Lost Foam Inside

For the use of
aluminum,
cast iron, steel
and non-ferrous
metals

Editor
Lost Foam Council e.V.

The reference book
on the lost foam casting
process

The reference book was written with the participation of the Lost Foam Council members and the companies listed below. We would like to take this opportunity to express our gratitude and to thank them for the provision of pictures and information.

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1 Preface

The versatility of the lost foam casting process opens up countless new possibilities for the production of castings and is the perfect complement to other casting processes.

With this reference book the Lost Foam Council e.V. (LFC e.V.) informs about their practical experience with the lost foam casting process and assists and supports users and newcomers to this process. In addition to the foundries, the LFC e.V. sees the designers and design engineers as a user target group, since they have a decisive influence on and determine the possibilities for value creation already in the development phase of a component. This is because considerations for weight and material savings as well as for function integration and parts reduction must be taken into account already in the early phase of component design.

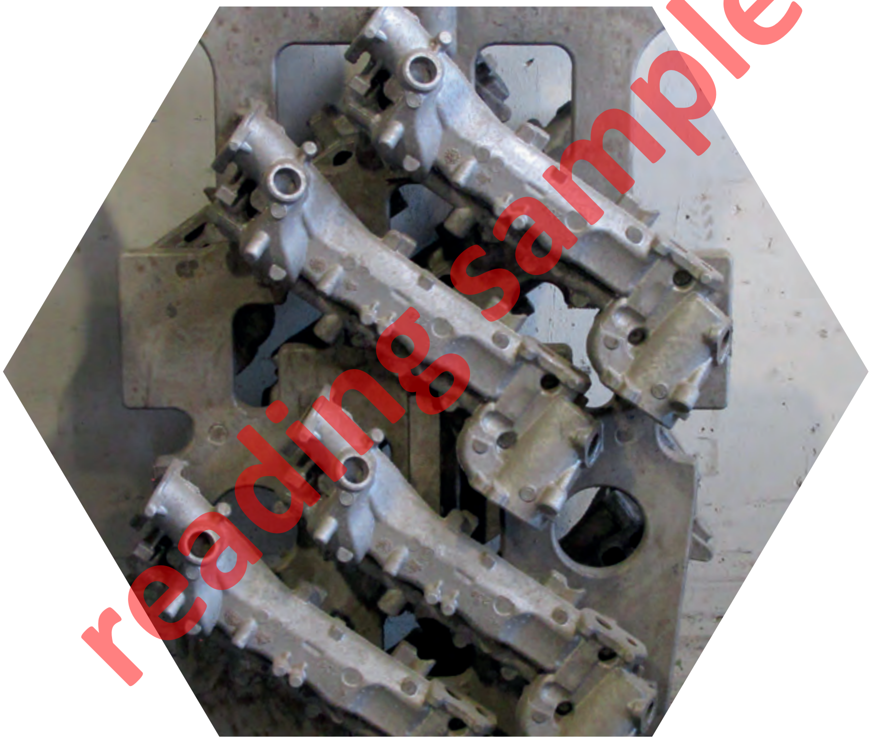
The Lost Foam Inside offers a comprehensive insight into the possibilities of component design, application and entry into the process. In addition to this publication, we are personally available to you as LFC e.V. for further information or application-related advice.

At www.lostfoamcouncil.de you will find contact persons, detailed profiles of our members and further information on the lost foam casting process.

As a registered association, the LFC e.V. serves as a mediator between business, industry, research and politics and promotes the scientific and technological development of the lost foam casting process in Europe. All companies and institutions involved in the process chain benefit from this - from the development and production of the polymer foam patterns to the completion of cast parts as prototypes, small or large series.

In addition to foundries and pattern molders, the members of the LFC e.V. also include equipment and material manufacturers. The reference book „Lost Foam Inside“ was produced with the participation of all members and reflects their many years of experience.

In addition to the cooperation with the individual members, the LFC e.V. works closely together with the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research IFAM in Bremen. At the IFAM, the entire lost foam process chain with the technical know-how and metallurgical competence is available to you. This means that pre-development of cast components and development to series production readiness can be carried out without any investments in plant technology. In addition, the quality and function can be reliably evaluated with the first casting results and thus be used to support the underlying decision making.



