LIFE17 ENV/FI/000173

Green Foundry

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Green Foundry LIFE project

LIFE17 ENV/FI/173

Action B3 Test series of molds, cores and casts produced by inorganic and organic binder systems

Deliverable DeB3B Test cores produced by inorganic binder system sin Italian pilot foundry

Date 22.10.2020

Report of the tests cores

UNIPG – Fonderie di Assisi

The experimental work carried out at the foundry "Fonderie di Assisi" wants to determine the characteristics of the cores produced with the inorganic process. Some tests have been carried out to evaluate the behaviour of the material, regardless of the geometry of the cores.

The report describes:

- Cores production: the procedure for the production of cores with inorganic binders
- Cores analysis tests: test to evaluate and estimate the behaviour of cores produced with inorganic binders
- Tests on foundry castings: tests to evaluate the characteristics of castings made with inorganic cores

CORE PRODUCTION

To verify and evaluate the actual characteristics of the inorganic cores, their production is commissioned to a factory, the 2VI S.r.l. (http://2visrl.com/).

The UNIPG teams supervise the making of inorganic cores (see Figure 1 and Figure 2).

Figure 1 Visit at 2VI SRL factory

Figure 2 Green Foundry Project dissemination

2VI SRL is a small factory making cores for foundries. It makes classics cores with organic binders using shell moulding techniques, but it is skilled in making cores with inorganic binders. In particular, 2VI SRL has a line with 4 core blowing machines (specifically designed for inorganic binders), two of them made by PrimaFond. Figure 3 shows one of these core blowing machines made by PrimaFond.

Figure 3 Core blowing machine made by PrimaFond

Inorganic binder cores are mainly for aluminium in car industry (Ferrari and others).

In our tests, two different binders are used in order to identify and compare the different mechanical characteristics resulting on the forming of the cores.

The suppliers of the binders used are the two leading companies in the sector:

- SATEF HÜTTENESALBERTUS S.P.A.
- ASK CHEMICALS ITALIA S.R.L.

The supplier “Satef-HA” supplies a two-component product. The system consists of a binder composed of a solution of silicates, called "Cordis 8593" and an additive composed of a mixture of synthetic and natural powders based on refractory oxides, known commercially as "Anorgit 8608".

Also the supplier “ASK chemicals” markets a two-component product. The binder, called "Inotec hc 2000", is based on modified silicates and the additive, called "Inotec promotor tc 500", is made up of a mixture of synthetic and natural solids.

The compounds are very similar as regards the binder, an aqueous solution of modified sodium silicates. The major difference concerns the additive but detailed informations about their composition are not provided.

The forming process in our tests is carried out using a core box originally prepared by “Fonderie di Assisi” for use with the classic cold box process. Some resistors to heat the core are mounted on the core box.

After each shot by the core blowing machine, an operator applies the refractory plaster to the cores. An alcohol paint is used for both the cores produced with Cordis binder and with Inotec binder, while some cores are not painted. These differentiations better highlight the different properties of the cores. Figure 4 shows the procedure with which the refractory plaster is applied.

Figure 4 Cores painting

After each moulding, to avoid possible imperfections in the subsequent process, the excess sand is manually removed using an air flow (see Figure 5).

Figure 5 Excess sand removal

The cores produced (see Figure 6) are of good quality, even though an adapted core box is used and not expressly built for the inorganic process. Furthermore, the cores chosen to carry out the tests are characterized by various manufacturing difficulties, such as small thickness parts and small overall dimensions. Despite these difficulties, only some cores showed signs of surface cracks (see Figure 7) and a tendency to surface crumbling. This helps to validate the quality of the process used and the effectiveness of the binders.

Figure 6 Some cores produced

Figure 7 Inorganic core with surface break

The cores are packed and send to the "Fonderie di Assisi" (see Figures 8 and 9).

Figure 8 Cores packaging

Figure 9 Cores arrival at the foundry "Fonderie di Assisi"

CORES ANALYSIS TESTS

In the “Fonderie di Assisi” chemical laboratory, tests are carried out to characterize the cores.

