Ten Steps to Improving Casting Yield in Ductile Iron Foundries

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ABSTRACT

Ten steps for increasing yield in ductile iron castings are proposed. These include use of ceramic foam, shorter gating systems, non-turbulent gating system design, thinner runners and ingates, and proper and efficient use of risers. Many of these techniques have been reported in the literature. It is suggested that cost-savings achieved by application of these steps can be significantly higher than those achieved by conventional scrap reduction procedures. Two case studies outlining the use of these principles with yield improvements are shown.

INTRODUCTION

Several gray iron foundries are slowly adding ductile iron castings to their repertoire. Shrinkage and proper micro-structure problems are often their key challenges. There is also a misconception that ductile iron castings are often associated with large risers. It is common to see the bulky gating designs of gray foundries combined with large risers contributing to reduced casting yield in many ductile iron castings. On the other hand, the primary customer for these foundries (the automotive industry) continues to make increased demand for cost reductions and quality improvements. Globalization brings additional factors into play in these areas. The production engineer in a foundry has now become involved significantly in the commercial and economic aspects of running a foundry. The foundry process has significant variables and often optimization of competing factors is essential to meet the goals of productivity and quality. These efforts, in turn, lead to improved profitability of the foundry business unit. This paper outlines ten principles of gating and riser design that could help the foundryman to show dramatic improvements in casting yield and thus reduce his costs.

YIELD IMPROVEMENTS VERSUS SCRAP RATE REDUCTION

Conventional attempts at reducing costs are often focused on scrap reduction. Yield is often indicated as the ratio of the casting weight to the total pour weight. In a hypothetical case, let us consider a casting that has yield of 48%. If the current scrap level associated with the casting is around 5%, the effective yield is around 45.6 % (48% *(100-5/100) =45.6%). Let us assume that the yield of that specific casting is increased (by the principles outlined in this paper) to 73% and there is an associated scrap equal to 10%. The resultant effective yield (considering loss due to scrap) is around 65.7% (73% *(100-10/100)= 65.7%). Thus, the overall effect of yield improvement can be a more significant cost reduction tool in spite of an increase in scrap levels. The authors do not minimize the importance of quality improvements and scrap reductions. Scrap reduction through process control and continuous improvement is essential for the survival for most foundries. It is merely suggested that yield improvement should also be given due consideration.

Metal weight to mold ratio is often considered important since it indicates the volume utilization of the mold for a given casting. The increased volumes of cores used in a mold also lead to increased costs. All yield improvement efforts should include ways to get additional castings per mold and minimize the volume of cores used in each mold.

TEN STEPS TO ACHIEVE HIGH YIELD

The following ten steps or ideas assist in reducing the gating system dimensions and volume and result in higher yields without compromising casting quality. Two case studies at the end of the paper illustrate applications of these principles.

1) Use of Ceramic Foam Filters

Conventional application of filters is based on reducing the incidence of scrap related to inclusions. However, the proper use of ceramic foam filters in the runner system can help reduce the length of the runner and gates [1]. Flow modification can help reduce turbulence in the gating system and consequently the formation of reoxidation slag. Long runners and ingates are not needed to act as slag traps. Significant yield increases can, thus, be achieved by shorter runners and ingates.

2) Use of Stable Raw Materials

Optimum performance is obtained from use of raw materials that minimize variations in the process. For example, use of caruburisers that have a crystalline structure, homogeneous, pure or preferably of natural origin and free of any major impurities leads to good control of carbon content in the iron [2]. Good control over carbon content, in turn, leads to better control of shrinkage volume. Figure 1 shows typical ranges of carbon and silicon for sound castings [7].

