

# PRODUCING OF THE CAST MOULDS WITH GYPSUM MIXTURES BY CAPILLARY MOULDING

## ИЗГОТОВЛЕНИЕ ЛИТЕЙНЫХ ФОРМ ИЗ ГИПСОВЫХ СМЕСЕЙ МЕТОДОМ КАПИЛЯРНОЙ ФОРМОВКИ

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**Abstract:** This report represents the results from applying of capillary moulding for obtaining of moulds made of gypsum mixtures. Different technological methods and the influence of some factors over the tensile strength and over the quality of the structure of the obtained moulds have been researched. Moulds, obtained by investment casting made of gypsum-sand mixtures using capillary moulding have been manufactured and the quality of these moulds has been examined. The utilization of building pearlite as a fireproof filling in the mixtures has been experimented and the achieved results have been described.

**KEYWORDS:** GYPSUM MOULD, CAPILLARY MOULDING, LOST-WAX PROCESS, SILICA SAND

### 1. Introduction

The portion of the castings that require high dimensional and geometrical accuracy and low surface roughness is increasing in the contemporary foundry. Despite of the increasing number of the materials, technologies and methods, used for producing of so called “accurate castings”, the precision investment casting is one of the most advanced methods. The moulds of precision investment casting are made of different materials and using different technologies mainly depending on the material of the produced moulds. Gypsum moulds are widely used in casting using precision investment casting of non-ferrous metals as copper and aluminum [4,5,6]. These moulds are made of liquid pouring gypsum mixtures and have a lot of advantages. The most important advantages are:

- Comparatively low price of the used materials.
- Significant reducing of the technological cycle length, especially in comparison with the traditional siliceous shell moulds.
- Lower temperatures of baking
- Lack of toxic, fire burning and other noxious compounds in their composition
- Very good driving out.

The report purpose is to be expanded the possibilities of casting moulds made with these mixtures.

### 2. Experimental procedure

The composition of the liquid pouring gypsum mixtures normally includes: strengthened ( $\alpha$ -modification) or ordinary ( $\beta$ -modification) gypsum used as a bonding material, fireproof filling, water, supplements that affect particular features of the received moulds [3,4,5,7,8]. When using traditional methods first of all the so-called “dry mass” is being prepared by mechanical mixing of the gypsum and the fireproof filling in a strict proportion. The “dry-mass” is introduced on parts in the water having in mind the chosen water-mass ratio – the ratio between the quantities of the water and the dry mass. During the process a continuous mechanical mixing is going on until receiving a homogenous liquid-pouring mixture. This mixture is poured in a preliminary prepared mould box with a fixed casting pattern. Crystals of  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  are produced as a result of the interaction between the water and the gypsum. Stiffening of the mixture and the casting mould are the result of the interaction of  $\text{CaSO}_4$  and  $2\text{H}_2\text{O}$ . [10]. The next step is drying of the mould, taking out of the lost-wax pattern, baking at a temperature  $750^\circ\text{C} - 800^\circ\text{C}$  and pouring with melt [3,5,8,9].

Two main problems arise very often during manufacturing of the gypsum moulds by the described method. These problems affect on the quality of the received moulds and castings [4,5,7].

1. The mechanical mixing when causes air bubbles to be trapped in its volume. Part of them adsorbs on the surface of the moulds and causes defects to the surface of the castings. Vacuuming of the gypsum mixture must be done

before and after its pouring in the mould box in order to remove this problem.

2. Easily noticeable sediment of the mixture happens when using fireproof filling with bigger grains (silica sand, shamote) This causes problems when pouring the mixture in the mould box and decreases the quality of the received moulds.

The main purpose of the researches that have been made in the present work is to remove the indicated problems and to expand the technological ways for using of gypsum liquid-pouring mixtures when manufacturing moulds by investment casting. The way of manufacturing of gypsum moulds by applying the method “capillary moulding” has been examined for this purpose. As it is known, one of its main features is that the producing of the mould mixture is done in the box, without applying mechanical mixing in order to mix the compounds. [1,6] The very good results of its applying, when manufacturing moulds, made of different kinds of sand mould mixtures, are also known. [2].