The laboratory tests carried out on the cores, in comparison with a core normally produced by the foundry with organic binder and cold-box system, are:

- loss of ignition analysis or loss on calcination i.e. loss in weight of the sample after passage in the muffle at 900 °C for 2 hours
- Visual evaluation of the calcined residue
- Optical microscope evaluation of the sand residue obtained after calcination

The purpose of the tests is to evaluate and estimate:

- the reduction in the development of gas during casting, with an expected benefit from a qualitative point of view on the castings produced and from an environmental point of view for the consequent reduction of emissions
- the bench life of cores with inorganic binders compared to those with organic binders, as a function of time and storage conditions (to evaluate the possibility of storage of the cores)
- the ease of de-coring of the cores from the internal cavities of the castings, a fundamental parameter to ensure industrialization of the use of inorganic binders for cast iron casting

Further evaluations are made directly on the cast iron castings after the tests in production (casting, de-pressing and cleaning of the cast iron castings) and, through external laboratories, on the moulding sand which will receive the residues of the cores with inorganic binder, to evaluate their impact on the formability characteristics of the green sand.

Equipment used for testing

The following figures show the instruments used for the tests carried out in the chemical-metallurgical laboratory of the foundry:

- muffle furnace
- calcination crucibles
- analytical laboratory balance

Figure 10 Muffle

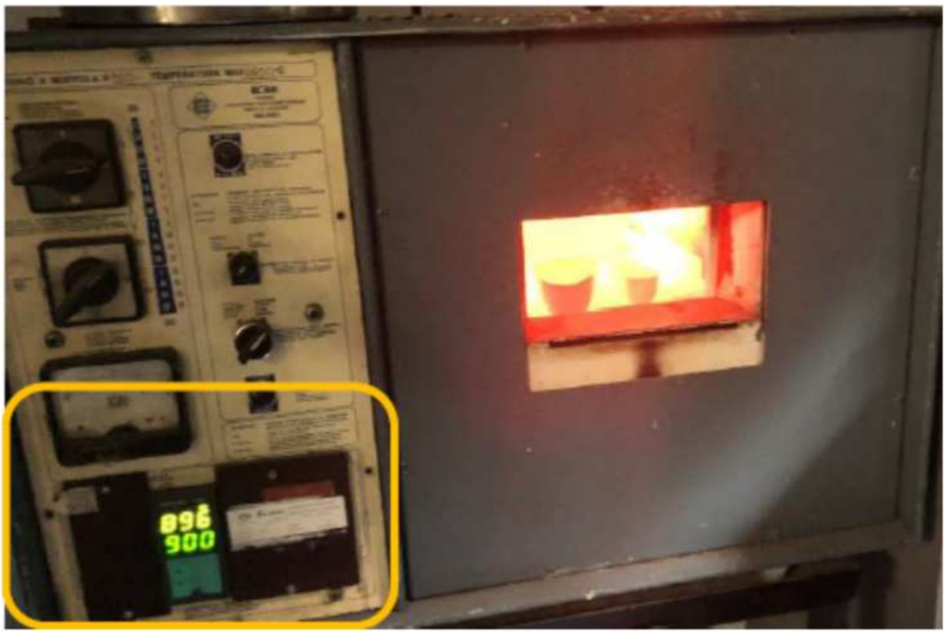

Figure 11 Calcination crucibles

Figure 12 Analytical laboratory balance

Samples analyzed

The tests concern 3 different types of cores:

- CORE WITH ORGANIC BINDER
  - Cold-Box system
  - phenolic isocyanic resin: 1.6%
  - Fonderie di Assisi production
  - color yellow-brown

- SOUL WITH CORDIS INORGANIC BINDER
  - 2VI SRL production
  - color dark gray

- SOUL WITH INOTEC INORGANIC BINDER

- 2VI SRL production
- color gray-brown

The following figures shows the different cores.

Figure 13 Core with organic binder

Figure 14 Core with CORDIS inorganic binder

Figure 15 Core with INOTEC inorganic binder

From an first analysis of the cores as soon as they arrive at the foundry, it can be seen that the cores produced with the inorganic binder INOTEC are less resistant to handling and transport.

