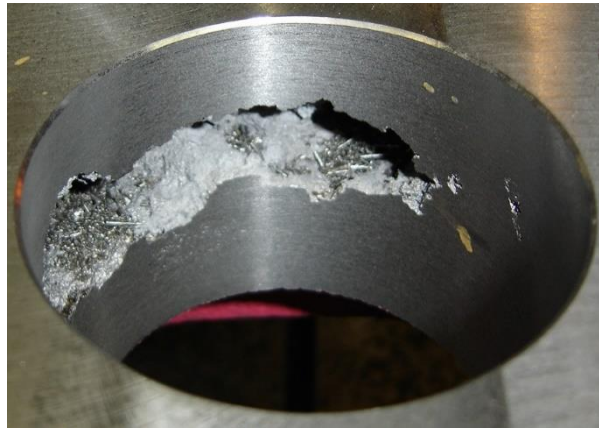


## MANUAL TO PREVENT SHRINKAGE IN SPHEROIDAL CASTING



This manual is based on Fumbarri's research and experience, with the collaboration of its Clients and Suppliers, and using information from Metallurgical Technological Centres to improve its product and minimise defects.

It has historically been common, during the machining of geometry parts, mortices, holes or housings in spheroidal casting parts (GGG or JS), for porosities of one size or another (macro or micro-shrinkage holes) to appear. So Fumbarri has drawn up this manual to find out the causes behind shrinkages and to minimise their appearance inside parts, by correctly defining the geometries of the parts in the design stage or during the patterns' manufacture.

### Index

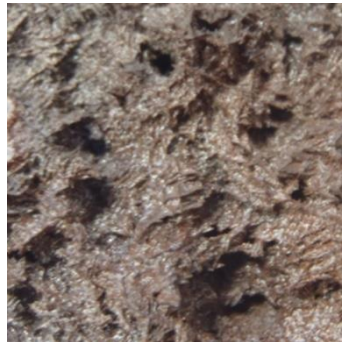
1. Shrinkage – Definition .....	2
2. General Characteristics of Shrinkage .....	2
3. Causes.....	2
4. Background.....	3
5. Preventive Action .....	9
6. Recommendations in the Construction of Patterns.....	10
7. Case Studies.....	11

## 1. Shrinkage – Definition

Cavity caused by liquid contraction. They are generally very irregular and have rough, dendrite-type walls. They are usually found in interiors, in the thickness changing elements of the part, or in the inside of extra-large zones, sometimes in the form of a surface depression in varying sizes.



## 2. General Characteristics of Shrinkage



They appear in the form of open cavities on the outside surface of a part, or closed cavities on the inside of a part. The interior surfaces may be smooth (primary shrinkage) or have a dendritic morphology (micro-shrinkage or secondary shrinkage). In certain eutectic alloys, primary shrinkages may appear with dendritic interior surfaces.

Given that it is a contraction defect, it is normally formed in final solidification zones (the part's thermal centres). This defect is formed in final solidification zones, which correspond to the part's thermal centre. They may appear in zones with interior angles, often revealed during machining operations, close to cores, sprues, etc., due to the difficulty of heat evacuation, a phenomenon which slows down the liquid metal solidification process.

Their occurrence depends on the alloy's liquid-solid contraction. In the case of graphite casting, spheroidal is more prone to secondary shrinkage (as far as micro or macro defects are concerned) than laminar, due to their different solidification patterns.

## 3. Causes

Technically, shrinkages are produced in the phase in which liquid becomes solid, due to the severe contraction that the metal has to undergo in this process. So, the geometrically extra-large zones, as they cool down at a slower rate than the rest of the part, provide material to the zones

