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# LOST FOAM CASTING
# - A PROMISING TECHNIQUE IN APPLIED ART -

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**ABSTRACT:**
The article presents some theoretical and practical aspects regarding the casting of alloys in lost foam moulds. The stages of the procedure, the economic benefits and several ecological aspects are synthetically presented.

**KEY WORDS:**
casting, alloys, lost foam, foundry mixture without binding

## 1. INTRODUCTION

The procedure of casting in lost foam moulds has been systematically researched since 1940. The technical-economic benefits of this procedure determined the implementation of the research results in highly industrialized countries like: USA, Japan, Germany, England, France, Russia and Italy.

The described procedure can be applied in obtaining decorative objects through casting and also references for different industrial fields (machine and naval industry, aeronautics, a.s.o.). A large area of ferrous (irons and steels) and nonferrous alloys (aluminium, magnesium, copper-based alloys) can be cast.

The article presents some theoretical and practical aspects regarding the lost foam mould casting of alloys. The phenomena appearing during the procedure, the economic benefits and several ecological aspects are synthetically presented.

## 2. THE ANALYSIS OF THE TECHNOLOGICAL LOST FOAM CASTING PROCEDURE

The essential steps of the lost foam casting procedure are: the execution of patterns, execution of moulds and casting the alloy.

### 2.1. GENERAL PRINCIPLES AND TECHNOLOGICAL ALTERNATIVES

The casting technologies principle which uses lost foam consists of the execution of polystyrene pattern, the execution of the casting mould covering the material in a refractory material and its consolidation.

The lost foam casting procedure is applied in two technological alternatives: FM (FULL MOULD) – casting in full mould, an alternative similar to the classical casting and CS (CERAMIC SHELL) – casting in ceramic shell, an alternative similar to casting in ceramic shells slightly fusible.

### 2.2. MATERIALS FOR PATTERNS AND METHODS OF EXECUTION OF LOST FOAM

The first and most important step of the lost foam casting procedure (because it directly influences the quality of the surface and the dimensional precision of the cast piece) is choosing the material for the execution of patterns. In respect of obtaining the proper cast piece, these materials are imposed strict conditions of quality, as follows:

- the sufficient resistance to a minimum density;
- the sufficient elasticity to minimise the permanent distortions;
- workability as easy as possible through expansion, injection or on machine tools;
- low values for heat consumption and volume of gases released at volatilization;
- high speed of volatilization at the contact of the casting alloy;
- few solid/liquid pattern's products formed at the disintegration caused by alloy heat;
- non-adherence at the moulding compound;
- non-dissolution in casting dyes or carpentry glues;
- non-generator of toxic products while working or volatilization.

Choosing the materials for the lost foam is performed taking into account: the casting procedure (FM or CS), the type of alloy cast and the characteristics of the cast piece (size, dimensional precision and wall thickness, size of the series of fabricated products…).

Literature recommends the following types of materials for lost foam: expended polystyrene (EPS), poly alkyl carbonate (PAC), polymethyl methacrylate (PMMA), or polymer with low content of carbon (LPC).

**Polystyrene**, expanded or nonexpendable, represents most often used raw material in the industry for the lost foam execution. Table 2 synthetically presents the initial phases and the properties of the expanded polystyrene used in the lost foam execution, in different phases starting with the raw material to the lost foam.

The execution procedures of the lost foam are professional secrets, the specialized publications containing few concrete technical data. There are specialized companies that execute lost foam and provide, along with the pattern, instructions for use and storage.

The execution of the lost foam patterns implies to work the raw material (expandable polystyrene granules) in two steps:

- *pre-expansion of the polystyrene granules*, in the presence of the saturated and dry vapour, at 110…120°C, resulting a 3…5 times dilatation of the initial particles volume;

- *expansion of the pre-expanded polystyrene granules*, in the presence of a dry vapour, at 110…120°C, resulting a volume increase of 40...50 times of the initial diameter (in fact the effective execution of the pattern).