Loss of ignition test

The LOI (loss of ignition) analysis, also called calcination test, consists of a high heating of the sample to be analyzed at a specific temperature (900 °C) that allows the evaporation of volatile substances with consequent decrease in the weight of the sample. The test measures the sample before and after heating in order to highlight the decrease in weight due to the loss of volatile substances. The test is repeated twice to ensure that all volatile compounds have evaporated and that the bulk loss is complete.

The following figures show the different status of aggregation of the sand after the LOI test.

Figure 16 Sand with organic binder

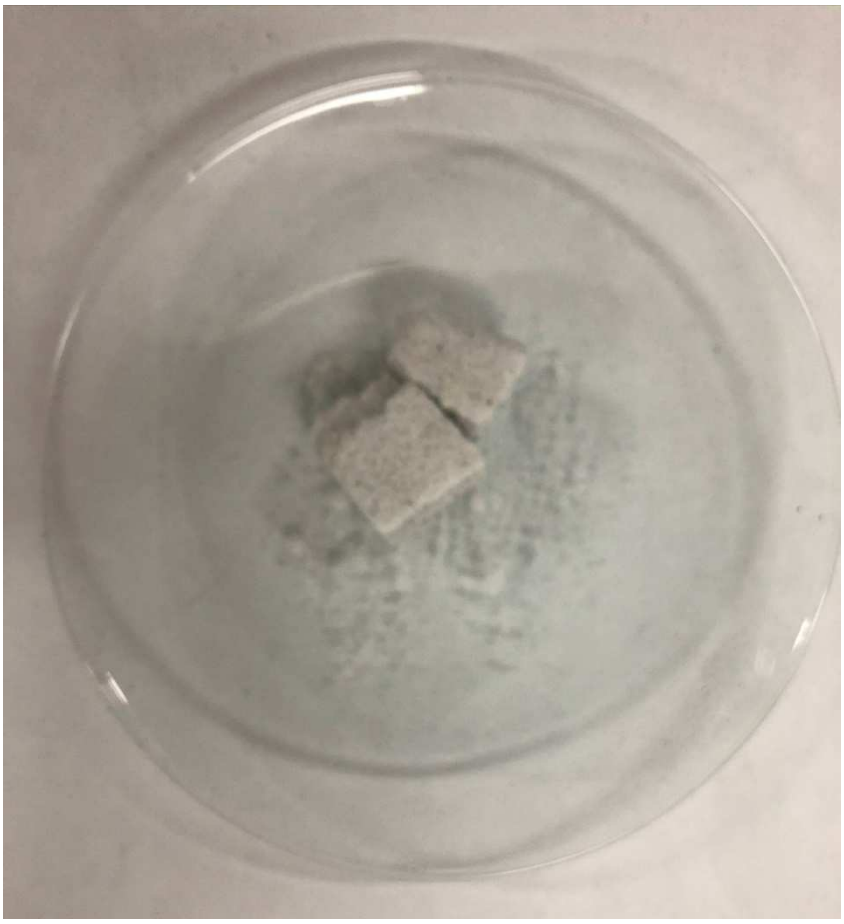

Figure 17 Sand with CORDIS inorganic binder

Figure 18 Sand with INOTEC inorganic binder

In the case of CORDIS inorganic binder, the sand remains compact and resistant to touch while for the INOTEC binder it is not aggregated as for the organic binder.

The table shows the weight loss expressed in percentage terms for the different types of cores and for different storage conditions.

Table 1 LOI (% w/w)

	Core with organic binder	**Core with CORDIS inorganic binder**	**Core with INOTEC inorganic binder**
Core upon arrival	1,60	0,42	0,57
Core after staying for 6 days in the laboratory	1,57	0,40	0,44
Core after staying for 6 days in the production department	1,54	0,27	0,40

The following figures show the visual evaluation of the sands before and after calcination in the muffle at 900 °C.

