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dr hab. inż. Janusz Lubas
dr hab. inż. Marek Mróz, prof. PRz

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prof. dr hab. Grzegorz Ostasz

R e d a k t o r   W y d a n i a
dr hab. inż. Andrzej Trytek, prof. PRz

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dr inż. Joanna Zielińska-Szwajka
mgr inż. Sylwia Sikorska-Czupryna

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Chapter 2.

Wojciech PRZETAKIEWICZ[1]
Katarzyna BRYLL[1,*]
Ewelina KOSTECKA[1]
Dorota STOCHŁA[1]
Marek STAUDE[1]

APPLICATION OF MICROSCOPY IN THE ASSESSMENT OF POROSITY IN COMPOSITE CASTS SATURATED WITH SILUMIN

Abstract
Composites produced by pressure infiltration are characterized by both a greater number and a larger variety of defects compared with traditional castings. Porosity is a significant disadvantage in such materials, and the pore formation mechanisms are closely related to the production of castings. This paper determines the usefulness of microscopy methods in the examination of porosity on example metal composites saturated with silumin.

Keywords:
Composite, metal matrix composite, silumin, porosity

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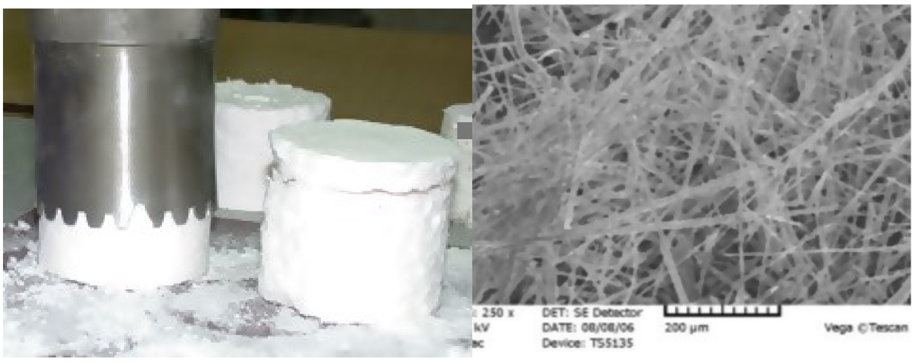
1. Introduction
The ideal structure of infiltrated composite castings consists of a metal matrix, typically a commercial alloy based on Al, Mg, or Ti, and a reinforcement material, most often a ceramic, in the form of unstructured fibres that form a system of capillaries with different sizes and shapes (Fig. 2.1).

[1] Department of Marine Engineering Materials, Faculty of Marine Engineering, Maritime University of Szczecin, Willowa 2–4, 71-650 Szczecin, Poland
[*]e-mail: k.bryll@am.szczecin.pl



a) b)

Fig. 2.1. Structure of a reinforcing aluminosilicate preform: (a) macroscopic view [1], (b) short unstructured fibre (SEM) [2].

Due to the poor wettability of the reinforcement material by the liquid matrix, the infiltration of a composite reinforcement material is sometimes forced by external pressure. The component properties and the reinforcement infiltration method make it practically impossible to obtain a nonporous saturated composite material [1-5]. Porosity in a composite structure may be caused by [5] insufficient saturation of the composite reinforcement capillaries by the liquid metal matrix, discharge of a gas dissolved in the matrix metal when it cools and solidifies, as well as the formation of gas occlusions during infiltration of reinforcement. Pores can have different shapes and locations in a casting, and their sizes can vary significantly, making it difficult to classify the porosity formation mechanism. Attempts to identify the type of porosity have been presented in various publications [1, 5-8]. The assessment of a composite material's porosity is used to judge its quality, whereas the type of pores makes it possible to determine the causes of their formation, which allows process parameters to be adjusted to minimize the casting's porosity. In addition to densitometry, ultrasound, X-ray, and other methods, microscopy techniques are used to assess the porosity of cast metal composites. In order to detect porosity using microscopy, an appropriate area for analysis must be selected, and pores must be identified by noting a clear distinction between pores and other components of a composite, e.g., impurities or inclusions. It is also important to select the appropriate microscopic technique for the type of reinforcement metal in an infiltrated composite. The quantitative porosity determined for the material tested by microscopic methods is also influenced by the preparation of polished sections, i.e. metallographic specimens (a very complex process which requires experience since metal composites such as those with a soft silumin matrix have a varying hardness due to the presence of hard reinforcement), the selection of appropriate magnifications, and unambiguous interpretation of visible objects. In this paper, the usefulness of various microscopy methods for the identification of porosity of metal composite materials with different types of reinforcement was determined. After the porosity was unambiguously identified, a quantitative description can be performed.

