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Production of Non-Compact, Lightweight Zinc-Tin Alloy Materials for Possible Storage of Liquid Hydrogen

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Unfortunately, in connection with the application of the Actavia anti-plagiarism system, we cannot accurately describe our paper, which deals with the production of non-compact materials based on zinc and tin alloys, which have a higher density than aluminium (ρ = 2700 kg.m^{-3}) and its alloys, such as zinc alloys (ρ = 6980 kg.m^{-3}) or tin (ρ = 7580 kg.m^{-3}). Test samples were prepared from these materials, which were characterized by material non-compactness based on the use of NaCl particles. For this purpose, two different size groups of NaCl particles (3 to 5 mm and 5 to 7 mm) were used. In the production of non-compact metallic materials, it is assumed that half of the volume of the work piece cavity will be occupied by NaCl particles and half of the volume of the workpiece cavity will be filled with a melt of the relevant alloy (ZnAl4Cu1 or Sn89Pb). This is different from our previous experiments [24, 25]. In the case of this paper, the fabrication consisted in the fact that in a special preparation, the melt of the respective alloy was forced between the NaCl particles. The produced samples of non-compact material were analyzed and their specific gravities were determined. In a standard manner (as may be against the findings of the Actavia system), the microstructure was observed on an electron microscope and EDS analysis was also performed. It is anticipated that the non-compact materials thus produced from these two alloys will be used to produce not only filters but also bodies for liquid hydrogen storage.

Keywords: Non-compact material, Sodium chloride, Density, Hydrogen storage

1 Introduction

In the past five years (2018 to 2022), the Technical University of Liberec (Czech Republic, Europe) has been working on the project "Hybrid materials for hierarchical structures", research goal: Composite materials and structures, research program: Materials and structures on the metal basis, reg. No. CZ.02.1./0.0/0.0/16_019/0000843 provided by the European Union and the Czech government. This project focused on the production of metallic "lightweight" materials in the field of metallurgy. For the next five years, as part of the so-called sustainability of the project, we have to present two scientific papers on this topic every year. This is quite complicated, as we have to create and send the publications to be presented within the framework of control systems (e.g. Actavia System) to monitor the conformity of already published labels and words. By creating this publication of ours, we are trying to fulfill the tasks prescribed for the above project. Today, lightweight, cellular metal materials are increasingly being used. These lightweight materials are found in nature (bone coral, wood, etc.), [1] [2]. The following researchers have focused on the industrial production and application of non-compact (porous) ones: [3], [4], [5], [6], [7], [8], [9], [10]. Fig. 1 shows a schematic breakdown of the most commercially important methods for the production of non-compact metallic materials, [4]. As can be seen from Fig. 1, there are a number of manufacturing processes for metallic cellular materials (metal foams, metal sponges and porous metallic materials). Fig. 1 shows that there are two types of non-compact (porous) materials (open and closed cell). Closed-cell non-compact metallic materials are produced either by direct melt processing or by powder metallurgy. Open cell non-compact metallic materials are produced by polymeric sponge structures or by the use of spatial formations which are removed from the material once the metal melt has solidified. Another manufacturing factor is the use of molten metal or metal powder (although the actual foaming is always in the liquid state). Some methods have been named, others have been given a trade name after the manufacturer [3], [4].

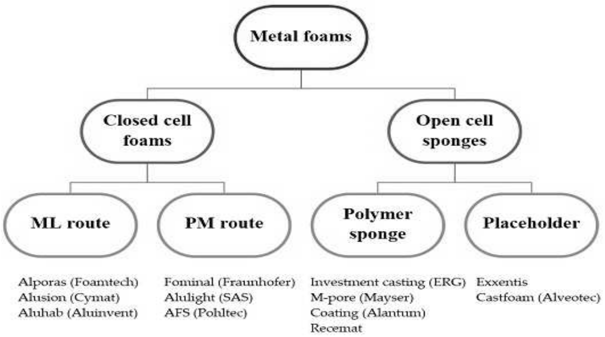
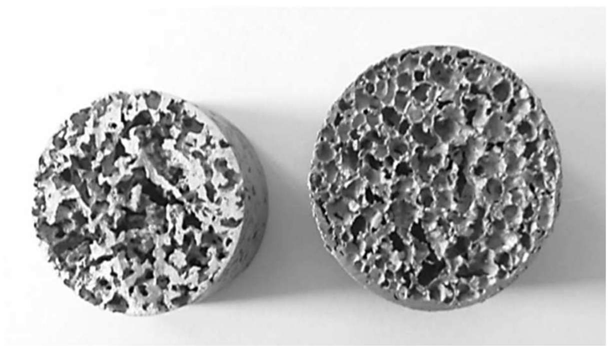


Fig. 1 *Schematic diagram of the grouping of the most commercially important manufacturing methods of GARCIA-MORENO metallic cellular systems [4]*

2 Characteristics of non-compact metallic materials

Non-compact metallic materials are basically divided into metallic foams and porous metallic materials, both types of materials are characterized by cells visible to the eye, a) porous metallic materials, i.e. materials with open cells, see Fig. 2.



(a) with open cells; (b) with closed cells

Fig. 2 *Structure of cellular metallic materials*

Metal foams are made up of closed cells and are cellular metallic materials of composite nature. They are made up of a metal matrix, very often aluminium or aluminium alloy, which surrounds the gas cells (pores). Besides aluminium alloys, copper alloys, zinc alloys or even lead alloys can also be foamed [3]. The production of metal foams, most commonly aluminium foams, is based on different production methods [2], [3] and [4]. Non-compact metallic materials have been developed for various engineering applications, [11], [12], [13], [14], [15], [16], [17], [18], [19], [20] and [21].

Non-compact metallic materials made of aluminium alloys in arbitrary shapes are produced by Exxentis (Wettingen, Switzerland) with pore diameters of 0.14 to 3 mm [22]. Also Alveotec (Venissieux, France) produces non-compact metallic materials with ordered structures [23].