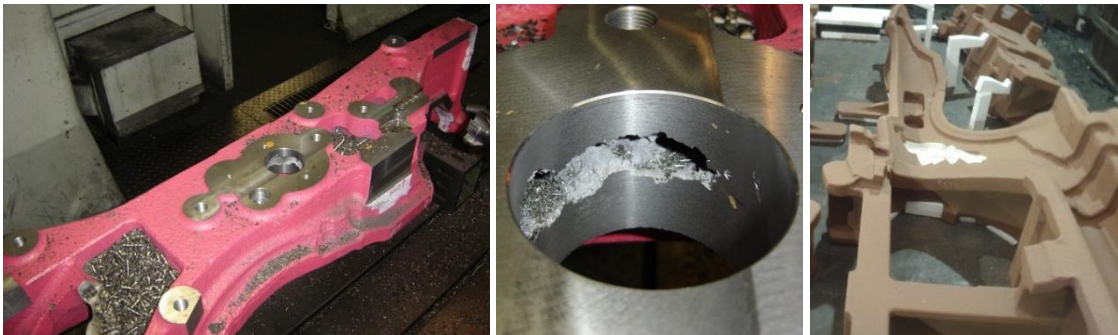
that cool faster, generating dendritic caverns (shrinkages) in the interior. The causes behind the appearance of shrinkages are:

- Unsuitably designed part to be cast, as well as inadequate casting methods.
- The main cause is the contraction that the metal undergoes between the semi-solid state and final solidification. The lower the metal's tendency to contract, the lower the risk of this defect appearing.
- In graphite casting, an expansion is produced due to the formation of graphite at the heart of the metallic material. This phenomenon can cause swelling inside the moulds and increase the parts' volume.
- The feeding difficulties that are produced as the solid fraction increases must also be taken into account: diameter and/or incorrect design of the risers, use of metal entry points with thin sections, which solidify quickly, incorrectly designed parts (ISOLATED EXTRA-LARGE SECTIONS), etc.
- The use of high casting temperatures (which increase the mould's instability due to the intense heat, slowing down the solidification period) or excessively low temperatures (with a fast solidification of entry points or necks, even in the risers).

#### 4. Background

Below you can see some examples of parts that have suffered shrinkages

- Shrinkage in housing for the piston guide bushing



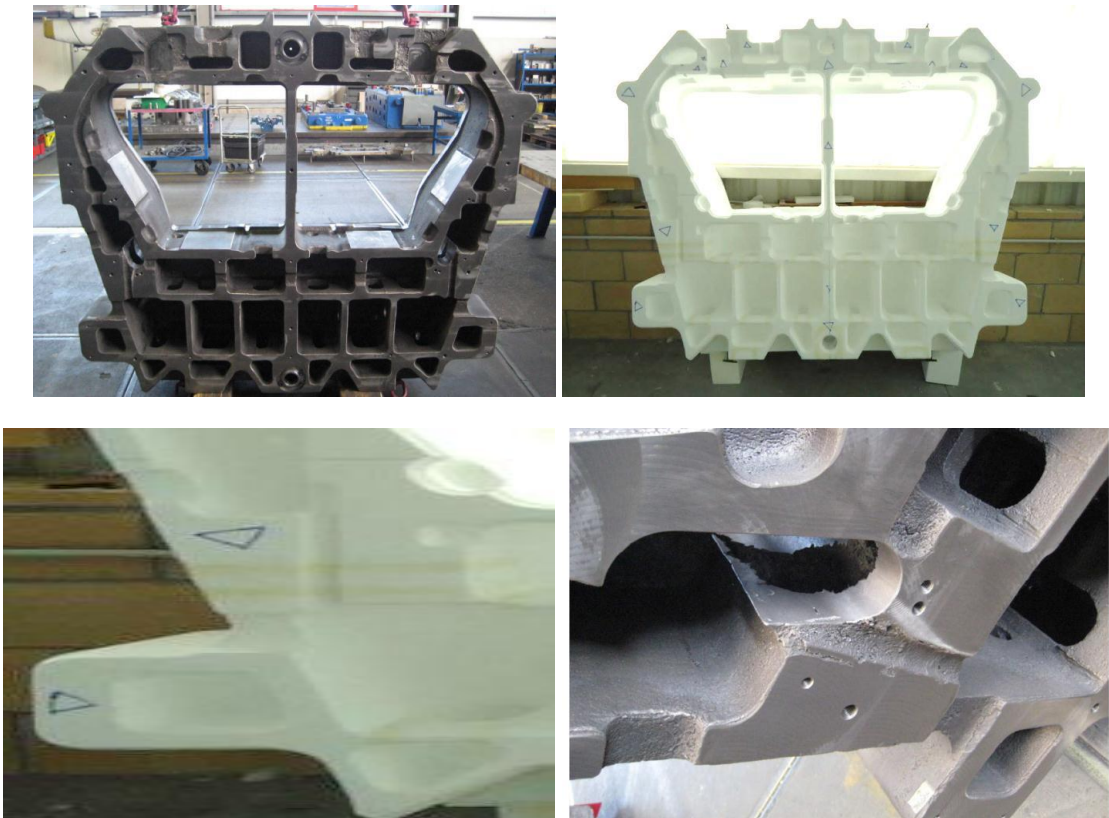
In these patterns, the holes for the housing of the guide bushings were not made.