The mixtures, which have been used for conducting of the researches in the present work, have the following composition: gypsum, foundry silica sand, water. Some technological methods have been established and researched due to the special features of producing gypsum mixtures and moulds from them. The main differences between them are in the consequence of the operations when producing the mixture and the mould and the ratio of the compounds of the mixture. Figure 1 shows the principal scheme of gypsum-sand mixture mould manufacturing by means of “capillary moulding”. Different technological versions for carrying out of the process are shown on figure 2.

The received experimental samples have been dried at room temperature during 24 hours and after that have been baked using typical for gypsum mixtures regime:  $750^\circ\text{C}$  temperature and 1 h holding time.

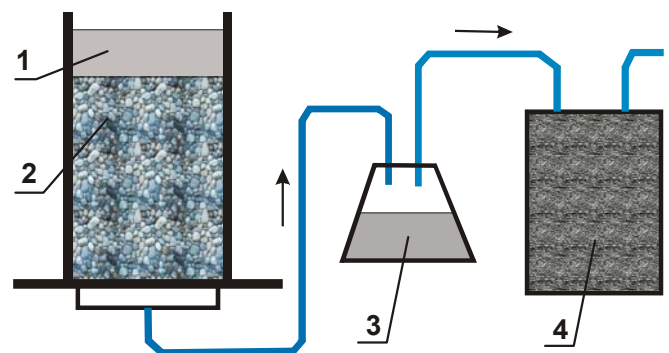


Figure. 1 Principal scheme of capillary moulding  
1 – liquid compound      2 – fireproof filling  
3 – intermediate container      4 – vacuum system

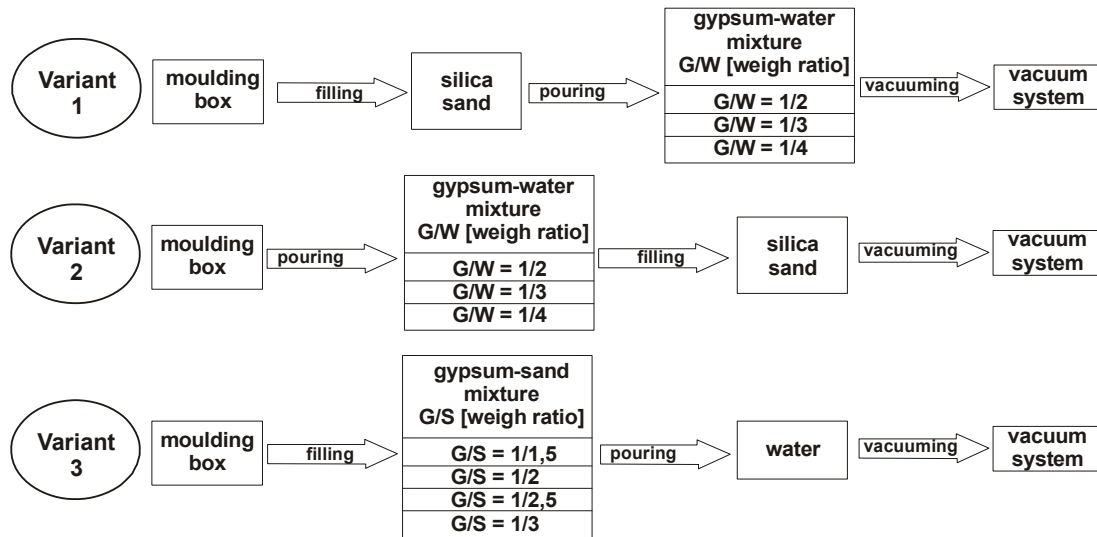


Figure 2. Technological variants of obtaining of moulds made of gypsum mixtures by capillary moulding

Experimental samples of the type "eight" (figure 3) have been made and their tensile strength  $R_r$  have been examined. The results are used to be determined the influence of capillary moulding version preparing and the ratio of the mixture compounds on the strength.



Figure 3. Sample for determining of the tensile strength  $R_r$

Gypsum moulds have been produced by means of capillary moulding and lost-wax patterns. They are used for an estimation of the moulds quality.

Experiments for producing of gypsum moulds with fireproof filling „building pearlite” have been carried out additionally. The traditional technology for preparation of the liquid-pouring mixture by means of mechanical mixing of the compounds is practically not applicable because of the pearlite low specific weight.