3 Experimental production of zinc and tin non coppact material

The experiments focused on the production of non-compact materials from other non-ferrous metals and in the context of our earlier research are conducted [24], [25]. We focused on tin and zinc alloys and compared them with aluminium alloys. The production of these non-compact materials was based on the use of NaCl particles between which the respective metal melt was sandwiched.

Tin alloy Sn89Pb (liquid temperature 218 °C, solidus temperature 183 °C, density 7560 [kg m^{-3}]) and zinc alloy ZnAl4Cu1 (melting temperature about 388 °C, density 6700 [kg m^{-3}]) were used for this production of non-compact materials. The chemical composition of the alloys used was determined using an optical emission spectrometer, see Tab. 1 and Tab. 2.

Tab. 1 *Prescribed and actual compositin of ZnAl4Cu1 alloy*

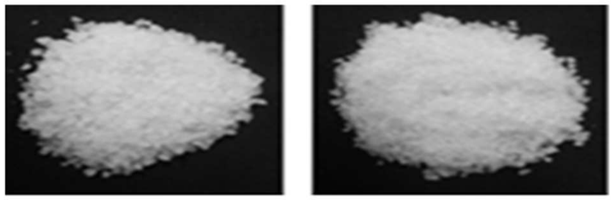
Composition according to EN 1774 [w %]									
Al	Cu	Mg	Pb	Fe	Cd	Sn	Si	No	Zn
Composition according to EN 1774 [wt %]									
3.8-4.2	0.7-1.1	0.035-0.06	≤ 0.003	≤ 0.002	≤ 0.003	≤ 0.001	≤ 0.02	≤ 0.001	Residual
Actual alloy composition									
3.91	0.83	0.05	0.002	0.0015	0.0016	0.005	0.01	0.09	95.01

Tab. 2 *Prescribed and actual composition of Sn89Pb alloy*

Sn89Pb alloy							
Pb	Bi	Fe	Cu	As	Sb	Zn	Sn
According to EN [wt %]							
11.5 - 9.5	2.0 - 3.5	≤ 0.002	≤ 0.003	≤ 0.001	≤ 0.003	≤ 0.003	Residual
Actual alloy composition							
7.9	2.6	0.001	0.003	0.001	0.0025	0.001	89.49

Particle size sodium chloride was used 5 to 7 mm and 3 to 5 mm, for the experiments, see in Fig. 3. The quality of the sodium chloride used and its analysis was reported in our publication [26].

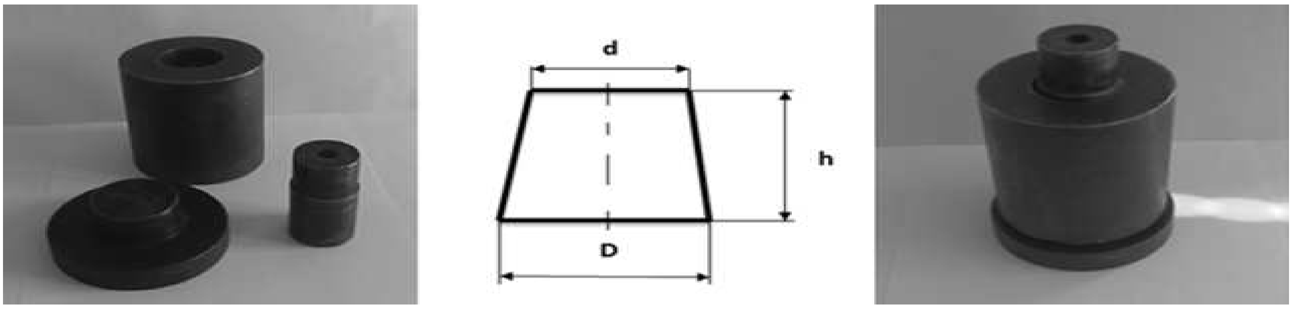
These experiments of ours were based on the injection of melt (alloy of unwanted metals ZnAl4Cu1 or Sn89Pb) between NaCl grains. For this purpose, a special jig made of EN 1.2343 steel was used, see Fig. 4, right. The melt injection jig contains a cone-shaped cavity as can be seen in Fig. 4(b).



(a) (b)

(a) 5 to7 mm; (b) 3 to 5 mm

Fig. 3 *NaCl particles used to produce non-compact materials from the alloys shown*



(a) (b) (c)

Fig. 4 *Parts of a metal jig for the manufacture of non-compact materials (a); shape of the inner part of the jig (b) jig in functional position (c)*

Fig. 5 *Alloy melting and preheating of sodium chloride in a resistance furnace*

Pressing of the respective melt between the NaCl particles into the melt was performed on a press, see Fig. 6, left. The working cavity of the jig, shaped like a cone, was chosen so that the produced samples of non-compact material could be easily removed from the jig. Our detailed mathematics for the fabrication of porous materials is given in reference [25], but is based on pressing NaCl particles into the appropriate metal melt. Fig. 7 shows the fabricated samples of the non-compact zinc alloy material ZnAl4Cu1 and tin alloy Sn89Pb. Table 3 shows the basic data of the fabricated samples of ZnAl4Cu1 zinc alloy and Sn89Pb tin alloy.