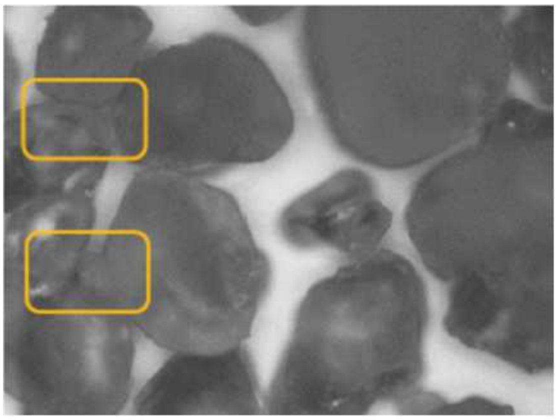

Figure 19 Sand with organic binder before calcination

In Figure 19 the areas where the resin holds aggregate the sand grains are highlighted in yellow.

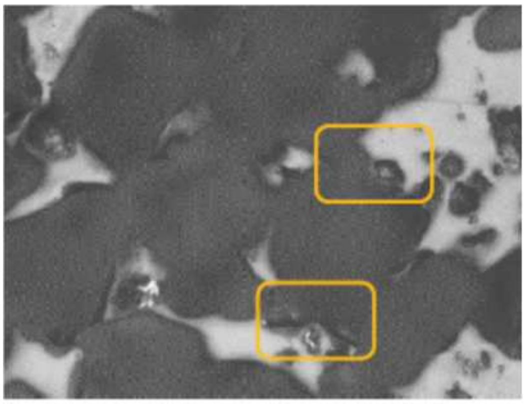

Figure 20 Sand with CORDIS inorganic binder before calcination

Figure 20 shows the area in which the silicate holds aggregates sand grains and the area with free silicate particles, released during the crushing of the core.

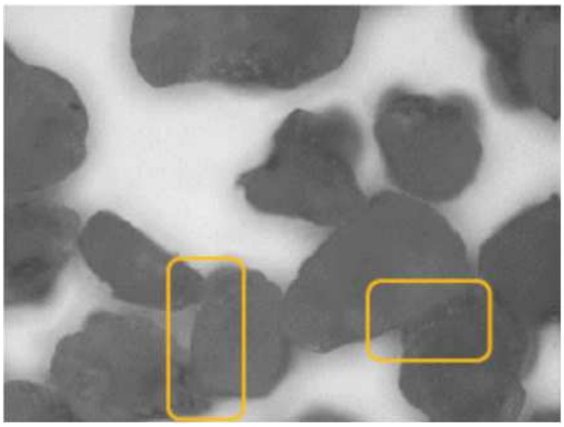

Figure 21 Sand with INOTEC inorganic binder before calcination

Figure 21 shows the area in which the silicate holds aggregates sand grains and the area with free silicate particles.

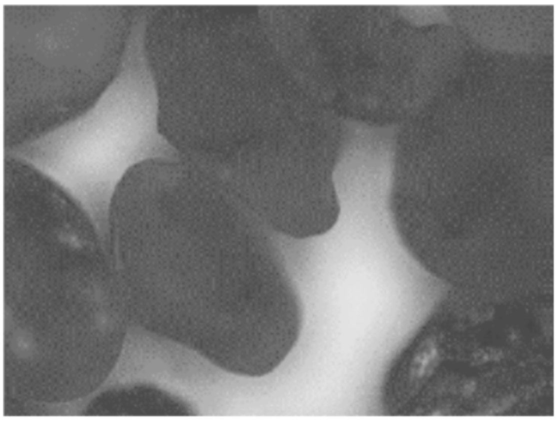

Figure 22 Sand with organic binder after calcination

In Figure 22 it is possible to see the grains of sand are loose, without areas of resin that aggregate them.

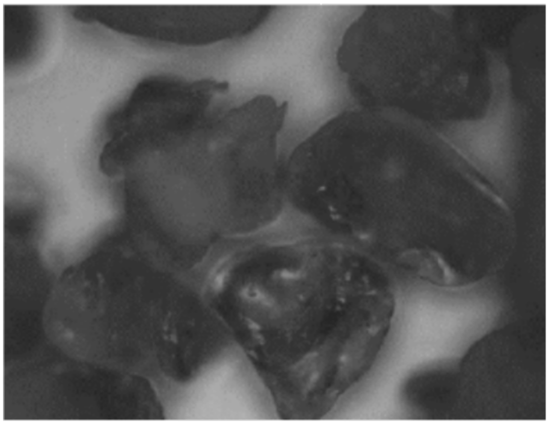

Figure 23 Sand with CORDIS inorganic binder after calcination

In Figure 23 the free grains but coated with a film of vitrified material.