2. Testing of the porosity of metal composites using microscopy

Two types of metal composites were tested in this paper that differed in their reinforcement material. In the first material, composites with a silumin matrix and aluminosilicate reinforcement in the form of short fibres (unstructured and shaped in preforms), were examined. In the second case, composites with a silumin matrix and carbon reinforcement in the form of short, unstructured fibres formed into preforms were investigated. Reinforcement preforms (dimensions of D=60 mm x L=20mm) were introduced into a metal form (the aluminosilicate reinforcement was heated in a furnace at 760 °C for 60 minutes), filled with liquid silumin (AlSi11), and infiltrated at 20 MPa for 300 seconds (Fig. 2.2). All requirements were met for the technology of making castings by infiltration using squeeze casting [3-5].

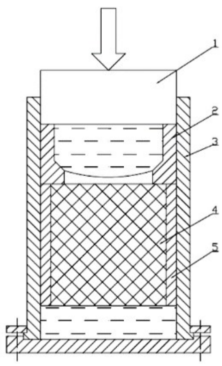
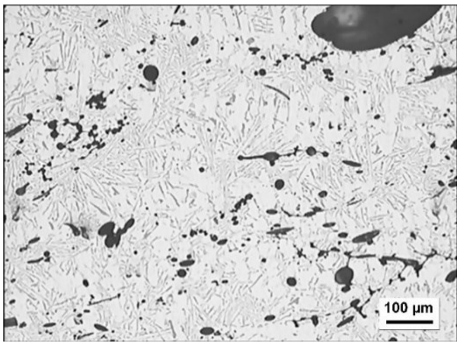


Fig. 2.2. Production of composites by infiltration of a porous structure with a liquid metal matrix: scheme of a mould with a preform prepared for saturation: 1 – stamp, 2 – piston, 3 – bushing, 4 – ceramic preform, and 5 – reinforcement seat.

2.1. Testing the porosity of the composite of AlSi11 and aluminosilicate fibres

Non-etched polished specimens were cut from a cast composite of AlSi11 and aluminosilicate fibre and used as samples for microscopic observation. Porosity was examined using a Neophot 2 optical microscope. Attempts were made to digitally process the recorded images (Fig. 2.3a) using Aphelion software [1]. However, the results were not satisfactory (Fig. 2.3b-c). A similar test was carried out for silver-sprayed specimens (Fig. 2.4a), which also returned unsatisfactory results (Fig. 2.4 b-c). For these composites, the use of optical microscopy for porosity analysis is inappropriate because it is impossible to identify these defects in an unambiguous way. Therefore, to determine the porosity of a composite with an aluminosilicate reinforcement, it was decided to analyse images obtained from a scanning electron microscope (SEM) [1].



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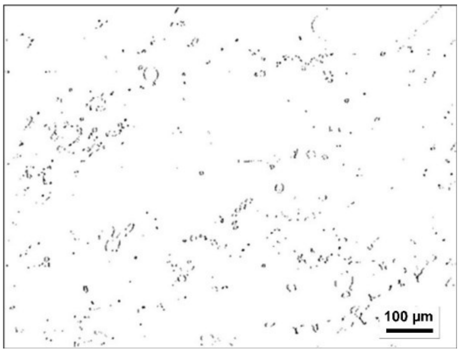