**Table 2.** The main phases of transformation and properties of the expanded polystyrene

| **Steps for the material working** (phases of the material) | **Properties / Characteristics** | **Result** (accomplishment) |
|---|---|---|
| **Raw material** (expanded polystyrene granules) | • expandable polystyrene is found as small particles and has a glassy aspect;<br>• the polystyrene contains 94%C and ~4% $H_2$ and rest tracks of other elements<br>• apparent density in bulk ρ=600-700kg/m³<br>• density $\rho=1{,}05\cdot10^3$kg/m³<br>• resistance to: alkali, alcohol, mineral and vegetable oils, acids, water<br>• soluble in: ether, benzene, esters, acetone, chlorinated hydrocarbons<br>• stable up to 70-80°C,<br>• discontinuous structure<br>• thermoplastic, good heat and electric insulator<br>• PSE symbol by the IUPAC polymers schedule | • the expandable polystyrene is obtained by styrene polymerization (block or emulsion)<br>• styrene:<br>• is represented by $C_8H_8$ formula<br>• molar weight 104,14<br>• is a colourless to yellowish liquid<br>• is hardly water, alcohol, ether, acetone, carbon sulphide soluble |
| ↓ **Pre-expansion** (pearls of pre-expanded polystyrene) | • the pre-expanded polystyrene is found as small white particles<br>• after the pre-expansion the glassy aspect disappears<br>• density in bulk ρ=15-30 kg/m³ | • the pre-expanded polystyrene is obtained through a heat treatment of pre-expansion, at temperatures between 110-120°C<br>• there are more pre-expansion procedures |
| ↓ **Drying** (pearls of pre-expanded polystyrene) | | • it is performed with the purpose of eliminating the water surplus during the pre-expansion<br>• drying is performed in liquefy bed (min. 6 hrs, max. 24 hrs) at the environmental temperature |
| ↓ **Storage** (pearls of pre-expanded polystyrene) | | • it is performed with the purpose of removal the tensions that appear on pre-expansion |
| ↓ **Expansion** (expanded polystyrene) | • The expanded polystyrene has the aspect of a solid spongy material with up to 5000 cells /cm³<br>• the specific weight vary from 160 N / m³ for light categories to 400-600 N / m³ for very dense categories (lower than the normal polystyrene)<br>• the physical-mechanical characteristics of polystyrene are influenced by its density<br>• the chemical properties are not modified by expansion | • the expanded polystyrene is obtained through a heat treatment of expansion at:<br>- temperature of 110-120°C<br>- pressure $p=0{,}33\text{-}1{,}75\cdot10^5$ N/m² |

To applied this technology is needed only the pattern of the piece and of the funnel which are been polystyrene-made (components that are positioned inside the casting mould). These components are assembled through sticking or fixing with special elements - figure 1.

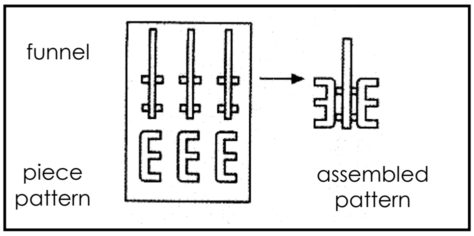


FIGURE 1. The components of a polystyrene pattern
and the assembled pattern for mounting in the cast mould

### 2.3. FULL MOULDS WITH LOST FAME PATTERNS

The most important properties of the moulding component are: good filling capacity, reduced abradibility towards tools, devices and verifiers, high permeability, low sensitivity for succeeding castings and a low cost price.

The granulation of the moulding materials is very important, influencing the cast piece quality, as follows: good permeability at high granulation and good reproduction of the pattern configuration at low granulation. Because these criteria are contradictory, the practical experience imposed the use of materials with a granulation between 30…55 AFS, depending on the cast alloy, the permeability of the mould, etc. It must be underlined that the process of ramming vibration and its influence on the lost foam pattern strain has been not enough studied and the researches are still pursued.

As moulding material are used: sand without binder, sand and water for which the binding is performed by frizzing (frozen shapes) or metallic shots for which the mould is reinforced by magnetic field. For this method, instead of casting frameworks we should use, cylindrical or polygonal, cast or welded, metal container-like boxes with simple or double walls, with holes and openings (for the aeration of the mould) or the additional use of air space for the stiffening of the mould or the absorption, before casting, of the gas resulted from the thermal destruction of the polystyrene. The holes are fitted with wire mesh, smaller than grained moulding material.

The moulding compound must represent less than 49% of the available storage of the container, lest it should distort the polystyrene pattern.

In order to obtain a superior quality of cast pieces, specialized literature recommends the painting of the lost foam patterns used for the casting of ferrous alloys (cast iron and steels) but there are no specifications for the aluminium-based alloys.

The pattern is painted directly on its surface, after a preliminary preparation, which consists in: covering the pinholes with different materials (depending on the type of the cast alloy) and grinding/polishing the surface (if is required smooth areas obtained directly from the casting). Paint coating can be performed in three ways: brushing, immersion or spraying, at the technologist choice - Figure 2. After covering the pattern, the stiffening of the paint is performed by:

- evaporation, for the alcohol based paints;
- self stiffening for the resin based paints;
- drying for the water based paints.

The stiffening of the paint film must not reduce the flexibility of the pattern and must allow the adoption of its distortions without scraping or exfoliating it.