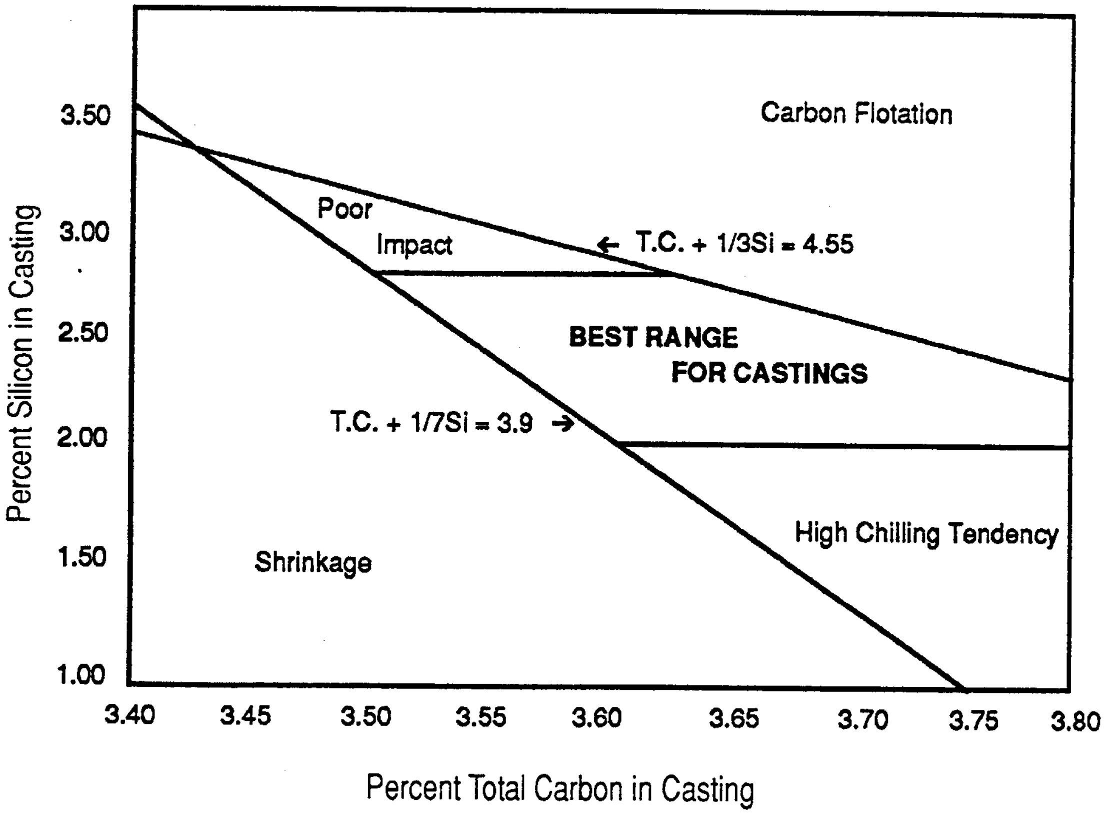
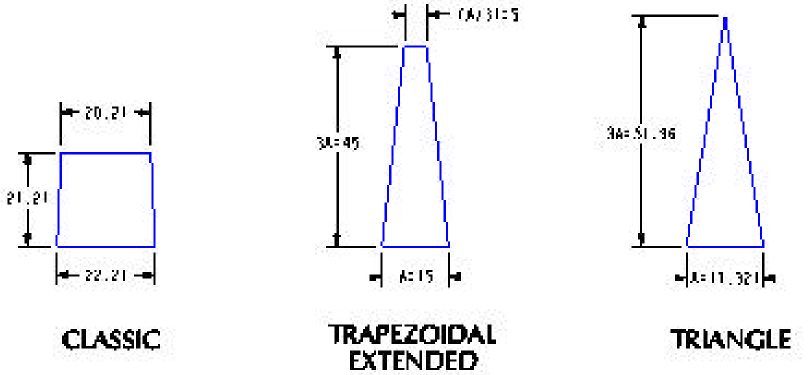


Figure 1: Carbon and silicon ranges for sound ductile iron castings [7].

3) Use of Trapezoidal Gate Cross-Sections to Minimize Turbulent Flow

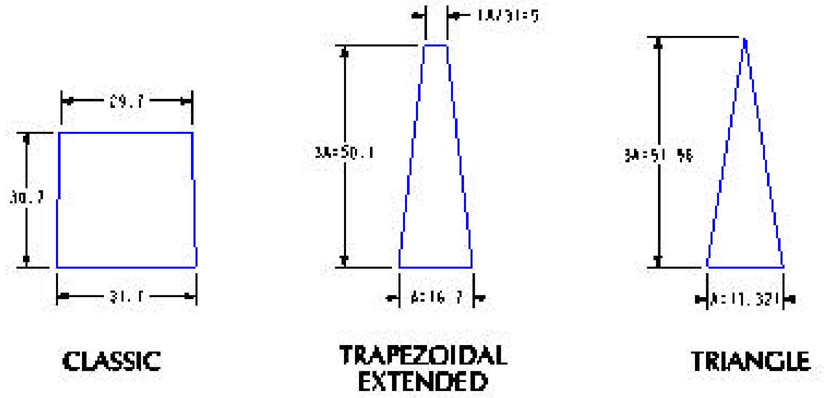
As mentioned above, the use of a ceramic foam filter minimizes the need to use runner and ingate sections as slag traps. Table I compares the gating elements of rectangular, trapezoidal (base= a height =3a, top= a/3 to a/5) and triangular cross-section along with corresponding modulus, Reynold's numbers and weight of these cross-sections. The top row has cross-sections that have constant weight per unit length. It can be seen that the classic rectangular cross-section has the maximum turbulence (as shown by a high Reynold's number)[3]. The lower row consists of gating cross-sections with the same Reynold's numbers (same associated level of turbulence). The weight of the triangular cross-section ingate is the lowest. However, the triangular cross-section is not preferred by most foundrymen since there is a risk of mold erosion in the corners. The very low modulus of the corners can also negatively affect the solidification characteristics of the triangular ingate. Therefore, these analyses suggest that a trapezoidal cross-section shown above can give a balance between good flow characteristics and lower weight.