(a) (b)

Fig. 6 *Melt pressing jig for pressing the melt between the NaCl grains under the press (a), working scale of the press (b)*

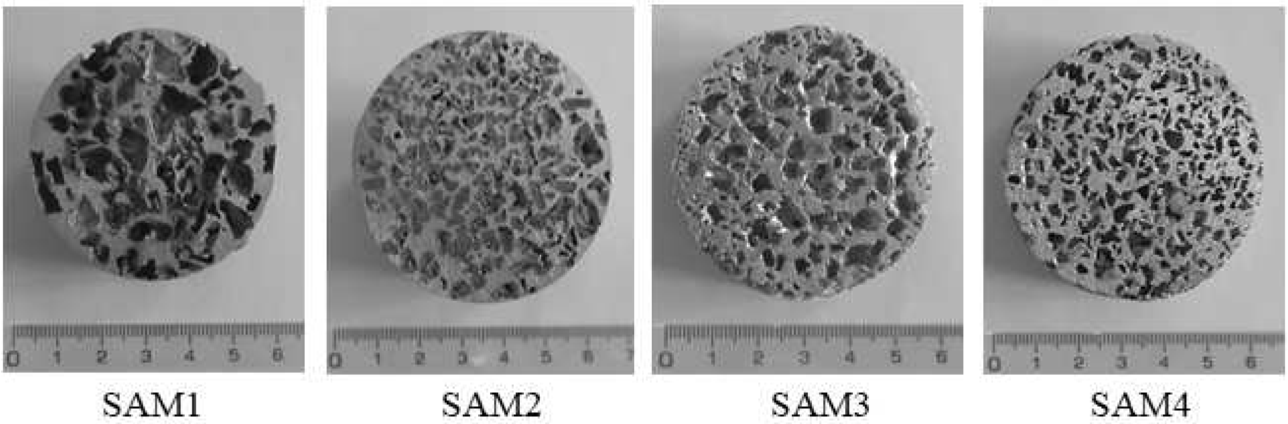


Fig. 7 *Fabricated samples of non-compact materials from ZnAl4Cu1 zinc alloy and Sn89Pb tin alloy*

Tab. 3 *Basic data on ZnAl4Cu1 zinc alloy and Sn89Pb tin alloy samples*

Alloy ZnAl4Cu1							
Samples	NaCl	D [mm]	d [mm]	h [mm]	m [kg]	V [m]^3	ρ [kg m]$^{.-3}$
SAM1	5 to 7	46.0	43.2	26.4	0.1005	$4.124 \cdot 10^{-5}$	2436
SAM2	3 to 5	45.5	41.9	32.5	0.1297	$4.875 \cdot 10^{-5}$	2661
Sn89Pb alloy							
SAM3	5 to 7	52.9	50.0	19.9	0.1091	$4.138 \cdot 10^{-5}$	2878
SAM4	3 to 5	51.3	49.5	17.8	0.1100	$3.551 \cdot 10^{-5}$	3098
Note: The meaning of D, d, h is indicated in Figure 4; m (mass of the non-compact sample), V(volume of the non-compact sample,ρ - density of the non-compact sample).							

4 Evaluation of the properties of fabricated samples from non-compact materials

Non-compact samples made of ZnAl4Cu1 zinc alloy and Sn89Pb tin alloy were analyzed. On the basis of their material characteristics, which are given in Tab. 3, Tab. 4 and Tab. 5, the values of the physical quantities were calculated. The weight of the porous samples was carried out using RADWAG WPS electronic equipment, model 4000/C/2 from RADWAG, Poland.

4.1 Properties of non-compact materials

The evaluation of the material properties of the non-compact samples of ZnAl4Cu1 zinc alloy and Sn89Pb alloy was carried out according to the methodology presented in the publication produced by pressing NaCl into the magnesium alloy melt. The methodology for evaluating the properties of the prepared porous magnesium alloy system was developed to determine the relevant physical-material characteristics is presented in reference [25]. In this context, the values of physical quantities of non-compact materials were determined. Unfortunately, in the context of the Actavia system, we have not been able to write another characterization of the content of the paper in a way that is transparent and scientifically credible. Nevertheless, the relations for the calculation are made:

4.1.1 Determination of the density of the compact material of a given alloy ϱK (Alloy)

$$\rho_{K\ (alloy)} = \frac{m_{K\ (alloy)}}{V_{K(alloy)}}, \quad (1)$$

Where:

$M_{K.(alloy)}$…The mass of the compact sample of the respective alloy (ZnAl4Cu1 or Sn89Pb) [kg],

$V_{K.(alloy)}$…The volume of the compact sample of the respective alloy (ZnAl4Cu1 or Sn89Pb) [m^3].

4.1.2 Determination of the specific density of a non-compact sample of the relevant alloy (ZnAl4Cu1 or Sn89Pb), $\varrho_{N\ (Alloy)}$ respectively $\varrho_{N\ (ZnAl4Cu1}$ and $\varrho_{N\ (Sn89Zn}$) respectively

$$\rho_{N(alloy)} = \frac{m_{N\ (alloy)}}{V_{N(alloy)}}, \quad (2)$$

Where:

$\varrho_{N\ (ZnAl4Cu1)}$…Specific density of the non-compact alloy sample (ZnAl4Cu1 or Sn89Pb) [$kg \cdot m^{-3}$],

$m_{N\ (alloy)}$…Mass of the non-compact alloy sample [kg],

$V_{N\ (alloy)}$…Volume of the non-compact alloy [m^3].

4.1.3 Determination of the relative specific density of a non-compact sample of the relevant alloy

$$\rho_{REL(alloy)} = \frac{\rho_{N(alloy)}}{\rho_{K(allloy)}} \quad (3)$$

Where:

$\rho_{REL(alloy)}$…The relative specific density of a non-compact material [1],

$\rho_{N(alloy)}$…The specific gravity of a sample of a non-compact alloy (ZnAl4Cu1 or Sn89Pb) [$kg \cdot m^{-3}$],

$\rho_{K(alloy)}$…The specific weight of a compact sample of an alloy (ZnAl4Cu1 or Sn89Pb) [$kg \cdot m^{-3}$].

4.1.4 Determination of the porosity of a sample of non-compact alloy material (ZnAl4Cu1 or Sn89Pb)

$$P = (1 - \frac{\rho_{N(alloy)}}{\rho_{K(alloy)}}) \cdot 100\ [\%] \quad (4)$$

4.1.5 Determination of Young's modulus of elasticity of non-compact material, according to the relation [26]

$$E_{N\ (alloy)} = k \cdot E_{K(alloy)} \cdot (\frac{\rho_{N(alloy)}}{\rho_{K(alloy)}})^m \quad (5)$$

Where:

$E_{K(alloy)}$…Modulus of elasticity of the observed alloy in the compact state [MPa],

k…Porosity constant [1],

m…Material constant [1].

