New approach for porous materials obtaining using centrifugal casting

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Abstract. It has been presented different methods for obtaining porous materials, (mainly used for metallic foams) and highlighting a new technology developed in the Faculty of Materials science and engineering, of Iasi. Our technology for obtaining porous materials is called centrifugal casting for porous materials. This technology is included in the method number 8: co-pressing of a metal powder with a leachable powder being in the same time a newer approach in the porous materials field. This technology is currently in the developmental phase. Since now we made experiments on the metallic materials, aluminum alloys. The technology is briefly described in this paper. The obtained parts were used for making samples in order to characterize the properties of the materials. The cellular structure of metallic foams requires special precautions that must be taken in characterization and testing. In this paper we have characterized the samples structurally by its cell topology (open cells, closed cells), relative density, cell size and cell shape and anisotropy. Also it was used scanning electron microscopy (SEM) which is straightforward; the only necessary precaution is that relating to surface preparation.

1. Introduction
Porous materials offer potential for lightweight structures, for energy absorption, and for thermal management; and some of them, at least, are cheap. There are known 9 types of methods used in industry, and presented in literature since now as:

- Bubbling gas through molten alloys [1, 2];
- By stirring a foaming agent into a molten alloy [4];
- Consolidation of a metal powder with a particulate foaming [3];
- Manufacturing a ceramic mold from a wax or polymer-foam precursor [2];
- Vapor phase deposition or electro deposition of metal onto a polymer foam precursor [2];
- The trapping of high-pressure inert gas in pores by powder hot isostatic pressing (HIPing), [1];
- Sintering of hollow spheres [4];
- Co-pressing of a metal powder with a leachable powder [3];
- Dissolution of gas (typically, hydrogen) in a liquid metal under pressure [5, 6].

It has been presented a different method for obtaining porous materials, mainly used for metallic foams and highlighting a new technology called centrifugal casting for porous materials.

2. Installation and working method
It has been built a centrifugal casting machine with a vertical axis of rotation and constant speed. It is a machine that required low cost design, production, and maintenance. This type of machine (figure 2) can be used in mass production, in setting at the outset size parts, alloy nature, gravity coefficient,
mass form and its construction elements [7].

Usually such machines can be mounted on a conveyor served by several workstations (preparation of molds, pouring the liquid, solidification and cooling of the piece, extracting part).

Figure 1 shows the centrifugal casting machine with a vertical axis of rotation and constant speed. The rotation speed of the centrifugal casting machine is 1390 rot/min.

![Diagram of a centrifugal casting machine](image)

**Figure 1.** Constructive scheme of a centrifugal casting machine with a vertical axis of rotation and constant speed: 1- tacho; 2- vertical shaft for driving in rotation; 3 - form metal castings (chill); 4 – electric motor [7].

Recorded data for obtaining porous materials are as follows: Initial mass [g]: NaCl – 200; Aluminum – 230; Mass of casted piece (NaCl+Al) [g] – 327; Technological losses [g]: NaCl – 47; Aluminum – 58; Piece mass after dissolving the NaCl [g] – 203 and NaCl dissolved [g]: 124.

It was used food grade salt, grit between (1.6-2.2)mm. The salt was dried at 720°C for 30 minutes.

![Image of a centrifugal casting machine](image)

**Figure 2.** Centrifugal casting machine with vertical axis of rotation and continuous variation of speed: 1 – push buttons; 2 – electromotor of alternating current, three phase; 3 - mainboard; 4 - protective case; 5 - centrifugal casting machine body.

### 3. Results and discussions

The characteristics of a foam are best summarized by describing the material from which it is made, its relative density, \( \rho/\rho_s \) (the foam density, \( \rho \), divided by that of the solid material of the cell wall, \( \rho_s \)), and stating whether it has open or closed cells.

\[
\rho/\rho_s = \frac{1.66}{2.7} = 0.61 \text{ [g/cm}^3\text{]} \tag{1}
\]

where: the foam density \( \rho = 1.66 \text{ [g/cm}^3\text{]} \) and the solid material of the cell wall density \( \rho_s = 2.7 \text{ [g/cm}^3\text{]} \).
Figure 3 shows casted part and the measured dimensions of our sample which was obtained in the laboratory on the centrifugal casting machine with vertical axis of rotation and continuous variation of speed.

The porous material poured show open pores with uniform distribution due to centrifugal force and vibration that occurs in the machine shaft which presses and forces the particles to occupy the position most favorable to a volume as small pore of them. Knowing that salt particles are actually topology after dissolution voids results, it can be said that by this method can get a good index factor of relative density. This index expresses the uses degree of the material.

In the 4b image is observed salt particles included in the solidified melt casting shape wall. Seeing this figure it can be said that the outside pores are open.