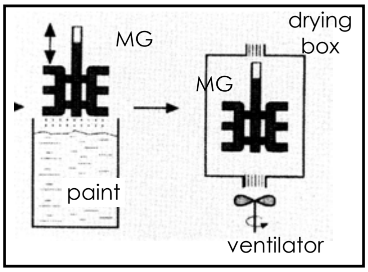


FIGURE 2. Painting by immersing and drying of an expanded polystyrene pattern

The performance of casting moulds comprises the following phases: the laying of the pattern, in a central position in the moulding box, on the layer of moulding material; mould ramming and the stiffening of the compound material. Illustration 3 briefly presents the performance of a casting mould with polystyrene pattern.

The ramming of the pattern is performed by gravity laying of the moulding material by its free flow in the container. The stiffening of the moulding material can be performed by: vibration, shaking, pressing, loading or air exhaustion. The exhaustion process is compulsory in the case of pieces with cavities and steel casting. The vibration parameters for the stiffening of the moulding material (amplitude, frequency, duration) must correspond to the properties of the pattern (the geometry of the piece). In order to obtain a maximum vibration intensity with minimum energy consumption, the vibration direction must be correlated to the position of the cavities of the pattern (therefore, the sand core) and in order to assure the resonance effect, the width of the moulding box must be correlated to the point of application of the vibration in relation to the load centre of the box.

Surpassing the optimum level of vibration ramming leads to the appearance of micro cavities in the moulding material from the box, areas with different levels of ramming and faulty casting of the pieces, like crusts, regains or superficial pinholes.

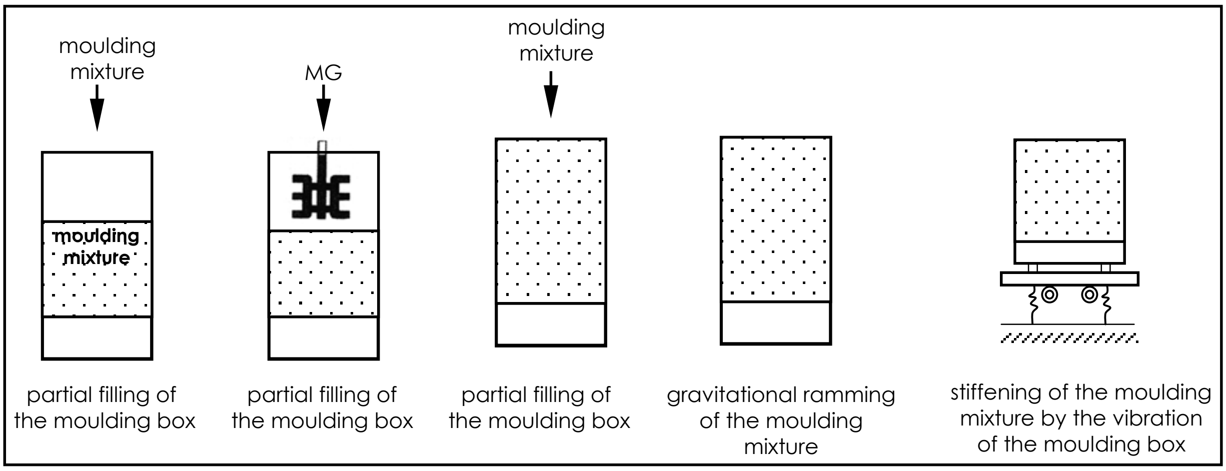


FIGURE 3. The execution phases of a casting mould with polystyrene pattern

The stiffening of the moulding material by air exhaustion consists in the strengthening of the mould using air space. To this effect we must apply a subsidence to the moulding box, in accordance with the rules of "V method", but only after the vibration of the mould in order not to reduce the moulding capacity of the grained moulding material on the polystyrene pattern.

After the stiffening of the moulding mixture, the running basin is fitted on the mould, as figure 4a shows. The casting process by lost foam patterns does not require loading of the mould, as figure 4b shows.

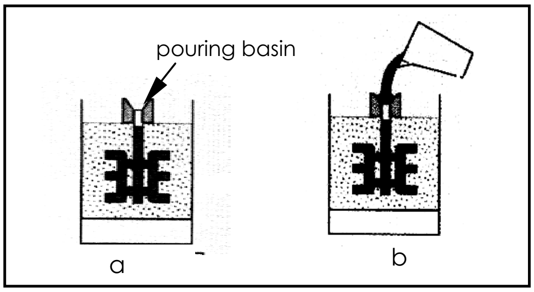


FIGURE 4. The casting of a mould with polystyrene pattern

Most of the defects encountered in mould casting with lost foam patterns are: incomplete filling with alloy of the casting mould, the embedment of the gas resulted from the thermal destruction to the alloy, the appearance of glossy carbon, obtaining rough surfaces etc. These defects have the same cause: incomplete and lengthy exhaustion of the gases resulted from the thermal destruction.