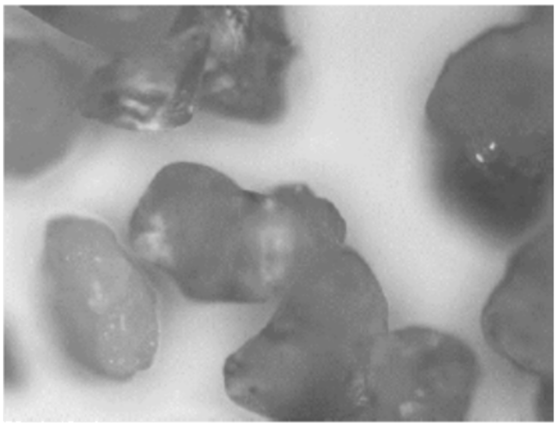

Figure 24 Sand with INOTEC inorganic binder after calcination

In Figures 23 and 24 there are the free grains but coated with a film of vitrified material.

From the tests carried out on the cores produced by the 2VI SRL with the two types of inorganic binders based on sodium silicate (CORDIS and INOTEC), it appears that:

- The cores have a significantly lower LOI than those produced with organic binder and Cold-Box system (isocyanic-phenolic resin). This leads to the deduction that during the casting phase there is a considerably lower gas development with potential reduction of defects;
- The manipulation and the calcination test, repeated after a few days in different storage conditions of the cores, do not lead to significant changes: in particular, the cores with inorganic binders are not particularly hygroscopic and do not show any visible weakening upon handling;
- It can be assumed, given the type of materials used, that the weight lost during the passage at 900 °C is essentially constituted by water vapor and not by organic compounds;
- the two binders, despite having similar weight loss values at 900 °C, have different behaviours such as state of aggregation and resistance of the core after calcination. So, it can be assumed a greater difficulty in removing the core from the internal cavities after casting. This aspect is further investigated after casting: in the shakeout phase, the cores remain compact within the casting but in the shot blasting phase the cores are easily extruded;
- the sand grains after calcination, for both cores produced with an inorganic system, appear to be coated with a vitrified and adherent layer, which could influence the behaviour of the sand reused as material for external moulding bonded with clay (green sand). The tests on green sand are being carried out in external laboratories. Figure 25 shows the package of the residual sand.

Figure 25 Residual sand for the analysis in external laboratory

However, it is still necessary to make evaluations after many cycles of use in production and with significant quantities.

TESTS ON FOUNDRY PRODUCTS

Inside the foundry, the inorganic cores are used to replace the organic ones and they face all the production phases necessary to obtain the finished pieces. In this way it is possible to concretely observe the possibility of using inorganic cores in the production process, evaluating the problems and their real effectiveness.

The cores are marked in order to recognize the different binder used in the forming:

- cores produced with CORDIS binder (supplied by SATEF HA) → I
- cores produced with INOTEC binder (supplied by ASK CHEMICAL) → X

The cores are used to cast grey cast iron - GJL 250 type - (according to UNI EN 1561), with a casting temperature of 1389 °C.

Figures 26-30 show some casting operations.