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Design characteristics

2 Design characteristics

The lost foam casting process enables the integration of secondary functions and the realization of complex components without having to cope with the generally quite common restrictions of the other casting processes. In order to fully exploit the potential of these process-specific advantages, designers, design engineers and foundry men have to cooperate right from the beginning, and besides the actual function of the component they should also try to consider the whole process chain. This includes:

- the segmentation of the cast part,
- the designing of the gluing surfaces and acceptable pattern segmentation angles
- the in- and outflow of the coating during the coating process in order to achieve an even and closed layer of coating,
- opening for a complete and controlled drying of the coating,
- the filling of all cavities with molding material,
- drafts of the pattern sections,
- necessary tool slides,
- machining allowances,
- boundary conditions for machining and assembly, as well as
- the possibility to combine the parts with neighboring components in order to reduce the number of machining and assembly steps.

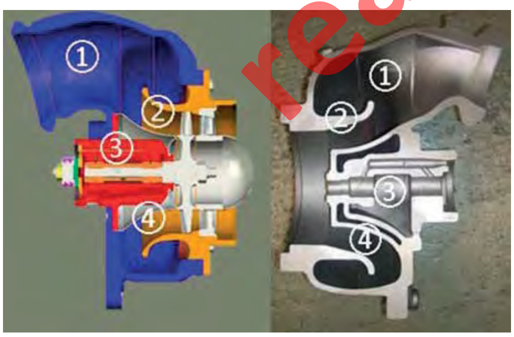


Figure 9: Design representation (cross-section) of the individual parts of a turbine housing (left) and complex lost foam cast iron Cast part (cross-section) of the company Lovink Technocast B.V. (Copyright) produced in one casting (right)

Application example:
The adjacent images show a turbine housing of the company Lovink Technocast B.V., in which four components were realized in one lost foam casting:

1) Diffusor
2) Diffusor inlet
3) Bearing housing
4) Heat shield

The lost foam pattern could be produced from six individual segments (figure 10).

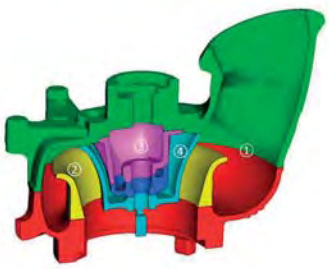


Figure 10: Design representation (cross section) of a lost foam pattern consisting of six segments, turbine housing of the company LOVINK TECHNOCAST B.V. (COPYRIGHT)

Lost foam cast parts can already be cast with passages in order to reduce the later post-treatment. Therefore, it needs to be segmented in a way that as many passages as possible can already be molded in the tool with as few slides as possible. In this pattern segmentation process, the boundary conditions for the gluing surfaces and the acceptable segmentation angle have to be respected. (Note: the segmentation angle is important for the following gluing process, because if the angle is too sharp, the glue will start to flow and the gluing joint will become uneven.) This procedure reduces the scope of post machining as well as the complexity of the foaming tool.

Application example:

FIGURE 11: Design representation of a charge air manifold with (left) and without (right) machining surfaces (COPYRIGHT ALBERT HANDTMANN METALLGUSSWERK GMBH & CO.KG)

The figures above show the design of a charge air manifold without and with and without machining surfaces (green) of the company Albert Handtmann Metallgusswerk GmbH & Co.KG.

The following information has proven its worth in practice and represents experiences in lost foam casting with several million cast parts.

2.1 Pattern segmentation

Simple geometries without any undercuts can often be foamed in one piece. Complex components with undercuts can only be produced using slides in the tool, which makes the tool more complex, but at the same time enables less gluing seams. Alternatively, very complex geometries are dismantled into undercut free individual segments in order to enable the production in aluminum tools.

Figure 12: Glued pattern with horizontal parting lines and pattern segmentations with 45° inclination (COPYRIGHT LOVINK TECHNOCAST B.V.)

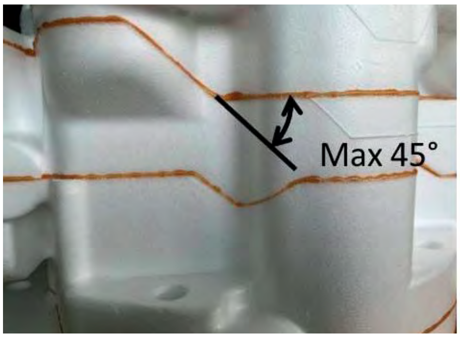


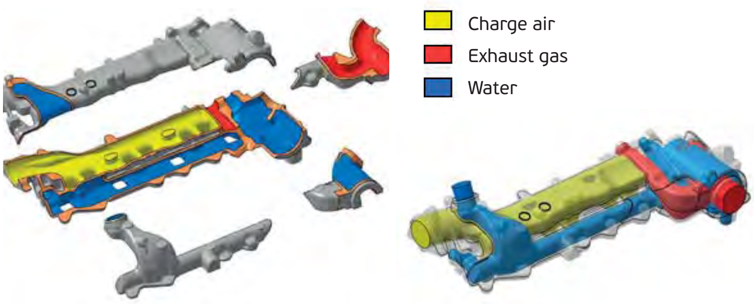
Figure 13: Cross-section of a pattern for the representation of the gluing seams, the inclination of the gluing seams does not exceed 45° (COPYRIGHT LOVINK TECHNOCAST B.V.)