Table 1: Comparison among the different types of runners. (Flow = 2.5 Kg/sec.)



AREA (mm^2)	450		450		450
PERIMETER (mm)	84.89		110.55		122.68
MODULE (cm)	0.53		0.41		0.37
REYNOLD "Re"	29450.9		22613.4		20378.1
Weight (g/25.4mm)	81		81		81

(A) : Weight – Const.



AREA (mm^2)	942		544		450
PERIMETER (mm)	123		123		123
MODULE (cm)	0.77		0.44		0.37
REYNOLD "Re"	20353		20395		20378
Weight (g/25.4mm)	170		98		81

(B) : Re – const.

4) Optimizing Pour Times and Pouring Sequence

Conventional gating designs often focus on simultaneous filling of all cavities in a mold. This results in large sprues and runner systems needed to deliver the required flow rates. It is suggested that designs that permit sequential filling of cavities can reduce the need for high flow rates, consequently, the gating system can be leaner in size [4].

5) Optimum Gating/Runner Modulus to Control Temperature Loss

It is generally known that shrinkage will increase as pouring temperatures decrease. The modulii of the gating channels must be kept in mind, since high values (thicker and heavier runners and ingates) decrease the yield. However, too low values (very thin runners and ingates) will cause gating elements to solidify rapidly and cause localized shrinkage in the castings. Care must be taken to ensure that significant metal temperature loss does not take place in the gating system.

6) The Use of Risers to Compensate Expansion

Risers must be considered as compensators (for shrinkage volume). The supply of molten metal needed for filling the casting comes from the ingates. The objective is to avoid the over pressurization that generates the expansion during the solidification producing the formation of secondary shrinkage. The application of this concept allows the use of small risers improving the casting yield [5,6]. Periodic sectioning and examination of the risers is essential to verify that the risers are working as designed. The volume of metal fed by each riser should be determined.

7) Placing Risers at Optimal Locations

It is important to analyze the critical sections of a casting to ensure that solidification progresses in a logical fashion. The use of risers at key locations to ensure a sound casting cross-section is essential. Figure 2 shows sectional views of a carrier housing casting and the basis for locating risers. The modulii of various sections are grouped together for feeding by two risers. Feeding distance of each riser should be considered when deciding on the location and position of the risers.

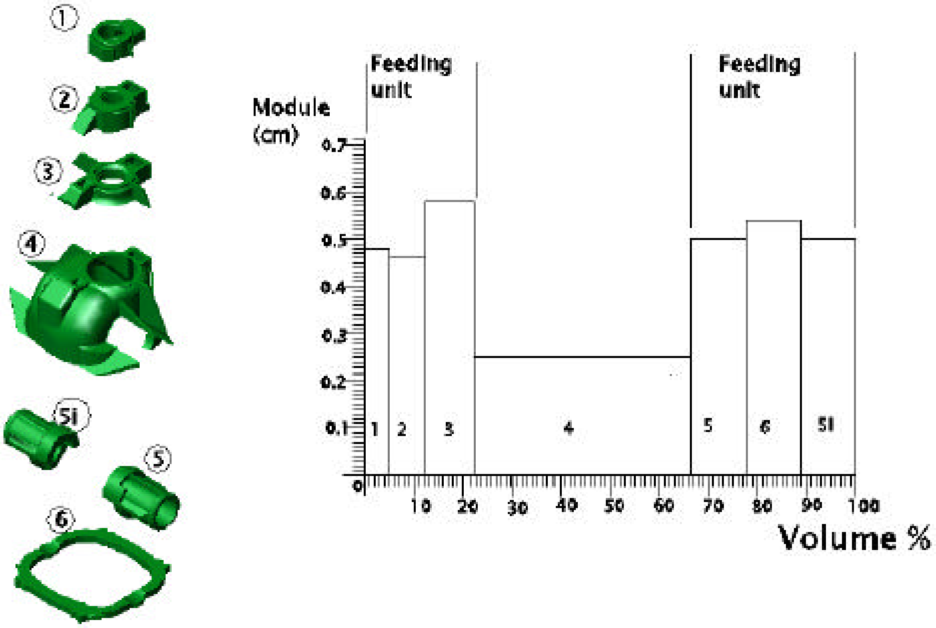


Figure 2: Positioning of risers based on modulii of important casting cross-sections.