Using equations (1)-(5), the values of physical quantities characterizing the fabricated samples of non-compact materials from zinc alloy ZnAl4Cu1 and tin alloy Sn89Zn were calculated. The values are presented in Tab. 4 and Tab. 5.

***Tab. 4** Characteristics of ZnAl4Cu1 zinc alloy non-compact material samples*

Characteristics of sample 1 and 2		
Samples	1	2
NaCl particle size [mm]	5 to 7	3 to 5
Specific density of ZnAl4Cu1 alloy$\rho_{(ZnAl4Cu1)}$ [$kg \cdot m^{-3}$]	6980	6980
Volume of compact sample 1 of ZnAl4Cu1 alloy [m^3], $V_{C1\ (ZnAl4Cu1)}$ [m^3], (∅ D = 46.0 mm;∅ d = 43.2 mm; h = 26.4 mm); Volume of compact sample 2 of ZnAl4Cu1 alloy [m^3] (∅ D =45.5 mm;∅ d = 41.9 mm; h = 32.5 mm), $V_{C2\ (ZnAl4Cu1)}$ [m^3].	$4{,}124 \cdot 10^{-5}$	$4{,}875 \cdot 10^{-5}$
Weight of compact sample 1 of ZnAl4Cu alloy; $m1_{(ZnAl4Cu1)}$ [kg]; Weight of compact sample 2 of ZnAl4Cu alloy; $m_{2\ (ZnAl4Cu1)}$ [kg].	0,286	0,340
Volume of non-compact sample 1 of ZnAl4Cu1 alloy; $V_{N1\ (ZnAl4Cu1)}$, [m^3]; Volume of non-compact sample 2 of ZnAl4Cu1$V_{N2\ (ZnAl4Cu1)}$ alloy [m^3].	$4.124 \cdot 10^{-5}$	$4.875 \cdot 10^{-5}$
Weight of non-compact sample 1 of ZnAl4Cu1 alloy; mP1 $_{(ZnAl4Cu1)}$; [kg]; Weight of non-compact sample 2 of ZnAl4Cu1; mP2 $_{(ZnAl4Cu1)}$ [kg].	0.1005	0.1297
Specific density of sample 1 of non-compact ZnAl4Cu1 alloy;$\rho_{N\ 1(ZnAl4Cu1)}$, [$kg \cdot m^{-3}$] Specific gravity of sample 2 of non-compact ZnAl4Cu1 alloy;$\rho_{N\ 2(ZnAl4Cu1)}$, [$kg \cdot m^{-3}$].	2436	2661
Relative specific gravity of a non-compact sample (1 and 2) of ZnAl4Cu1 alloy, $\rho_{REL\ (ZnAl4Cu1)}$ [1]	0.35	0.38
Porosity of non-compact sample (1 and 2) of ZnAl4Cu1 alloy; P [%]	65	62
Young's modulus of the non-compact sample (1 and 2) of ZnAl4Cu1 ZnAl4Cu1 alloy, $E_{N\ (ZnAl4Cu1)}$ [MPa].	1035	1236
Note: Young's modulus of ZnAl4Cu1 alloy, E = 85 000 MPa; k = 0.1; m = 2		

Tab. 5 *Characteristics of Sn89Pb alloy non-compact material samples*

Characteristics of samples 3 and 4		
Samples	3	4
NaCl particle size [mm]	5 to 7	3 to 5
Specific density of Sn89Pb alloy $\rho_{(Sn89Pb)}$ [$kg \cdot m^{-3}$].	7580	7580
Volume of compact sample 3 of Sn89Pb alloy, $V_{C3\ (Sn89Pb)}$ [m^3] (∅ D = 52.9 mm;∅ d = 50.0 mm; h = 19.9 mm); Volume of compact sample 4 of Sn89Pb alloy, $V_{C4\ (Sn89Pb)}$ [m^3] (∅ D =51.3 mm;∅ d = 49.5 mm; h = 17.8 mm).	$4.138 \cdot 10^{-5}$	$3.551 \cdot 10^{-5}$
Weight of compact sample 3 of Sn89Pb alloy; $m_{N3\ (Sn89Zn)}$ [kg]; Weight of compact sample 4 of Sn89Pb alloy; $m_{N4(\ Sn89Zn)}$ [kg].	0.314	0.269
Volume of non-compact sample 3 of Sn89Pb alloy, $V_{N3\ (Sn89Pb),}$ [m^3]; Volume of non-compact sample 4 of Sn89Pb alloy, $V_{N4\ (Sn89Pb),}$ [m^3].	$4.138 \cdot 10^{-5}$	$3.551 \cdot 10^{-5}$
Weight of non-compact sample 3 of Sn89Pb alloy; $m_{N3\ (Sn89Pb)}$ [kg]; Weight of non-compact sample 4 of Sn89Pb alloy; $m_{N4\ (Sn89Pb)}$ [kg].	0.1091	0.1100
Specific density of sample 3 of non-compact Sn89Pb alloy; $\rho_{N3\ (Sn89Pb)}$, [$kg \cdot m^{-3}$]. Specific density of sample 4 of non-compact Sn89Pb alloy; $\rho_{N4\ (Sn89Pb,}$ [$kg \cdot m^{-3}$].	2878	3098
Relative specific gravity of a non-compact sample (3 and 4) of Sn89Pb $\rho_{REL\ (Sn89Pb)}$ [1]	0.38	0.41
Porosity of non-compact sample (3 and 4) of Sn89Pb alloy, P [%].	62	59
Young's modulus of a non-compact sample (3 and 4) of Sn89Pb alloy, $E_{N(Sn89Pb)}$ [MPa].	677	784
Note: Young's modulus of Sn89Pb alloy, E = 47 000 MPa; k = 0.1; m = 2		

Figure 8 shows a bar graph of the density of compact ZnAl4Cu1 alloy material and non-compact ZnAl4Cu1 alloy materials using NaCl particles (5 to 7 mm) and NaCl particles (3 to 5 mm).