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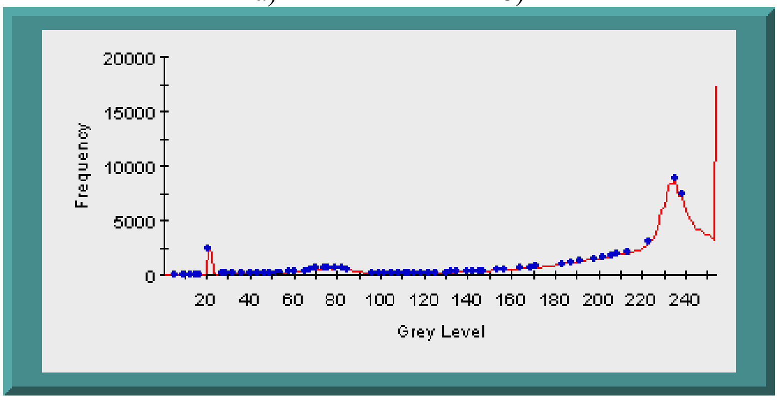
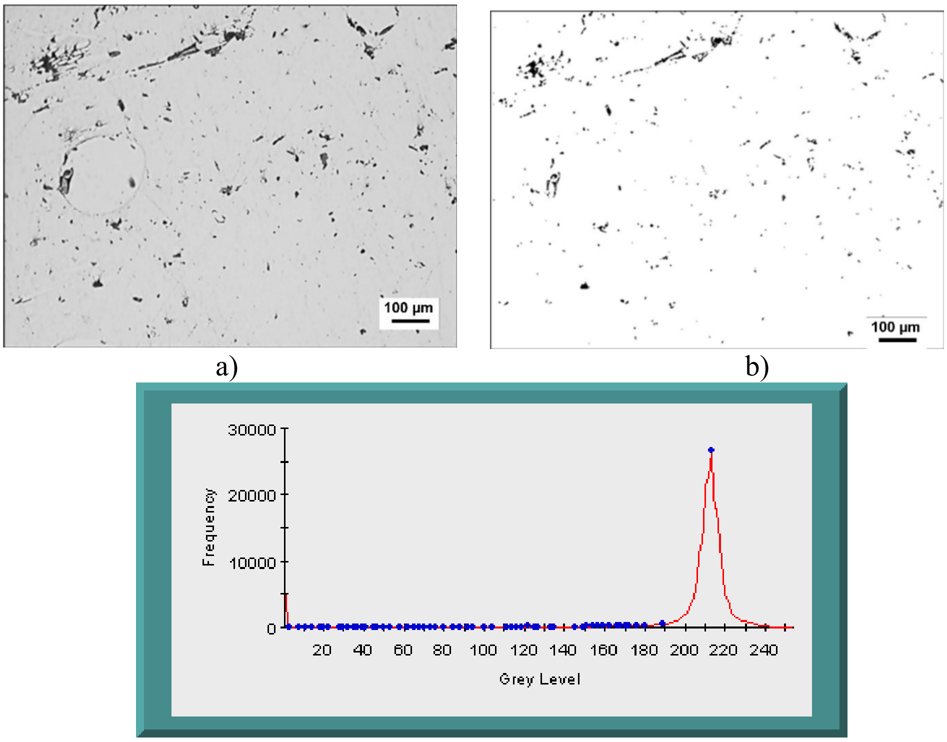


c)

Fig. 2.3. A trial computer-aided analysis of a porosity image (Aphelion software); material: Al_2O_3/SiO_2 fibre, AlSi matrix (non-etched specimens); a – output image [1], b – unsuccessful attempt [1], c – grey level histogram.