Figure 26 Cores before the insertion into the mould

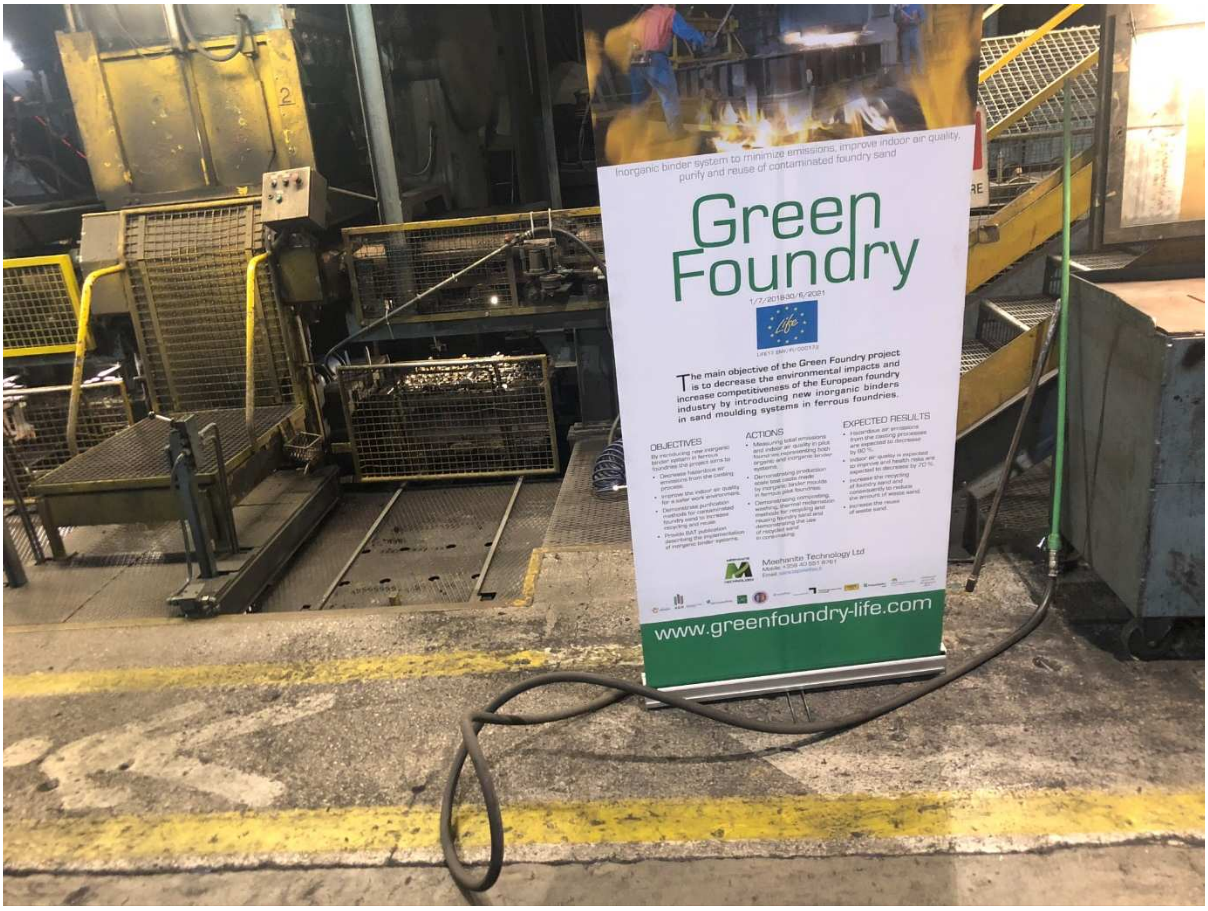

Figure 27 Start of casting operations – part 1

Figure 28 Start of casting operations – part 2

Figure 29 Casting operations – part 1

Figure 30 Casting operations – part 2

A total of 320 castings are produced. Figure 31 shows the castings before the knocking and Figure 32 shows a detail of one casting.

Figure 31 Castings before the knocking

Figure 32 Detail of one casting before the knocking

96 pieces are knocked out by hand: picking the casted mould (sand mould with metal bracket) from the automated plant of still closed, opening in two parts with tools, handily extraction of the casted parts (with feeding system) from the moulding sand.

The remaining 224 are knocked out in automated plant with vibrating channel: automated system of extraction of the sand mould with casted part and feeding system, from metal bracket by mechanical system through a piston and subsequent passage on a vibrating belt that separates the loose sand from the cast metal.

Decoring operations and control check of casted parts

Decoring, that is the ease with which it is possible to remove the cores and sand residues from the casting, is first of all visually evaluated without further finishing operations.

Both with regard to the castings knocked automatically by the vibrating channel, and for those knocked manually (Figures 33-34), it should be noted that the castings are free of internal cavities, as they are completely filled with sand, with a difference between the two types of core used in favour of type X which is more brittle to the touch than type I. However, both are very compact. Figure 35 shows the 2 type of castings after the knocking.

