The presentation states the latest minirisers innovations on applications and designs on steel and ductile iron. The paper describes the advances reached on the removal of risers in ductile iron castings produced in green sand lines, as well as, the main defects of the ductile iron castings produced by the sleeves, their causes and possible solutions.

It also explains the minirisers applications for manganese, carbon, stainless, duplex and superduplex steels where a 50% of yield increase has been reached, compared to the standard technology, in addition of the advantages on quality improvements produced by less thermal inertia in the mould, such as cracks and hot-tears.

Keywords: steel, yield increase, ductile iron, defects
1. INTRODUCTION

The casting technologies applied to steels and complex alloys present a number of particularities that have limited their advances in terms of net/gross yield and productivity, especially if compared to other cast metal families.

The work presented in this paper is based on an intensive review of the feeding systems that are currently employed in the manufacturing of cast steel components. It is also reviewed the latest designs and formulations of minirisers in order to improve, in ductile iron, the separation from the castings and to avoid the related defects, such as fish-eye, canning and graphite degradation, when using other types of risers.

The industrialization stage has been performed together at the facilities of ASK Chemicals and in several foundries where substantial improvements on yield in the steel castings and cost decrease on the riser removal of the automotion castings.

2. TYPICAL DEFECTS IN DUCTILE IRON RELATED TO THE SLEEVES

The most typical defects in the ductile iron foundries are:

1. **Sleeve design related:**
   1.1. Wrong breakage of the riser: In that we have developed the EXACTCAST™ OPTIMA (patented) which not only has a very good breakage, but also avoids the mould contamination with particles coming from the sleeves.

![Mould without inclusions from minirisers using EXACTCAST™ OPTIMA & KMV QP](image1)

![Inclusions coming from the standard Minirisers](image2)

Figure 1: “Inclusions” defect
1.2. Canning defect: When the sleeve is inserted in the mould and the dimensional tolerance does not fit the green sand cavity, the metal goes around the sleeves creating a malfunction of the feeding and originating shrinkage on the neck. The EXACTCAST™ KI and KIM, being produced as a core, has a tolerance of \( \pm 0.1 \) mm versus the \( \pm 0.5 \) mm of the fibre sleeves. This small tolerance avoids this trouble.

2. Contamination defects related to fluorine content in the sleeve:

2.1. Fish-eye defect: When the green sand is contaminated with fluorine over 400 ppm, it causes a typical defect called fish-eye which is easy to solve by changing to fluorine free sleeves. A short-term solution is to dilute the green sand with new sand. This defect has two versions, one looks like the fish-eye and the other occurs in the hot area of the casting moulded in green sand which appears as small holes. In both cases, in the microscopic images, it is possible to see a slag, a part of degenerated nodules and the part of the unaffected metal.
Figure 4: Fluorine defects - “Fish-eye” defect on the Casting Surface and as holes in the hot areas of the casting

2.2. Graphite degradation defect: Sleeves with fluorine cause degradation in the metal inside the sleeve, feeding this metal to the casting. The solution is to use sleeves fluorine free.

Figure 5: “Graphite degradation” defect depending on the type of the miniriser with and without fluorine
2.3. This trouble is increased by the heat generated by the sleeve to the casting surface that can be visually observed after machining the casting. In extreme cases, to separate the riser from the casting helps solve the trouble.

![Image of casting surface with heat generation](image)

Figure 6: Shadow created by the graphite degradation under the sleeve

3. YIELD INCREASE WITH MINIRISERS IN STEEL

**Studied Process Variables:** The basis of this study is the optimization of the yield and, thus, the process variables affecting the contraction model have been identified and evaluated. Among all of them, the most significant ones have been selected and they have been assessed in terms of contraction. The most relevant process variables are:
- Solidification rate.
- IN-EXO riser sleeves and feeding system designs.
- Metal superheating.

The figure 7 shows clearly, in detail, the main variables affecting the solidification volume.
4. RESULTS

Solidification Rate: The analyses that have been performed with virtual tools have outlined that as the cooling rate increases, the shrinkage associated to the liquid-solid interval is reduced.