- Shrinkage at the bottom of the mortice to release the sheet metal detection device



The release mechanisms were not completed in the pattern for the sheet metal detection devices or for the centring mechanisms.

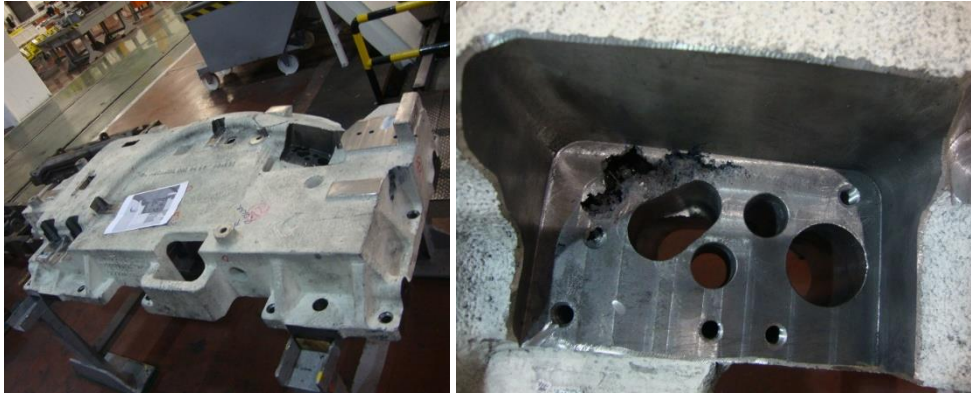
- Shrinkage in the release mechanisms for the passing of turrets in the piston



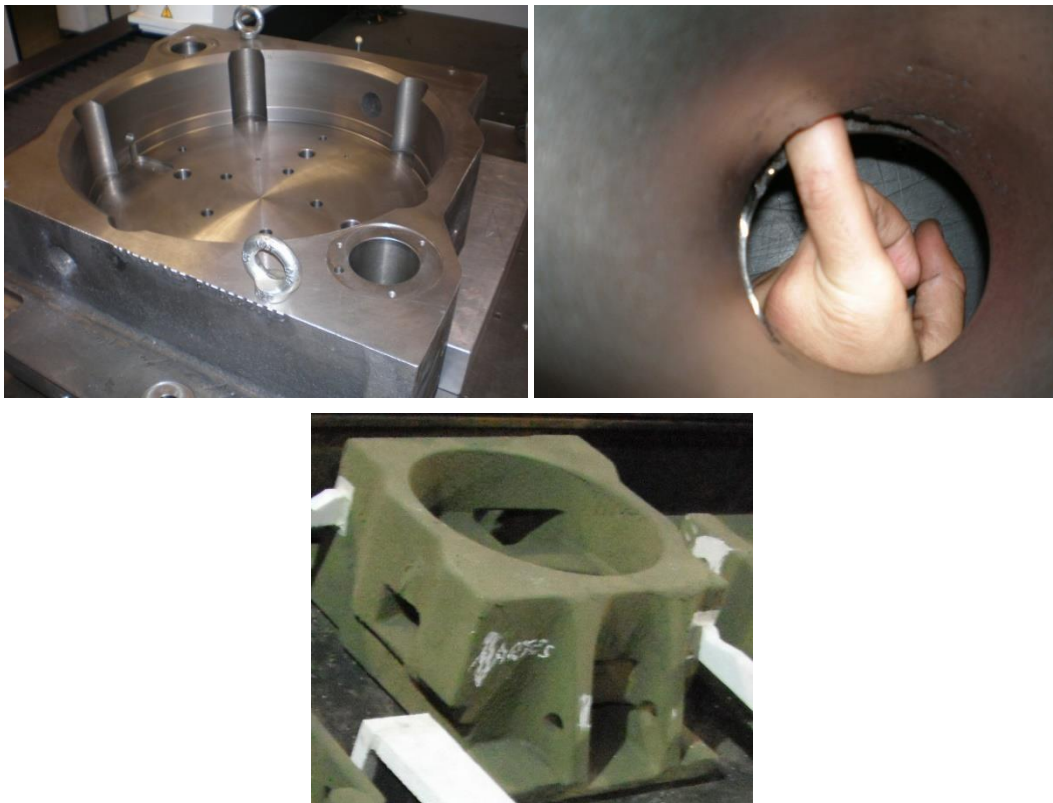
The release mechanisms for the passing of turrets were not completed in the pattern, generating a huge mass.