### 3. Results and discussion

#### 3.1. Moulds production by means of capillary moulding

The technological variants of applying capillary moulding have been investigated. It can be accepted that **Variant 1** (figure 2) is practically not applicable for receiving of a good quality mould. The mixture of gypsum and water penetrates on a small depth after its pouring on silica sand that has been preliminary filled in the mould box. The gypsum particles fill the spaces between the sand grains and generate a dense layer with determinate thickness, which prevents the filling of the sand remaining part with a bonding substance. In this case the application of vacuuming does not improve mould quality. Figure 4 shows an experimental pattern that

has been made by this method using gypsum-water weigh ratio of the mixture 1: 4.

Figure 5 shows the result of **Variant 2**. In this case, first of all, the preliminary prepared gypsum-water mixture is poured in the casting box. The silica sand is introduced on portions after that and the vacuum system is turned on after filling up the volume of the box. The extra quantity of water, which has not reacted with the  $\text{CaSO}_4$ , passes in to intermediate container. Figure 5 shows a longitudinal cross-section of the gypsum mould, produced by the described method. The mould structure is comparatively homogenous without signs of sediments or layer separations. It can be noticed however that there are spaces between sand grains without bonding substance. Such kind of zones can be spotted mainly on the patterns that have been poured with a mixture with a gypsum-water weigh ratio of the mixture 1:2. Possibly the main reason for this is the low fluidity of this mixture.



Figure 4. Sample, obtained by Variant 1; weigh ratio G/W = 1/4

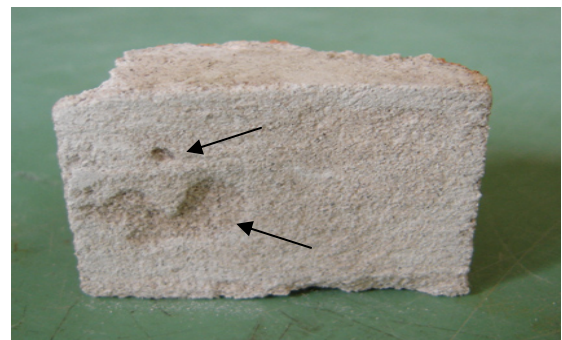


Figure 5. Sample, obtained by Variant 2; weigh ratio G/W = 1/2

The best quality of the structure of the gypsum moulds is achieved when applying **VARIANT 3**. In this case, first of all, the box is filled with “dry mixture” with the corresponding ratio between the gypsum and the silica sand. The water is poured onto it and the vacuum system is turned on. As a result of the created difference in the pressure, the water goes through the spaces between the sand grains in force, interacts with the gypsum and the extra quantity of it is separated in the intermediate container. Except this, as a result of the vacuuming process, the gypsum mixture becomes more dense which improves the quality of the imprint and prevent the creation of air bubbles and sediments. Figure 6 shows a view and a longitudinal cross-section of the gypsum mould, produced by that way.



Figure 6. A view and a longitudinal cross-section of a sample, obtained by Variant 3; weigh ratio G/W = 1/2

### 3.2 Strength of capillary moulded gypsum mixtures

The results of the gypsum mixtures specimens examination of the tensile strength  $R_r$ , using Variant 2 and Variant 3 of capillary moulding, are shown on figure 7 and figure 8. It is clear that the strength of the gypsum moulds variant 2 decreases significantly when the quantity of the water increases in the gypsum-water mixture. The decreasing of the strength is nearly 8 times when gypsum-water weigh ratio of the mixture changing from 1:2 to 1:4. On the other hand, the increasing of the quantity of the water, as it is shown above, improves the fluidity of the gypsum-water mixture and farther improves the filling of the mould and makes its structure more homogenous. This leads to the conclusion that when using silica sand as a fireproof filling, the correct gypsum-water weigh mixture ratio is around 1:2. This ratio help to be achieved a good combination between quality of the structure and the strength of the obtained moulds.