After the molding process, the segments are assembled to complete patterns by gluing. It should be ensured that the number of segments and thus also the number of gluing joints is kept as low as possible. Each gluing joint represents a barrier for the melt in the mold filling process which stops it for a short moment and due to its high glue concentration thus drains more energy from the melt.

The mold parting faces, also called split faces, should possibly show a horizontal mold parting (maximum 45°, figures 12-13) so that the glue application can be kept as low as possible and the glue cannot run off.

Application example:
The figures below show the design and the pattern structure of a charge air manifold of the company Albert Handtmann Metallgusswerk GmbH & Co.KG. In the smallest installation space, the charge air manifold contains ducts for charge air, exhaust gas and water. The wall thickness is 4.5 mm. For this component, a

Figure 14: Design of a charge air manifold (top) with ducts for charge air, exhaust gas and water (middle) and disassembled design model, divided into its individual segments (right) (COPYRIGHT ALBERT HANDTMANN METALLGUSSWERK GMBH & CO.KG)



5

Casting process – from pattern to cast part

5 Casting process – from pattern to cast part

The casting process consists of three essential steps: molding in binderless molding material under vibration, casting of the pattern cluster with decomposition of the pattern material and emptying the flask (figure 97).

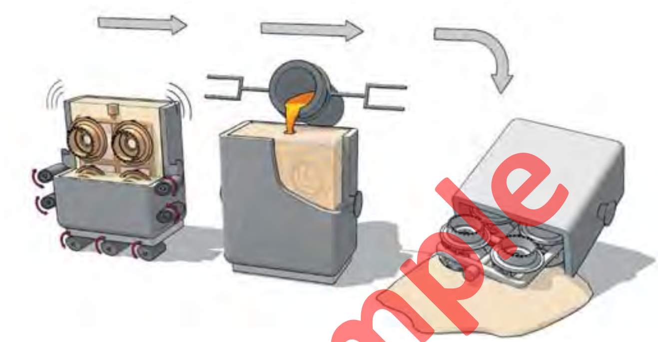


Figure 97: Molding, casting and emptying the flask (Copyright Lost Foam Council e.V.)

5.1 Molding of the pattern cluster

Before the actual casting step, the coated and dried pattern cluster is embedded in binderless molding material. For this purpose, first of all, a layer of molding material is filled into the flask under vibration and then the pattern cluster is placed on the compacted layer (figure 98). Afterwards, the flask is filled with further binderless and well-flowing molding material until the cluster is completely enclosed (figures 99 and 100). The vibrations in the horizontal and vertical direction fluidize the molding material and thus allow its transport into all undercuts of the pattern. The compaction of the molding material increases its resistance to the metallostatic pressure when the melt flows in. This prevents a mold collapse and inhibits penetration of the melt into the molding material.

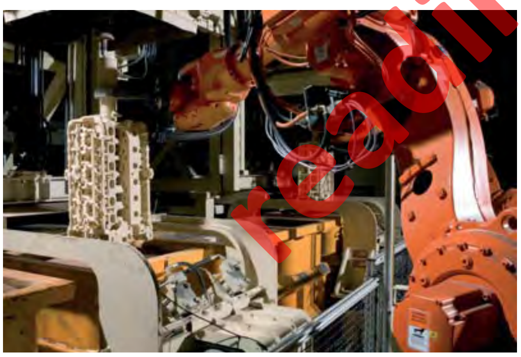


Figure 98: Insertion of the cluster into the flask (6-cylinder heads of the company BMW Group (Copyright))

An adapted filling speed is a prerequisite for a homogeneous filling. How long the process step of filling and vibration takes depends on the pattern geometry and is usually determined by the time required to fill and compact all mold cavities.

Filling and vibration are usually conducted in parallel to ensure a better filling of undercuts. It is recommended to fill and compact the molding material in layers. With a single complete mold filling, internal cavities are not completely filled and compressed because the molding material no longer fluidizes („flows“) in the deeper layers.