In order to experimentally verify this behaviour a specimen based test has been designed and carried out. Utilizing the very same moulding and feeding system, with three different minirisers KMV 1650, KMV 780 and KMV 590 with modulus of 5,7; 4,2 and 3,9 cm (2,24, 1,65 and 1,54 in.) respectively are moulded, one of them having a chill at the bottom while the two others do not. In this condition, metal from the same ladle is poured in both moulds and, after they are cooled down, the shrinkage cavities are evaluated.

It is verified that the shrinkage defects related to the primary and secondary contraction are bigger in the case of the specimen without chills. The increase of the cooling rate by means of using a chill changes the thermal modulus, which is evident, but it also changes the contraction model.
Figure 8: The test specimen was free of shrinkage porosity in the three shown cases. Sample #1 with chills and samples #2 and #3 without chills.

Figure 9. Constitutive elements of a design

Sleeves – Geometries/models: Depending on the application, three base designs have been employed as starting points.
- IN-EXO sleeves: Due to their particularities they require a smaller weight of metal than conventional sleeves, considered the modulus is kept constant.
- PADDING Sleeves: An adaptation of their geometry to each application avoids the metallic padding removal and increases the feeding distances; in this way avoiding the use of chills.
- WELL sleeves: The sleeve and the well are produced in EXACTCAST™ exothermic material. New designs and geometries have been developed in which remarkable benefits have been identified, since the possibility of increasing the riser’s action radius area and the feeding distance can be added to the IN-EXO response of the mix itself.
For ductile iron we have concentrated in models KMV, KIM and KI, our efforts on designs which improve the riser removal avoiding subsequent reworks and formulations and designs to prevent defects such as fish-eye, inclusions, canning and graphite degradation.

Figure 10: Geometries, composition design tested in the Project.

Metal superheating in steel: The criteria that are managed for the definition of an alloy’s superheating temperature are very subjective and its effect in the contraction is seldom considered. In a generic way, it can be stated that as the superheating temperature is increased, the tendency to shrink also increases. When optimizing the response of the IN-EXO mini-risers, the volume increment per each 100ºC of superheating has been used as reference, which corresponds to values around 1%.
Figure 11: Modelling of the three contraction stages

Metallurgical considerations: The productivity and cost reduction advantages that come along with the yield optimization must be added to a complete set of metallurgical improvements that have showed up in the different melts of the experimental stage. Amongst the discovered advantages, it is worth citing:

- Lower mould thermal inertia meaning a reduction in local thermal loads, which becomes a foundry related defect prevention tool (cracks, segregations, etc.).
- More favourable micro-structures and minimization of the grain growth phenomena.
- Lower amount of scrap and higher material rotation. The furnaces are loaded with higher ingot percentages, which directly increase the quality of the metal.
- Lower material loss due to non-reusable in-house produced scraps (contaminated risers).
- Risers with reduced section can help avoid, in some cases, the annealing/tempering treatment needed to cut out the feeding system without generating cracks in the part.

5. INDUSTRIAL APPLICATIONS

This concept has been approved in several types of metals with, at least, 50% decrease on the riser size. See some examples.
Figure 12: Manganese Steel

Figure 13: Carbon Steel
Figure 14: Stainless Steel - Yield optimization on stainless steel components with fibre neck down sleeves (2) and minirisers (1)

Figure 15: Steel casting with miniriser and Exothermic Padding
For the big steel castings the padding sleeves concept has been used. That substitutes the metallic padding with the big advantage on cost as it does not need to remove the metallic paddings which is a very costly operation. Steel castings up to 10,200 kg have been produced with minirisers and exothermic padding, reaching yields of up to 82%.

6. ADDITIONAL ADVANTAGES

The foundries using this technology not only increased their yields, but also found other advantages coming from the less thermal inertia of the casting that can be seen, in detail, in figure 17.
7. FINAL CONCLUSIONS

The new minirisers using aluminium silicate microspheres and supported by innovative designs are able to reduce in ductile iron defects related to fluorine, such as fish-eye and graphite degradation; shrinkage associated to canning, as well as, to reach an optimum fettling that avoids extra rework. Furthermore, the application of this technology in steels has allowed us to achieve ratios that, up to now, were not reachable. The foundries using this technology are getting yields of 65% for stainless steel castings with radiographical control, up to 80% in big carbon steel castings and up to 90% in manganese steel castings.

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9. REFERENCES