- Shrinkage in the release mechanisms for the passing of turrets in the piston



- Shrinkage in holes for column housing



When the mortice is machined, shrinkage appears.

- Shrinkages in the water collectors of the hot stamping mould



When water pressure is introduced, the water leaks through the collector in the slots where the water passes through, due to the fact that there were shrinkages because the slots were closed in the patterns, generating isolated masses where the shrinkages are located.

- Shrinkages in lift housing



When machining the mortice for the lift housing, shrinkages are detected. If this mortice had been carried out in the pattern, the defect would not have appeared.



- Shrinkages at the bottom of the mortices



When machining the release mechanisms, shrinkages appear at the bottom of the mortices. The defect is due to the fact that the core pattern was manufactured without mortices.

- Shrinkages at the bottom of the lift housing.



- Shrinkages in the mortices and the lift guide holes



Very common defect. When machining the lift housing, shrinkages appear at the bottom of the mortices. This is due to the fact that the pattern did not have the mortices for the lift housing.

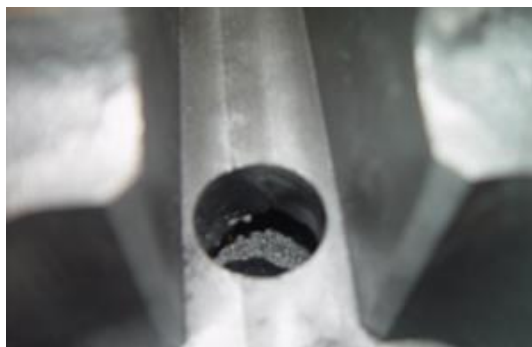
- Shrinkages in the limit mortices and in the seat for the piston guide strip



When machining the mortices and holes for the limitation rubber, shrinkages have appeared. The defect is due to the fact that the piston pattern was manufactured without mortices. Shrinkages have also appeared on the seats for the guide strips, which are due to the fact that, on those areas, the pattern had the previous handling eyebolts still in place, and when the part was machined, shrinkages appeared.



- Shrinkages in the mortices and the lift guide holes







Very common defect. When machining the mortices and holes for the lift housing and guide, shrinkages appeared at the bottom of the mortices and inside the holes. This is due to the fact that the pattern did not have the mortices for the lift housing.

## 5. Preventive Action

The preventive action to be taken to stop shrinkages from appearing is as follows:

- Suitable and adequate metal composition, nodulization and inoculation treatment.
- Efficient feeding of the part.
- Use of an appropriate casting temperature.
- Modification of the design to obtain more uniform sections of metal. If necessary, use coolers for the thicker sections. Level out the cooling speed of the extra-large zones by homogenising the thicknesses, preventing the generation of extra-large zones. To do so, you must always design the part to be obtained, endeavouring to ensure that the changes in sections are progressive, avoiding any abrupt section changes. Prevent the formation of extra-large sections, or at least limit abrupt section changes, by joining sections. Some examples of this are shown below.