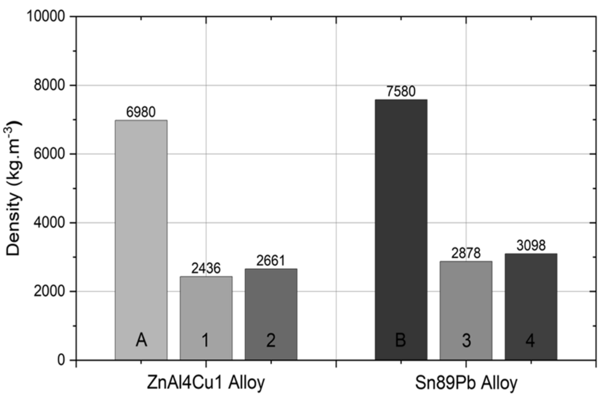


Fig. 8 *Specific densities of fabricated non-compact samples of ZnAl4Cu1 and Sn89Pb alloy*

Where:

A…Compact ZnAl4Cu1 alloy;

1…Non-compact ZnAl4Cu1 alloy (NaCl 5 to 7 mm);

2…Non-compact alloy ZnAl4Cu1 (NaCl 3 to 5 mm);

B…Compact alloy Sn89Pb;

3…Non-compact Sn89Pb alloy (NaCl 5 to 7 mm);

4…Non-compact Sn89Pb alloy (NaCl 3 to 5 mm).

4.2 Monitoring the structure of porous material samples

The open-cell structure of ZnAl4Cu1 alloy and Sn89Pb porous materials was observed using an electron scanning electron microscope (Vega Tescan, HV 20 kV SEM). Figure 7 shows a plan view of non-compacted samples 1 and 2, of ZnAl4Cu1 alloy and non compacted of samples 3 and 4 of Sn89Pb alloy, which were selected to identify their porosity. Fig. 9, Fig. 11, Fig. 13 and Fig. 15 show the structures of samples 1, 2, 3 and 4 respectively. Fig. 10. Fig. 12, Fig. 14 and Fig. 16 are their EDX analyses.

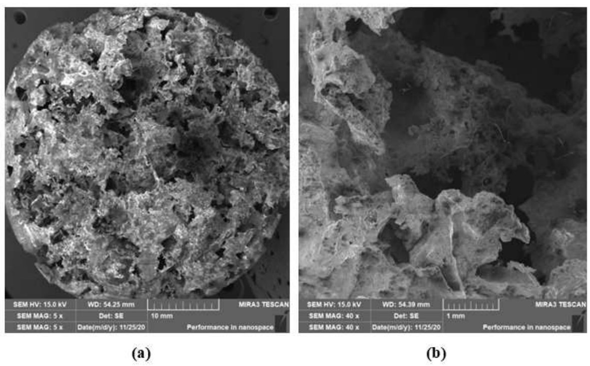


Fig. 9 *Example of the non-compact structure of ZnAl4Cu1 alloy (a), detail of non-compact structure (b), microscope (Tescan - Vega 3, SEM HV 20.0 kV), speciment 1*

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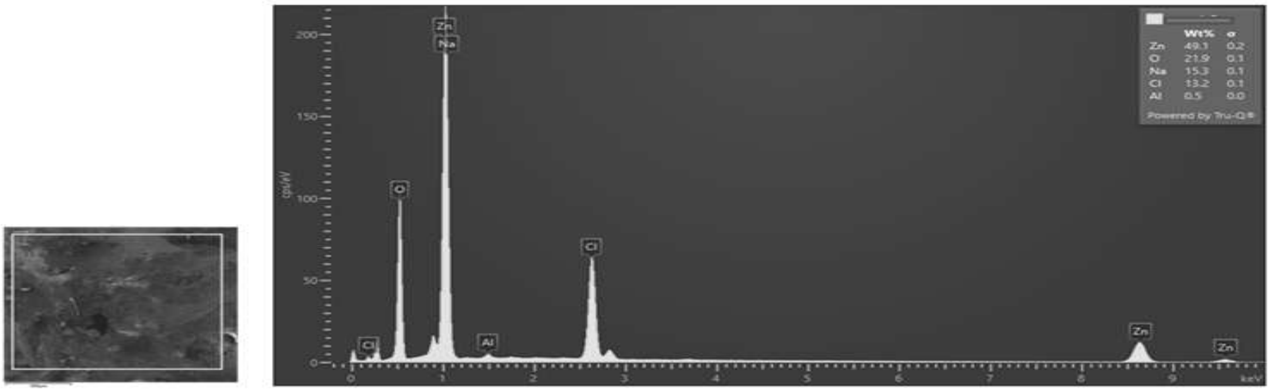
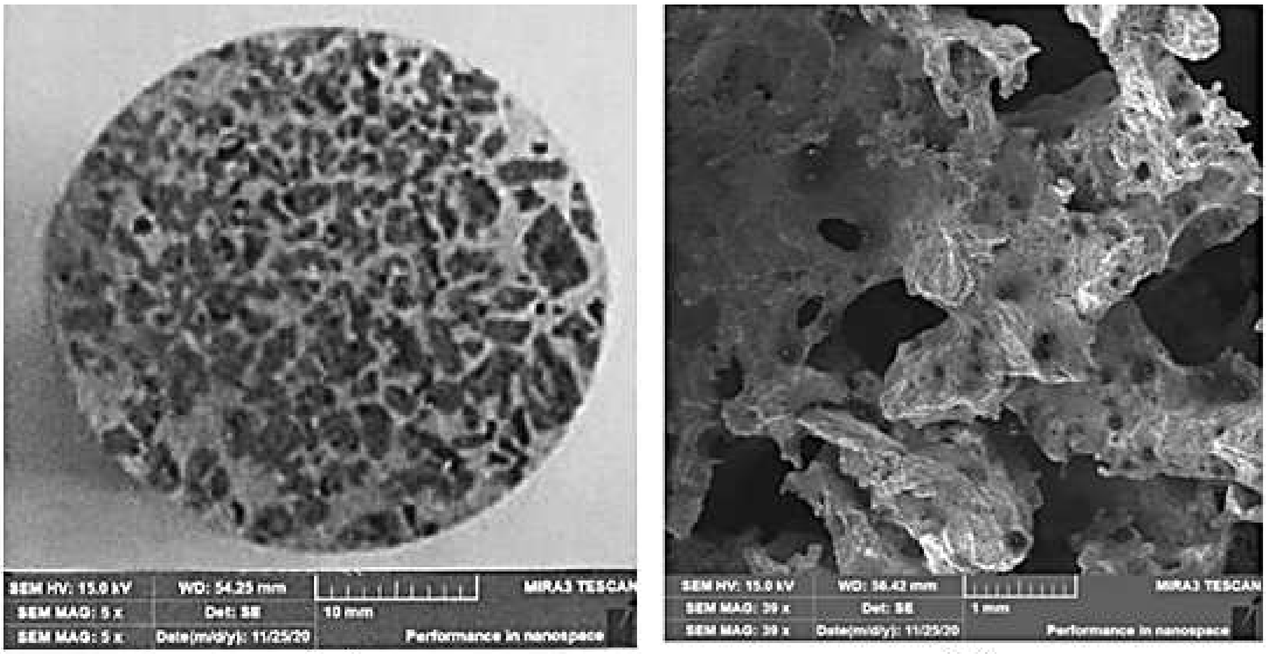