Figure 33 Knocking operations

Figure 34 One casting after the knocking

Figure 35 Type I and Type X of castings after the knocking

Usually this result is also presented for cores produced with organic binder, in fact a further operation called "shot blasting" lasting 20 minutes is required.

To better quantify the decoring process, it was decided to divide the external shot blasting (Figures 36 and 37) performed by the "carpet blasting machine" into two parts, each lasting 10 minutes.

Figure 36 External shot blasting process on carpet blasting machine

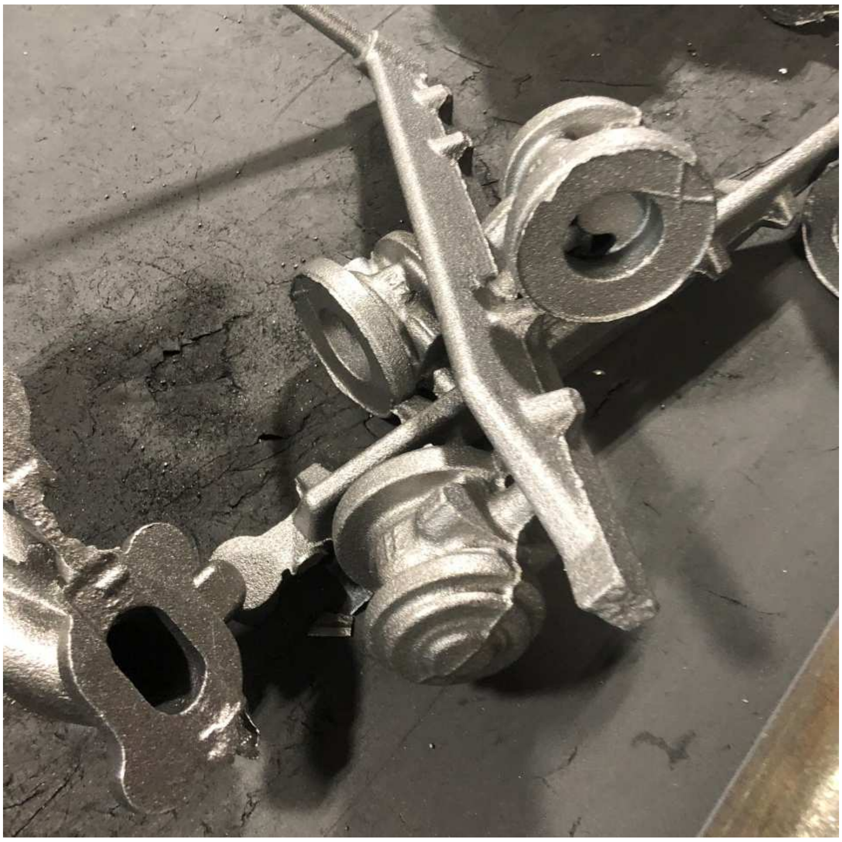

Figure 37 Detail of the shot blasting process

After the first blasting process, all product results with empty internal cavity but with some darkness. There are some scraps like in the following:

- Type X (Figure 38): total of 135 casted irons, 106 are ok, 29 broken core (21.5%)
- Type I (Figure 39): total of 84 casted irons, 83 are ok, 1 broken core (11.9%)
- No identification: total of 5, all KO because of broken core

Figure 38 Casting after shot blasting process – Type X

Figure 39 Casting after shot blasting process – Type I

Subsequently, both internal and external testing is prepared.

During the destructive internal testing, after cutting, the internal cavities are free for both type I and type X, but with some small sand residues (Figures 40 - 42).

Figure 40 Casting cutting operation

Figure 41 Casting Type I after cutting operation

Figure 42 Casting Type X after cutting operation

On two castings, one of each type, which had already undergone the first passage in the shot blasting machine, a further operation is made (not belonging to the usual production cycle). During internal destructive testing, after cutting, the cavities are free and there is no residual sand in the internal parts of the casting.

A second external shot blasting is carried out on all the remaining castings for a further 10 minutes, for a total of 20 minutes, equivalent to the normal production process.

Upon visual inspection, all the jets result with the internal cavities empty and well cleaned. It can be concluded that the result obtained is excellent.