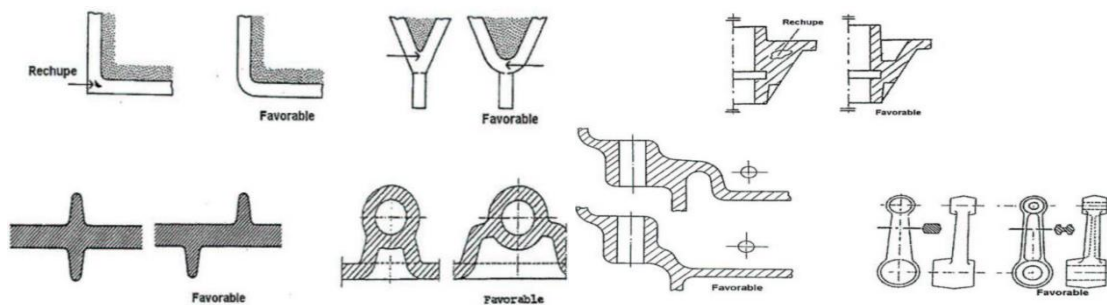


Figura 16: Detalle de uniones de secciones en distintos modelos.

Figura 17: Detalle de núcleos de masas.

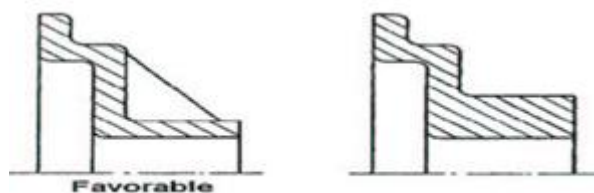


Figura 18: Cambio brusco de secciones.

- In the pattern's manufacture, keep the machining ridges constant at a minimum of 5 mm and up to a maximum of 15 mm. In this way, mortices, holes and, in general, deep machining or machining in extra-large zones, must always be made on the pattern and never be left blind to be obtained at a later date in the part that has been cast by machining.
- In this way, in the mortices of extra-large zones on the patterns, coolers will be included inside the mortices or holes, known as controlled cooling. For this practice to be implemented, the pattern must first have clearances in these zones to be able to house the coolers. This is a common practice in iron and steel casting companies, and it is also recognised in technical/scientific fields.
- Another solution is to provide material at the moment of solidifying (feeding and risering). We occasionally use this technique, but is not very common to use risers in the die mould system as it makes the part too costly, it also sets back the delivery date due to the analysis for risering and sometimes the part's geometry means that, even after risering, we still do not achieve the desired results. So, in the die casting system, controlled cooling is used, by means of coolers and, when possible, the reduction of masses. To apply this technique, and when the job in question requires there to be no zone with pores, it is necessary to first carry out a solidification simulation by finite elements in order to determine where and how to apply risers to counteract contraction.

## 6. Recommendations in the Construction of Patterns

- Machining ridges: We recommend that the machining ridges do not exceed 15 mm under any circumstances.
- To avoid deep machining, the patternner must include all types of recesses, prints and holes on the pattern, respecting the maximum ridges of 15 mm. In particular, the pattern should also have the clearances for the following elements:
  - Holes for columns and guide bushings,
  - Lift housing and holes for lift guides,
  - Release or housing for centring and detection mechanisms,
  - Core or turret passing,
  - Mortices for limit bolts or safety bolts,
  - And, in general, deep holes or mortice machining (>30 mm).