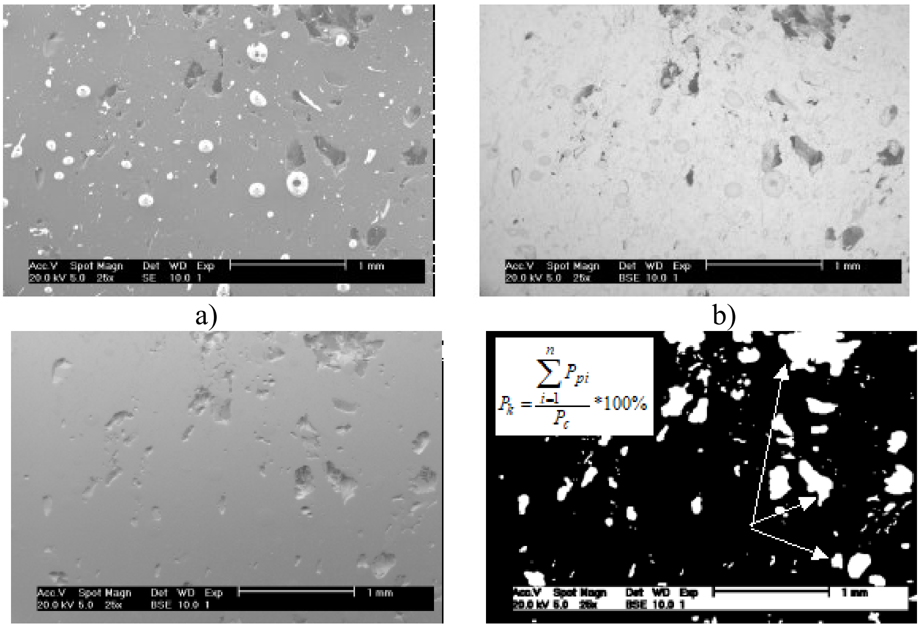


a) b)

c)

Fig. 2.4. A trial computer-aided analysis of a porosity image (Aphelion software); material: Al_2O_3/SiO_2 fibre, AlSi matrix (silver-sprayed sample), area of 225× ; a – output image, b – unsuccessful attempt, c – grey level histogram.

To identify pores, a Philips XL 30 Everhart-Thornley SEM was used, which ensured time-independent, high-quality topographic images of the tested sample surfaces (Fig. 2.5a). The use of the back-scattered electron (BSE) detector allowed differences in the chemical composition or topography of the metallographic specimens being tested to be observed (a “campo” or a “topo” image). This allowed an image to be appropriately transformed and modified (Figure 2.5c). In images processed in this way, a porosity-type defect could be unequivocally identified in this composite (Fig. 2.5d).

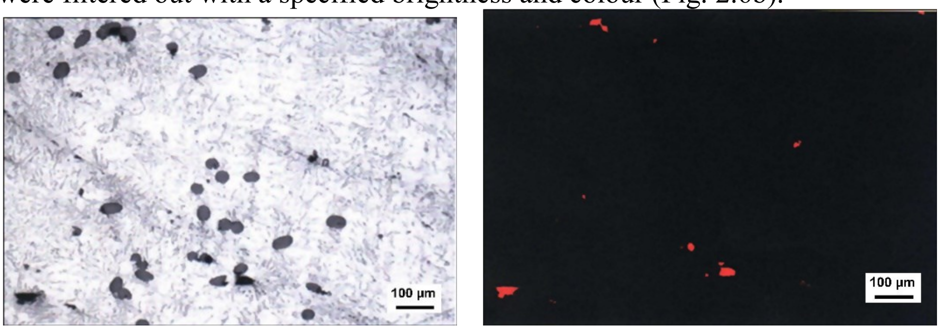


a) b) c) d)

Fig. 2.5. Example of a tested composite structure view (aluminosilicate reinforcement, AlSi11 matrix); a – SEM image, b – BSE image, c – BSE-TOPO image, d – a scheme for planimetric determination of porosity on a binary image [6].

2.2. Testing the porosity of the composite of AiSi11 and carbon fibres

Porosity was detected similarly to composites reinforced with aluminosilicate. The digital images (Fig. 2.6a) were subjected to processing with the Aphelion software. To identify objects, images were modified, and objects to be analysed were filtered out with a specified brightness and colour (Fig. 2.6b).



a) b)

Fig. 2.6. Example of porosity analysis: a – analysed area, b – porosity; computer-aided image analysis (Aphelion); composite: carbon fibre reinforcement, AlSi11 matrix; pressure of 20 MPa, optical microscopy.

In this case, there were no difficulties in distinguishing the pores from other elements of the composite. Thus, optical microscopy was determined to be sufficient to examine the porosity in composites of this group.

4. Summary

After appropriate computer processing, the image obtained from an optical microscope was sufficient to unequivocally identify a porosity-type defect in the examined surface of composites with a silumin matrix (AlSi11) reinforced with carbon fibre. Since an optical microscope image was not useful for determining the type of porosity of castings made of composites reinforced with aluminosilicate due to the presence of impurities and occlusions in the reinforcement material which may be erroneously interpreted as porosity [8-14], it was necessary to use other microscopy methods to identify pores. The examination of these materials with a scanning electron microscope was not difficult, however, the image must be prepared appropriately. Choosing the proper method to identify a porosity-type defect in the tested composites, depending on the type of reinforcement used, ensures the reliability of the subsequent quantitative assessment of this defect [1, 6, 14-20].

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