![Figure 3. Casted part and the measured dimensions.](image)

**Figure 3.** Casted part and the measured dimensions.

![Figure 4.](image)

**Figure 4.** a) Centrifugal casting piece; b) details on the external surface after the casting; c) detail on the inner surface of the workpiece after the dissolution of the salt.

In the following figures are presented macrographs (figure 5) and micrographs (figure 6) SEM, chemical analysis (figure 7) performed on EDX analyzer probe and scanning electron relief obtained (figure 8).

![Figure 5.](image)

**Figure 5.** Porous aluminum alloy, macro graphic obtained at a magnification of 10x.
Figure 6. SEM image of the structure of the porous material obtained by centrifugal casting: a) SEM image of 2mm to increase; b) 3D topography obtained from scanning electron; c) pore size.

Table 1 shows the size and number of the measured pores.

| Value          | \(x\) [mm] | \(y\) [mm] | \(d\) [mm] | \(r\) [mm] | \(d\) [mm] | \(C\) [mm] |
|----------------|------------|------------|------------|------------|------------|------------|
| Obj. count     | 3          | 3          | 5          | 3          | 3          | 3          |
| Summation      | 14.98      | 37.63      | 5.58       | 1.50       | 3.00       | 9.41       |
| Min. value     | 3.66       | 9.97       | 0.75       | 0.39       | 0.78       | 2.45       |
| Max. value     | 5.71       | 15.32      | 1.47       | 0.62       | 1.23       | 3.88       |
| Average value  | 4.99       | 12.54      | 1.12       | 0.50       | 1.00       | 3.14       |
| Std. dev.      | 0.94       | 2.19       | 0.28       | 0.09       | 0.19       | 0.58       |

It has been structurally analyzed at higher magnification and the results are shown in the following images (figure 7).

The above image is obtained by scanning electrons microscope and capture area of a single pore formed by a salt crystal (subsequently dissolved). It was also observed on the wall surface of the micro porous material inside the pores the appearance of the micro pores. There are two possible causes for these micro pores existence. The first one refers to the small salt crystals adherent to the main crystal surface. The existence of these small crystals is the result of large crystals breakage during operation of dehydration or strong adhesion to the surface of large crystals vibrating sorting operation. The second one can be the appearance of the gas micro bubbles due to the relative humidity of the salt.

Figure 7. Analysis of the microstructure and relief within a macro pores: a) direct image 2D, b) 3D processed image.
Next is presented a preliminary analysis of the micro pores main cavities (figure 8, table 2).

![Figure 8. Dimensions between the pore walls.](image)

**Table 2.** Macropore dimensions on the walls of main pores.

| Value             | x [mm] | y [mm] | d [mm] | r [mm] | d [mm] | C [mm] | A [mm²] |
|-------------------|--------|--------|--------|--------|--------|--------|---------|
| Obj. count        | 22     | 22     | 5      | 22     | 22     | 22     | 22      |
| Summation         | 81.80  | 96.11  | 5.00   | 1.74   | 3.47   | 10.91  | 0.46    |
| Min. value        | 0.15   | 1.57   | 0.68   | 0.05   | 0.10   | 0.30   | 0.01    |
| Max. value        | 7.32   | 6.56   | 1.53   | 0.13   | 0.26   | 0.81   | 0.05    |
| Average value     | 3.72   | 4.37   | 1.00   | 0.08   | 0.16   | 0.50   | 0.02    |
| Std. dev.         | 1.94   | 1.46   | 0.31   | 0.02   | 0.04   | 0.12   | 0.01    |

In table 3 are presented chemical analysis of the sample and chemical compositions made with EDX analyzer.

**Table 3.** Chemical analysis of the sample.

| Element     | AN | series | Net | [wt.%]   | [norm. wt.%] | [norm. at.%] | Error in [%] |
|-------------|----|--------|-----|----------|--------------|--------------|--------------|
| Aluminium   | 13 | K-series | 188131 | 74.46546297 | 77.79212988 | 78.47717861 | 3.760295    |
| Silicon     | 14 | K-series | 14413 | 21.25818296 | 22.0787012 | 21.52282139 | 1.004575    |
| Sum:        |    |         | 95.72364593 | 100       | 100           |             |             |

4. Conclusions

Compared with previous methods the centrifugal casting presents the following advantages:

- shows a high degree of safety in use as it requires no hazardous substances (gas introduced into the melt);
- preliminary operations are minimized because there are not necessary performs (precursors);
- reduced costs for raw materials and energy;
- installation is easy to maintain and does not require expensive operations and parts;
- it is not necessary to control operating parameters such as pressure, cooling rate;
- this method allows obtaining various pore sizes materials, which are uniformly distributed in the material volume;
• in industrial application the foaming agent may be recovered. After dissolving the salt, brine can be recycled by water evaporation;
• centrifugal casting technology is generally a well-known technology and this new technique can be used for obtaining porous materials just by using existing know how;
• unknown in specialized literature, using centrifugal casting technique is an original method for obtaining porous materials.

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