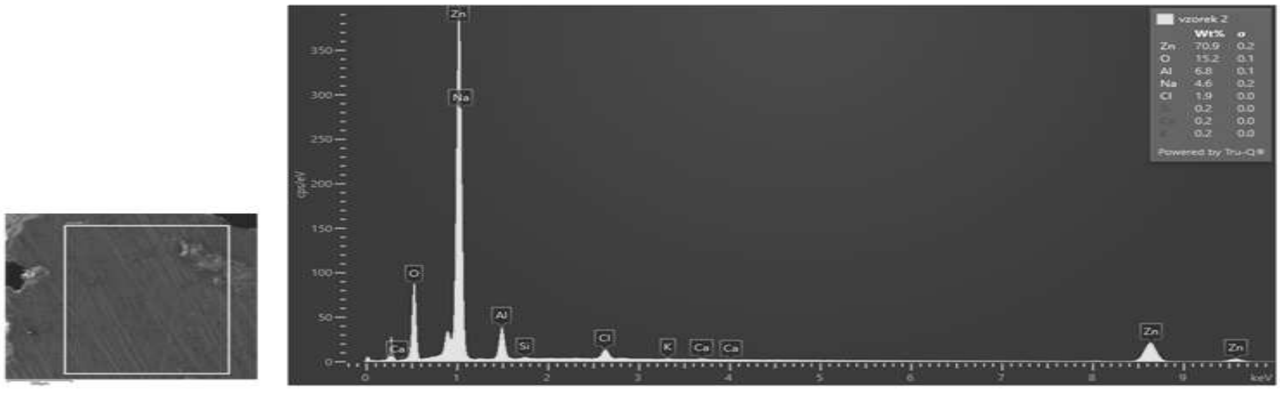
(a) (b)

Fig. 10 *EDX analysis evaluated for local chemical composition (a), chemical composition of the used ZnAl4Cu1 alloy (b); specoment 1*



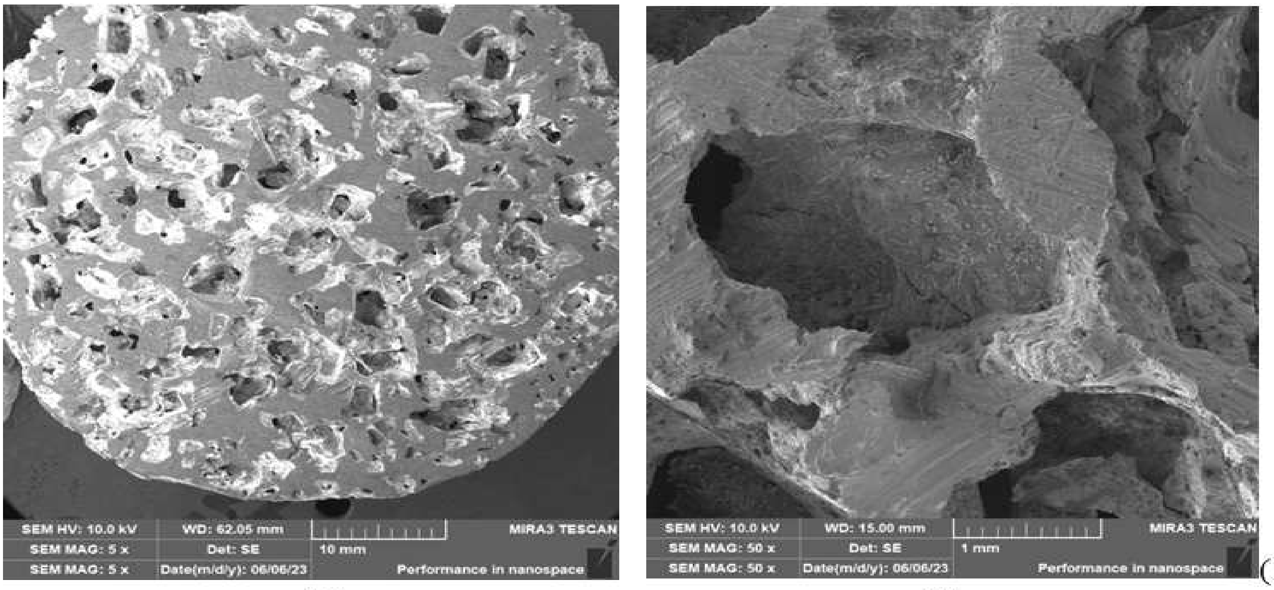
(a) (b)