In industrial applications, the process steps are controlled by a program. Depending on the type of compaction table used, a horizontal, vertical or a combination of both vibration directions is possible. In general, unbalance motors are used as power units. The following machine parameters are important for molding and compaction:

- frequency,
- amplitude,
- acceleration,
- time,
- spring rate,
- weight,
- form of the flask,
- clamping of the flask,
- sandbunker discharge,
- holding / gripping device,
- exciter power and damping, as well as
- density of the molding material, geometry and particle size.

Figure 101 shows a Vulcan Engineering Co. 3D compaction table. The plant has been installed at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen and is used for development work as well as the production of prototypes.

The molding material flows from the sand bunker above the flask through perforated plates, whose openings can be opened and closed automatically. Here, it should be taken care to ensure that the molding material is fed quickly and evenly and that the dropping height is reduced to a minimum.

Figure 99: Filling of the flask with molding material by opening a perforated plate (Copyright Albert Handtmann Metallgusswerk GmbH & Co.KG)

Figure 100: Molded cluster in quartz sand (6-cylinder heads of the company BMW Group (Copyright))

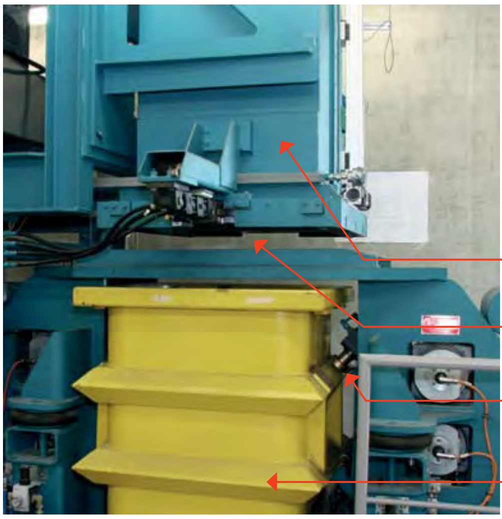


Figure 101: Vulcan 3D-compaction table at the FRAUNHOFER IFAM (COPYRIGHT)

The fixation ensures that the flask is firmly connected to the compaction table and the vibrations can be transmitted directly. The process parameters required for molding are influenced by the unbalanced mass, the speed and the direction of shaft rotation.

For the quality of the compaction, the following parameter settings can be varied:

- frequency,
- amplitude,
- direction of vibration / number of oscillating axes,
- duration of vibration.

The vibration parameters depend on the casting to be manufactured and must therefore be determined empirically for each casting. The duration of the vibration phase mainly depends on how quickly the pattern cavities, e. g. channels, fill up.

High vibration accelerations lead to a better flowability, but not to a better compaction of the molding material. Usual parameters are vibration accelerations between 0.9 g and 1.0 g.

5.1.1 Molding material

The molding material mainly used for the lost foam casting process is quartz sand (SiO_2). In most cases, the grain size H31 (0.2 - 0.5 mm) or H32 (0.1 - 0.3 mm) is used. The grain should be as round as possible for improved flowability, as this has a significant

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Process equipment

6 Process equipment

The plant for the pattern production includes the following components as schematically shown in figure 125 below: pre-expander (1), silo system (2), steam generation system (3), compressed air system (4), cooling water supply (5) and molding machine (6).

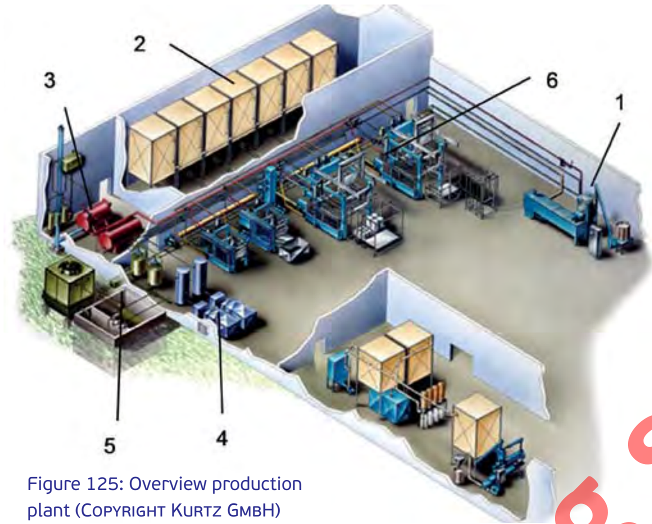

Figure 125: Overview production plant (Copyright Kurtz GmbH)

6.1 Steam generator

For the foaming process, dry saturated steam with a net pressure of 2.5 to 3.0 bar is required. To generate it, it is advisable to use a steam boiler that achieves its optimum efficiency at an operating pressure of 9 to 10 bar. As a buffer for periods of peak demand, a steam accumulator to be operated at a pressure of 2.5 to 3.0 bar needs to be provided. For the operation of the steam boiler, it is necessary to adjust the feed water to the boiler manufacturer's specifications and to adapt it to the respective local conditions. Usually, the steam boiler is fired with light oil or natural gas, but wood chips, district heating or biogas as well as small electrically operated plants for example can also be used for this purpose. The following figures 126 and 127 show the steam boiler and its functional principle.