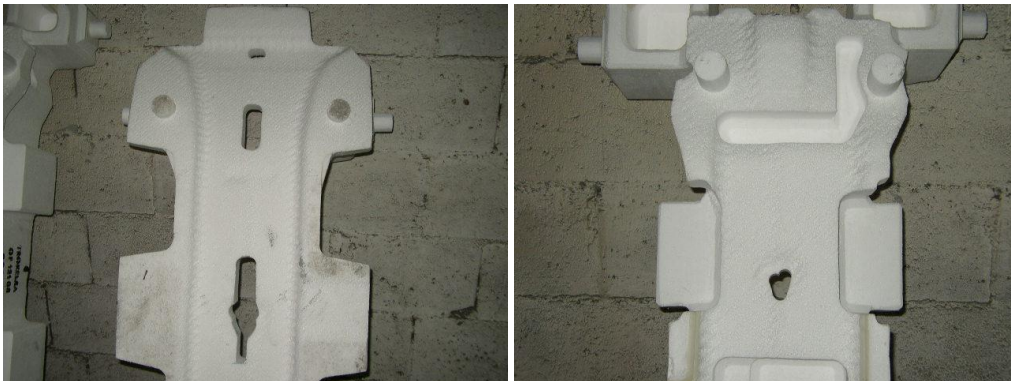
The patternner and the controller should not be concerned about any calcination in the aforementioned recesses, as there are means available to prevent this occurrence, such as: chromite sand, graphite, iron rods, etc.

The construction of a pattern following these principles will prevent the formation of unnecessary masses that generate shrinkages, which entail the use of feeding or riser systems that are not always effective, as their calculation can be affected by factors that are hard to predict.

When possible variations in the design lead to problems, in which case the patterner has to leave solid zones without casting, we recommend you check with the smelter so that, using the pattern, he/she can study the way to feed that zone and, if necessary, see the project designer about modifying the design so as to generate padding that would enable it to be correctly fed.

Avoid placing test specimens, handling eyebolts and other extra-large elements in zones to be machined. These types of elements further the appearance of defects and prevent coolers from being put in place.

## 7. Case Studies



These patterns show how small-diameter holes and reduced-width recesses have been obtained in the pattern. The smelter is responsible for preventing calcination. The lack of shrinkage means the product's good condition is guaranteed.



Small-diameter through hole



Grooves for lift housing





Pattern with four deep grooves for lift housing and through hole inside for lift guide



Material removed in different patterns in order to prevent extra-large zones. Usual practice agreed by many patterns



Occasionally, the eyebolts or plates are inappropriately placed for the job in question, generating hot spots that can cause shrinkages and which prevent coolers from being put in place.



This problem arises with the support blocks in the first phase of machining or with the test specimens placed in the copy zone, so we recommend you follow the same criteria as indicated above.

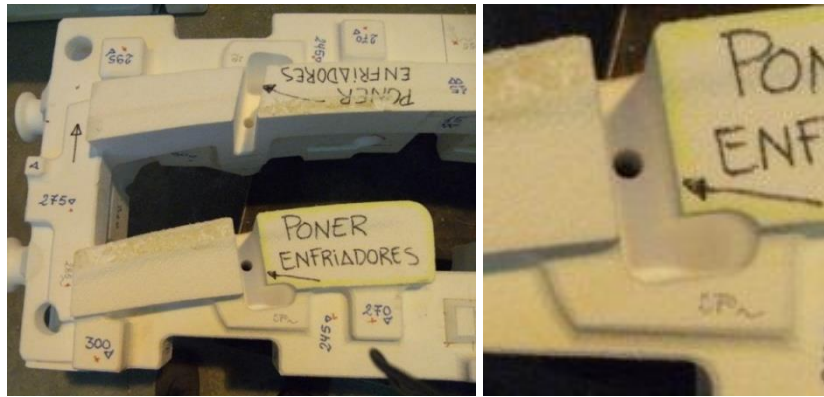


For this reason, we recommend that, wherever possible, these elements be placed on non-functional surfaces that minimise the importance of any shrinkage that may appear.

### EXAMPLES OF LIFT HOUSINGS – CORRECT WAY TO DEFINE LIFTS AND OTHER CASTINGS.



The core has two mortices for the lift housing, and Ø20 holes for the lift cylinder to pass.



The pattern has the housings for the lifts and the holes for passing and guiding the lift cylinders.



Mortise with machining ridges and hole for the lift cylinder to pass through

We hope the information contained in this manual will be clear and serve to prevent the appearance of shrinkages. In the event that the aforementioned recommendations are not followed in the design or in the pattern, it will be very difficult for them to be detected in the casting stage, as we will not know the zone in which this type of casting is going to take place, and if the recommendations are not followed, shrinkages will continue to appear.