Therefore, when using this casting method the pouring gate must assure: the correct filling of the mould with liquid alloy, the optimum gasification of the pattern and the timely exhaustion of the gases resulted from the thermal destruction of the pattern. The design of the casting technology based on polystyrene patterns is performed on the basis of two parameters: pouring temperature of the alloy and the rise rate of the alloy to the cavity of the mould.

### 2.4. TECHNOLOGICAL ASPECTS OF THE PROCESS

This method can use for: cast iron, steels, aluminium alloys, bronze and brass. Some restrictive measures must be taken in the case of steels with low C content. The casting of aluminium alloys presents the most numerous characteristic features, due to the products in liquid phase resulted from the thermal destruction of the polystyrene pattern. From a technological point of view this casting is simplified in comparison to the classical casting due to the elimination of mould loading process. The purpose of the load laid on the mould is taken over by the moulding compound, which covers the upper section of the container, the latter being super elevated.

Depending on the density of the alloy, mould casting can be performed: *in full mould over the pattern* (if the density is low) and *in empty mould after the removal of the pattern* (if the density is high).

In the case of *filling the full moulds* the alloy is poured over the pattern and the observance of two parameters is compulsory: **the pouring rate of the alloy** (which is correlated to the gasification rate of the pattern and both of them have to be maximum) and **the outflow rate of the alloy** (which is correlated to the metalostatic height of the mould and pattern, such as to accomplish the gasification of the pattern).

Filling the *empty moulds* is unproblematic due to the high temperature at the initial moment of pouring (500…1000$^0$C, thing that prevents the heat shock generated by the cold moulds. Therefore, besides the high permeability to gases caused by the previous calcinations, the uniform filling of the mould, within a short interval is assured.

The knock-out of casting moulds is accomplished by a process of overturning the container. The process is very simplified due to the lack of binder from the moulding compound and the special design of the moulding container, which allows a simple manipulation. The used equipment has lower installed output and low energy consumption in comparison to the classical equipment available in casting houses. So, the necessary surface for this technologic branch is considerably reduced.

After the knock-out of the moulds, with the view of reusing it, the moulding compound must be cooled because at temperatures of over $70^0$C the deterioration of the lost foam pattern takes place.

The cast pieces are cleaned by classical methods, but the manpower is considerably reduced. The abrasive cleaning is performed with metallic shots, assuring a superficial cold-hardening of the roughly cast surfaces.

The pouring gate shall be removed by breaking or by power-operated cutting, with plasma or flame arc.

Specific defects of the lost foam patterns casting process are due to the pressures accumulated during casting and due to the retention of the liquid phase resulted from the thermal destruction of the pattern.

It is known that on the surface between the liquid alloy and the gaseous phase on thermal destruction of the pattern there must be equilibrium of pressures. It has been ascertained experimentally that there is a pretty wide range for the equilibrium of pressures.

The explication of this phenomenon is that the binder free moulds used for casting by lost fame patterns generates a self regulation of this equilibrium following the direct correlation between the gas pressure from the cavity of the mould and its permeability. The correlation that must exist between the air pressure $p_0$, the mould permeability to gases, the size of the contact surface between the alloy and the mould and melting moment $r_c$ of the polystyrene can be determined mathematically.

Defects due to the retention of the liquid phase resulted from the thermal destruction of the pattern are: surface carburizing for steels and surface faults in the case of aluminium alloys.

## 3. CONCLUSIONS

- using the method of casting by lost foam patterns, we can obtain pieces for industry and ornamental elements / applied art, with complex layouts and different sizes, without the danger of offsetting
- using the method of casting by lost foam patterns we can obtain pieces with weights between a few kilograms and tenths of tones, with wall's width between 1 mm and 50 mm, made of different alloys: ferrous (cast iron and steel) and non ferrous (basic alloys of Al, Cu, Mg);
- using the method of casting by lost foam patterns we can obtain pieces with a low consumption of materials and energy;
- the method of casting by lost foam patterns can be used also for: structural changes and superficial alloying of the pieces; obtaining composite materials with powders insertion and the guidance of hardening by using some active powders, internal coolers or exterior coatings.

- the gases resulted from the thermal destruction of the polystyrene are toxic for the human being and can generate negative effects on the environment, aspect which imposes the obligation of maintaining under control both the evacuation in the working environment as well as the evacuation in the atmosphere.

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