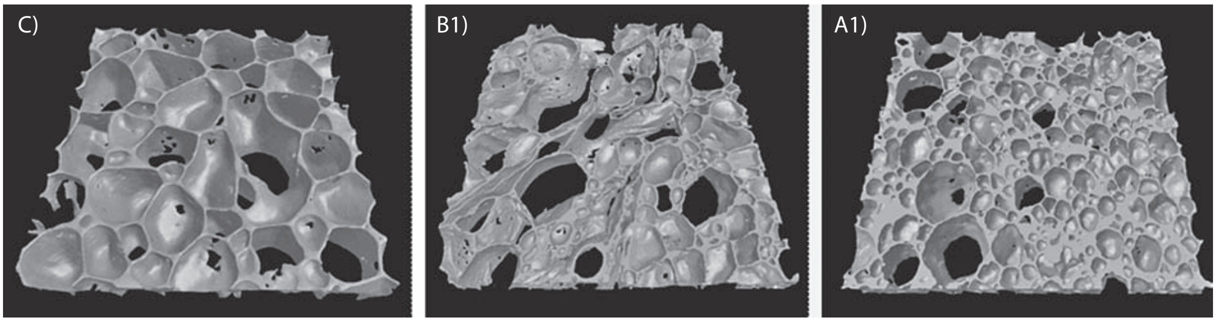

Figure 5 Three-dimensional models of foam fragments of the various density

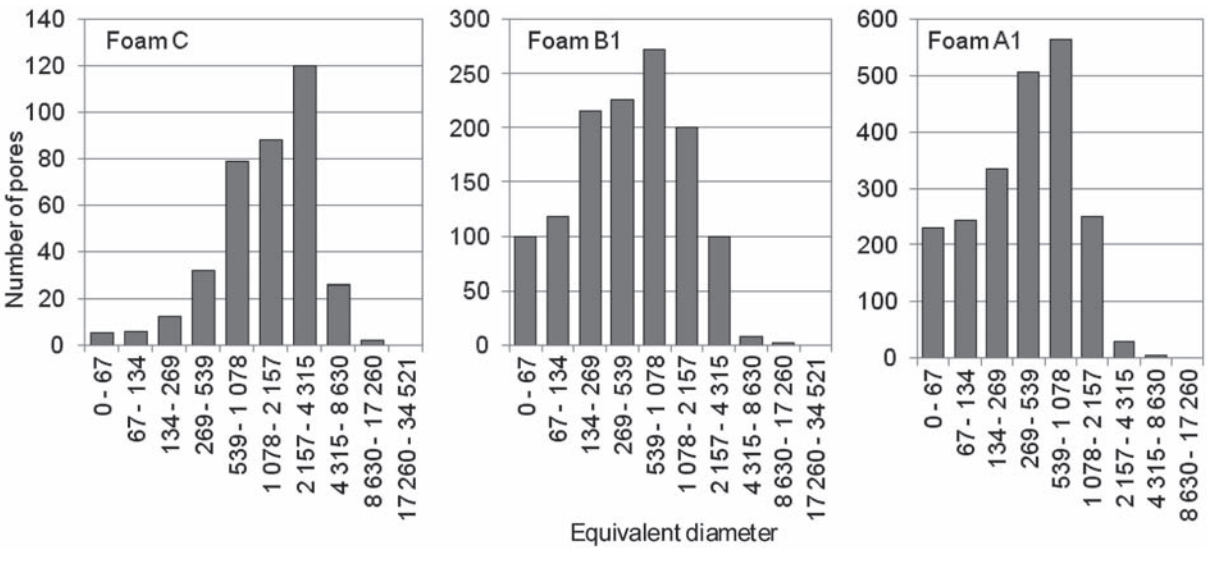

Figure 6 Distributions of the equivalent pore diameters in the foams of type C, B1 and A1

multiple, perpendicular or oblique sections. The Figure 2 presents an exemplary result of the study in form of the three perpendicular cross-sections.

Analyzing the reconstructed, two-dimensional sections of the examined foams, characteristic features of their morphology can be defined. The Figure 3 presents exemplary features of structure of the examined foams.

After the reconstruction, the files were imported into the CTAn program, developed by the SKYSCAN company. The basic functions of this program allowed to generate three-dimensional models of the whole samples of the composite foams and presentation of the accurate, rendered (rendering – presentation of information contained in the electronic document in the most appropriate visual form for a selected environment; in the computer software, mechanism responsible for the rendering is named the rendering engine or the renderer) models of fragment of their porous structure (Figures 4 and 5).

Additionally, after computer analysis of the image, porosity of the examined samples was determined (3D analysis), along with distribution of the pore size in the examined foams (2D analysis). The Figure 6 presents histograms of distribution of the values of equivalent

Table 1 **Results of the quantitative analysis of the selected composite foams**

Sample No.	Mass / g	Density / g/cm^3	Porosity / %	Average pore size / μm
A1	2,3254	0,377	81	800
B1	1,7009	0,236	85	1 300
C	1,8196	0,239	90	2 250

pore diameters in the composite foams of type C, B1 and A. Summary of results of the quantitative analysis is presented in the Table 1.

SUMMARY

The computer tomography is a valuable tool for description of the structure of the composite foams (AlSi9/SiC) with various density and porosity, which was presented in the Figures 4 – 6 and the Table 1. A size of pores (Figs 3, 6), their shape (Figs 2 and 3a – b) and identification of the reinforcing phase (Fig. 3c – d) can be performed in a precise way.

Unquestionable advantages of the computer tomography applied for examination of the composite metallic foams are as following:

1) non-destructive type of examination;
2) achieving similar resolutions in all directions during the examination (thanks to this, another 3D reconstruction allows to obtain real shapes and pore distribution, impossible to record using other methods);
3) obtaining precise information about size, shape and spatial location of the pores and the reinforcing phase in the studied materials thanks to the 3D analysis, which allows to evaluate the homogeneity of the composite foams.

Disadvantages of this method are as following:

1) high cost of the measuring device and appropriate programming systems for analysis with tools for the 3D analysis;
2) experimental selection of conditions, e.g. for improving the image, the detector should be in the farther distance from the sample, depending on power of the X-rays and micro-diversity which is about to be illustrated;
3) required high computing power and operating memory, necessary for programs of that computer analysis in the system.

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Note: W. Wiśniewski is resposible for English language, Szczecin, Poland