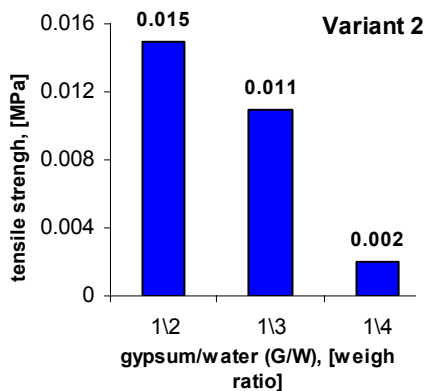


Figure 7. Influence of the compound of the gypsum-water mixture over the tensile strength of samples, obtained by Variant 2

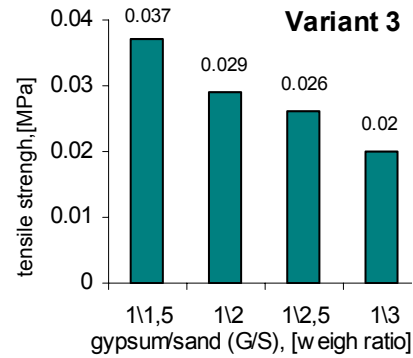


Figure 8. Influence of the compound of the “dry mass” over the tensile strength of samples, obtained by Variant 3

The gypsum moulds strength, obtaining by variant 3 of capillary moulding, depends on the composition of the “dry mass” mainly. The influence of this factor is similar for traditionally obtained gypsum moulds by mechanical mixing of the compounds. The tensile strength decreases from 0,037 MPa to 0,020 MPa when the gypsum-sand weigh ratio of the mixture changing from 1:1,5 to 1:3. No important visible differences in the filling of the spaces around the sand grains and in the mould structure of are observed. We can put the stress on the fact that, as a whole, the strength of the gypsum moulds, obtained by Variant 3 is significantly better than the strength of the moulds, obtained by Variant 2. This can be explained with the fact that the required fluidity of the gypsum-water mixtures, used in method 2, is achieved by means of less gypsum quantity in the gypsum-water mixture. That gypsum quantity affects badly on the strength of the obtained gypsum moulds.

Obtaining of real gypsum moulds by capillary moulding using method 3 checks the carried out experiments, having in mind the received results. A view of a cut mould after drying, separating of the melted pattern and baking at 750 °C temperature is shown on figure 9. It is clearly visible that the quality of its working surface is very good and defects consisting air bubbles have not been spotted on it.



Figure 9. Gypsum mould obtained by lost-wax pattern by capillary moulding by Variant 3; compound of the “dry mass” G/S = 1/2,5 weigh part

### 3.3 “Building pearlite” using as a fireproof filling

Some extra studies for utilization of building pearlite as a fireproof filling have been made on the basis of the good results concerning the possibilities of obtaining gypsum mixtures and moulds from them by capillary moulding. The main advantages of such moulds are the considerable reducing of their weigh, which strongly reduces the technological work concerning them, especially when the volume of the moulds is big. Except this, the

low heat conductivity of the pearlite provides better fluidity when obtaining complex thin-section castings made of light alloys, for example, aluminium alloys.

The manufacturing of gypsum moulds made of mixtures that consist pearlite filling, produced by mechanical mixing, is practically impossible because of the high level separation of the layers of the mixture. That is a result of the low specific weigh of the pearlite. The applying of capillary moulding in this case nearly completely prevents this effect and makes possible the obtaining of high quality gypsum-pearlite moulds. An engineering sample, made of this mixture and produced by Variant 3 of capillary moulding, is shown on figure 10. The composition of the "dry mixture" in this particular case is with gypsum-building pearlite volume ratio 1:2 vol. parts.



Figure 10. A sample made of gypsum-building pearlite mixture by capillary moulding by Variant 3; compound of the "dry mass" G/BP = 1/2 vol. part

#### 4. Conclusion

The carried out investigations and the obtained results allow some conclusions to be made. The more important of them are:

- The method "capillary moulding" can be successfully applied in lost-wax process for obtaining of gypsum mixture moulds.
- The best results from the examined technological variants are received at capillary moulding Variant 3 applying. The method includes: preliminary filling of the moulding box with "dry mixture" following by the subsequently water quantity introducing.
- The structure homogeneity and the gypsum mixtures moulds strength, obtained by capillary moulding, considerably depend on the composition of the gypsum-water mixture, when using Variant 2 and on the "dry mixture", when using Variant 3.
- The tensile strength of the mixtures, obtained using Variant 3, is considerably higher than the tensile strength, obtained using Variant 2.
- The applying of capillary moulding allows obtaining of high quality gypsum moulds using building prelate, one no traditional material for this kind of moulds, as a fireproof filling.

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