Fig. 11 *Example of the non-compact structure of ZnAl4Cu1 alloy (a), detail of non-compact structure (b), microscope (Tescan - Vega 3, SEM HV 20.0 kV), speciment 2*



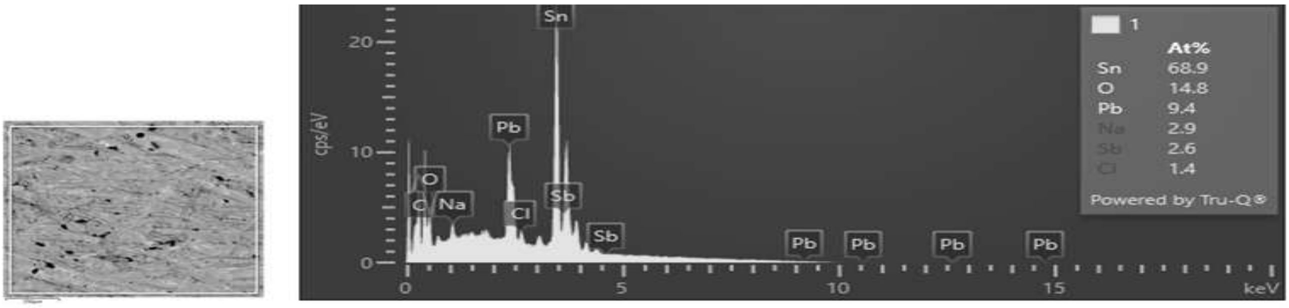
(a) (b)

Fig. 12 *EDX analysis evaluated for local chemical composition (a), chemical composition of the used ZnAl4Cu1 alloy (b); specoment 2*



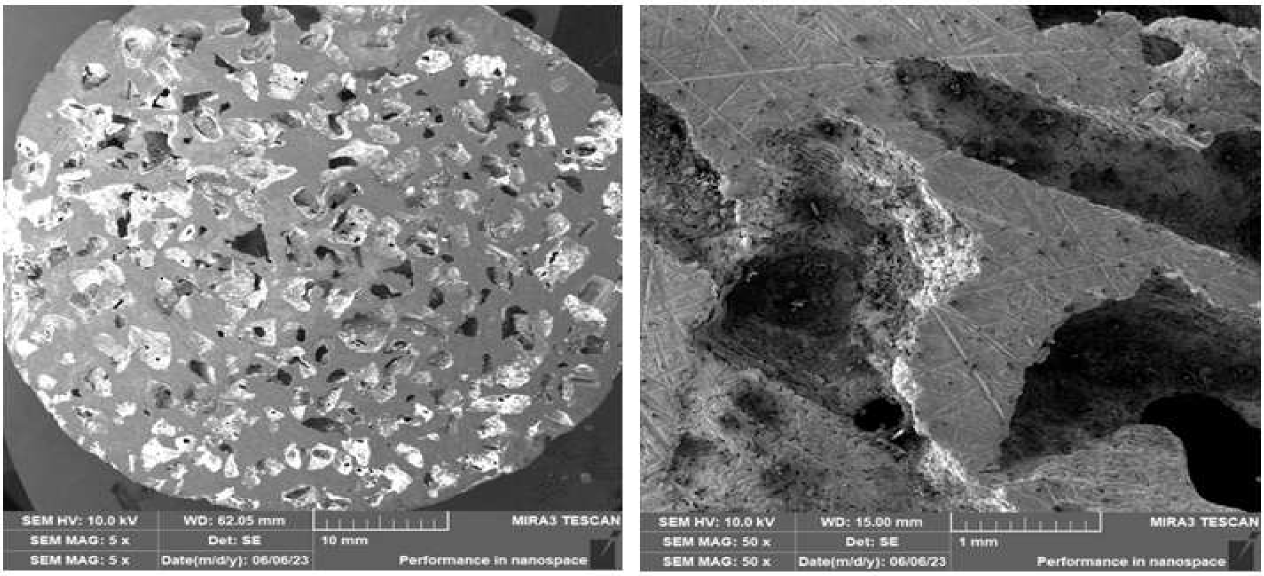
(a) (b)

Fig. 13 *Example of the non-compact structure of Sn89Pb alloy (a), detail of non-compact structure (b), microscope (Tescan - Vega 3, SEM HV 20.0 kV), speciment 3*



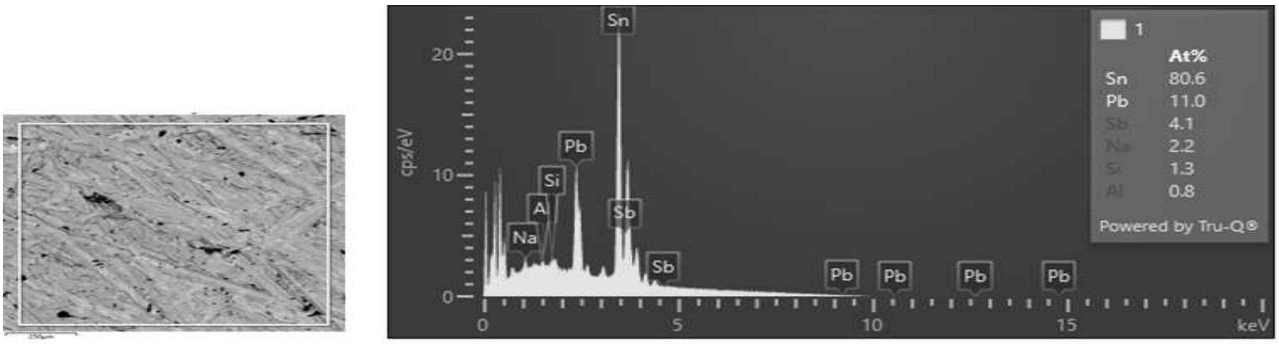
(a) (b)