Figure 126: Steam generator of the company LOOS at the Fraunhofer IFAM (Copyright) in Bremen

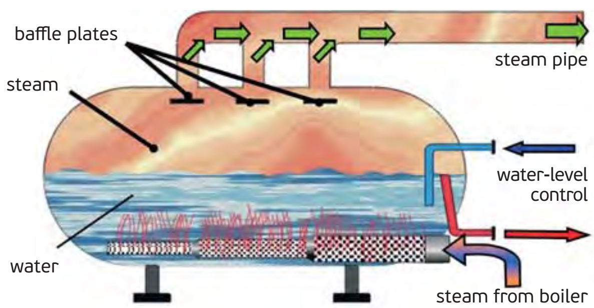

Figure 127: Schematic representation of a steam accumulator (Copyright Kurtz GmbH)

6.2 Pre-expander

The pre-expansion of the raw material is either done continuously or discontinuously. In continuous pre-expanders (figure 128) raw material is conveyed from an octabin into a dosing tank and from there it is continuously fed into the expansion chamber by means of a metering screw. There it is continuously exposed to steam in an open atmosphere, which causes the material to expand. In the form of light beads with a reduced density, the material then rises upwards in the filling to an overflow on the top. There, the beads fall onto a fluidized bed dryer where they are fluidized, dried and stabilized by a blower. After a certain retention time, they are then sieved in the fluidized bed and pneumatically transported to the intermediate storage silos. Any lumps that may have formed are dissolved mechanically. The level of pre-expansion is controlled by the retention time in the energy carrier medium. During continuous pre-expansion, the bulk density can be adjusted by changing the discharge height or the rotation speed of the metering screw.

Figure 128: Continuous pre-expander of the company Kurtz (Copyright)

In the discontinuous process (figures 129 and 130) the raw material is pre-expanded in batches. Here too, it is transported from the octabins (container) into a dosing tank. There, a pre-selected quantity is metered by means of a weighing bin and a load cell and then fed into the expansion chamber in order to pre-expand in a closed atmosphere under a selectable steam pressure. In this process, the bulk density can be adjusted by means of a pre-expansion volume that can be switched off exactly or by changing the initial weight at a fixed pre-expansion volume. Alternatively, the steaming time can also be changed accordingly. Afterwards, the beads are dried in a fluidized bed dryer, stabilized and transported to the intermediate storage silos.

Figure 129: Discontinuous pre-expander of the company Kurtz (Copyright)

In the lost foam casting process, the discontinuous process has become established over the course of time. One of its advantages is, that it offers the possibility to change the material densities quickly. This is possible from batch to batch, whereas in the continuous process a lot of material is constantly lost until the desired new density is reached. Since discontinuous pre-expanders work with a closed atmosphere under pressure, external influences can be excluded and higher steam temperatures can be applied. In the discontinuous pre-expansion process, a bulk density of 12 to 13 g/l can be achieved, whereas in the continuous process a bulk density of 16 to 17 g/l can be achieved.

Figure 130: Batch pre-expander PRO-A-500 of the company STYROLOGIC at the FRAUNHOFER IFAM (COPYRIGHT) in Bremen

The LFCP requires a constant bulk density and a uniform bead size. In order to achieve this, a high dosing accuracy for the batch, an exactly repeatable control of the expansion volume and a constant supply of steam are required. In order to achieve a homogeneous steaming of all beads in the complete expansion chamber, the steam should flow in as evenly as possible through a lid slot sieve (sieve that serves as a bottom for the steam chamber) and the surface area of the steam supply in the bottom area of the expansion chamber should be as large as possible.

To monitor the pre-expansion process, an automatic device which takes material samples from the fluidized bed dryer, measures the bulk density and records the measured value can be used. In case of a deviation, the control of the pre-expander can be influenced automatically.

6.2.1 Media supply

For the operation of a pre-expander, in addition to electricity, the media steam and compressed air must be provided. The electrical connection depends on the drives, blowers and control units used.

The compressed air connection for the pre-expander is mainly used to control pneumatic valves. Therefore a mains pressure of approx. 6.5 to 7.5 bar is required. The compressed air should be free of oil