Fig. 14 *EDX analysis evaluated for local chemical composition (a), chemical composition of the used Sn89Pb alloy (b); specoment 3*



(a) (b)

Fig. 14 *Example of the non-compact structure of Sn89Pb alloy (a), detail of non-compact structure (b), microscope (Tescan - Vega 3, SEM HV 20.0 kV), speciment 4*



(a) (b)

Fig. 15 *EDX analysis evaluated for local chemical composition (a), chemical composition of the used Sn89Pb alloy (b); specoment 4*

5 Discussion of results

Both alloys were used because this was a partial objective of the project No CZ.02.1./0.0/0.0/16_019/0000843. *The* choice of zinc alloys for the production of non-compact (porous materials) was based on the utility properties of zinc and the technological properties of zinc alloys. From the chemical point of view, zinc has an oxidation degree of +II. Due to the complete filling of 3d-orbitals, zinc is a diamagnetic element. Zinc does not react with hydrogen, carbon and nitrogen. The use of porous zinc materials is possible in the production of air filters. In terms of metallurgical production, zinc alloys are characterised by a simpler metallurgical process without complex metallurgical treatment of the melt, compared to aluminium alloys. The use of tin alloys has led to an enrichment of knowledge for its processing into a non-compact material. In general, tin-lead alloy is known to be characterized by very good sound properties.

Our first results on the fabrication of non-compact materials by embedding NaCl particles into molten aluminium alloy, [24], [25] suggested that such an idea of fabrication technology is feasible. As it is generally known (even considering the results of the Actavia control system), porous aluminium materials are mostly produced by infiltrating the melt between particles of suitable materials. Or by mixing NaCl particles with a suitable metal powder. Our methodology for producing non-compact zinc-tin alloy materials is based on melt infiltration between NaCl particles. For our production purposes, a preparation with an inner cavity of a conical cone has aproved very useful. The cavity was filled with NaCl particles between which the melt of the respective alloy was forced. The resulting samples of non-compact material are very valuable in their further application, i.e. for the filtration of various media in the energy industry. Our proposed methodology for the production of non-compact materials based on zinc and tin alloys well applies the higher density of both these materials.

A similar method of producing porous or non-compact materials (lead-antimony alloys) using sodium chloride was carried out by [26]. Our results of production of non-compact materials (zinc alloy ZnAl4Cu1 and tin alloy Sn89Pb) by melt injection method between 3 to 5 mm or 5 to 7 mm NaCl particles confirmed the suitability of the proposed methodology. The achieved structure can always be well presented using a scanning electron microscope, see e. g. Figure 9. With regard to the results of the Activia system, it is nevertheless necessary to mention e.g. Fig. 9, Fig. 11, Fig. 13 and Fig. 15, which show that care must be taken to ensure a uniform distribution of NaCl particles in the volume of the non-compact materials produced. The observation of a regular distribution of open cells in porous metallic material was also investigated by [27].

Using NaCl particles with sizes ranging from 5 to 7 mm, the specific gravity of ZnAl4Cu1 zinc alloy samples is approximately 2436 kg-m^{-3} , which is 35% of the density of ZnAl4Cu1 compact material. And using NaCl particles of 3 to 5 mm in size, the specific gravity of the non-compact ZnAl4Cu1 zinc alloy samples is approximately 2661 kg-m^{-3} , which is 38 % of the density of the compact ZnAl4Cu1 material. Using sodium chloride particles of 5 to 7 mm in size, the specific gravity of the non-compact Sn89Pb tin alloy samples is approximately 2878 kg-m^{-3} , which is 38 % of the density of the non-porous Sn89Pb tin alloy material. And using sodium chloride particles of 3 to 5 mm in size, the specific gravity of the porous Sn89Pb tin alloy samples is approximately 3098 kg-m^{-3} , which is 40 % of the density of the non-porous Sn89Pb alloy material. It can be assumed that these porous materials can be used for liquid hydrogen storage.

6 Conclusion

The following partial conclusions can be drawn from the above analysis:

- Porous metal materials produced using chloride particles and pressing them into the melt can be produced from ZnAl4Cu1 zinc alloy or Sn89Pb tin alloy.

- Because sodium chloride particles are water soluble, they can be easily removed from the solidified metal. This gives the solidified metal a porous integral structure. The irregular shape and inhomogeneous morphology of the pore structure in the metal is not decisive in their application for the production of various filters.
- This technological process for the production of metallic porous materials results in a relatively low specific gravity of the metallic materials. Using sodium chloride particles of 5 to 7 mm in size, the specific gravity of the ZnAl4Cu1 zinc alloy porous samples is approximately 2436 $kg.m^{-3}$, which is 35% of the density of the non-porous ZnAl4Cu1 material. The specific gravity of the Sn89Pb tin alloy porous samples is approximately 2878 $kg.m^{-3}$, which is 38% of the density of the non-porous Sn89Pb tin alloy material.
- Using sodium chloride particles of 3 to 5 mm in size, the specific gravity of the porous ZnAl4Cu1 zinc alloy samples is approximately 2661 $kg.m^{-3}$, which is 38 % of the density of the non-porous ZnAl4Cu1 material. The specific gravity of the porous Sn89Pb tin alloy samples is approximately 3097 $kg.m^{-3}$, which is 40 % of the density of the non-porous Sn89Pb alloy material.
- The use of sodium chloride is not only economically favourable but also very environmentally friendly.
- These porous materials may find future applications in liquid hydrogen storage.

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