8) Use of a Riser for More than One Casting (Whenever Possible)

When a system allows, a design factor that allows for improvement of the yield, is sharing a riser with several castings, since its function is based on its modulus; and only the size needs to be adjusted to achieve the required feeding volume to the castings.

9) The Use of Top Risers

In vertical molding systems, it is relatively simple to locate the top risers, but in a horizontal molding system, the situation is more complicated. The application of these kinds of risers in both cases, allows the handling of appropriate feeding volume (based on the difference between the riser height and the cope height) with smaller size riser contributing to increased yield.

10) The Use of Hot Risers

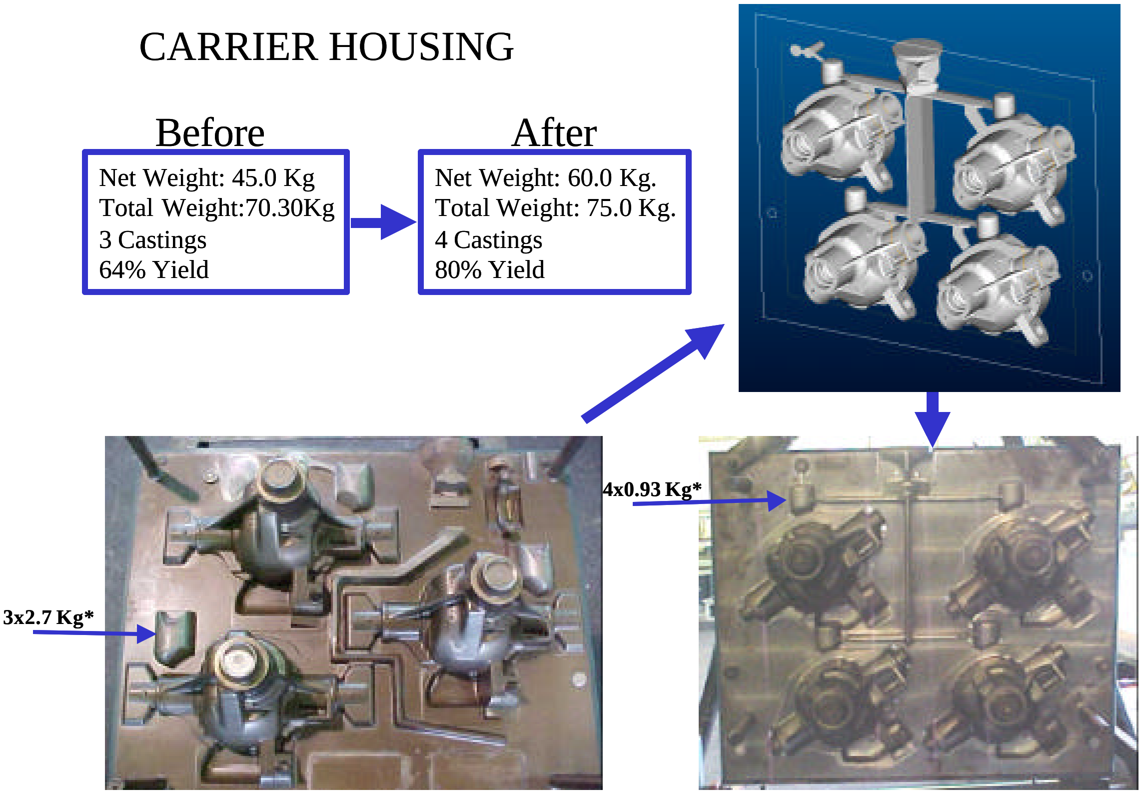
Hot risers are very efficient. The volume of metal that can be delivered to the casting is significantly larger than the volume supplied by a cold riser. Consequently, the riser volume tends to be smaller. As mentioned earlier, periodic examination of riser sections is necessary to determine the efficiency and effectiveness of the risers.

CASE STUDIES

While these case studies are specific to vertically parted molds, the principles can be used in horizontally parted molds also.

Example A Carrier Housing Casting

Figure 3 shows the initial and final gating designs for a carrier housing casting. Initial yield was 64% with three cavities per mold. The ten principles outlined above were applied to this mold. The main changes include placing a ceramic foam filter under the sprue, thinner ingates and reduced cores. The use of smaller top risers also helped in yield improvements. A final yield of 80% with four castings per mold was achieved.



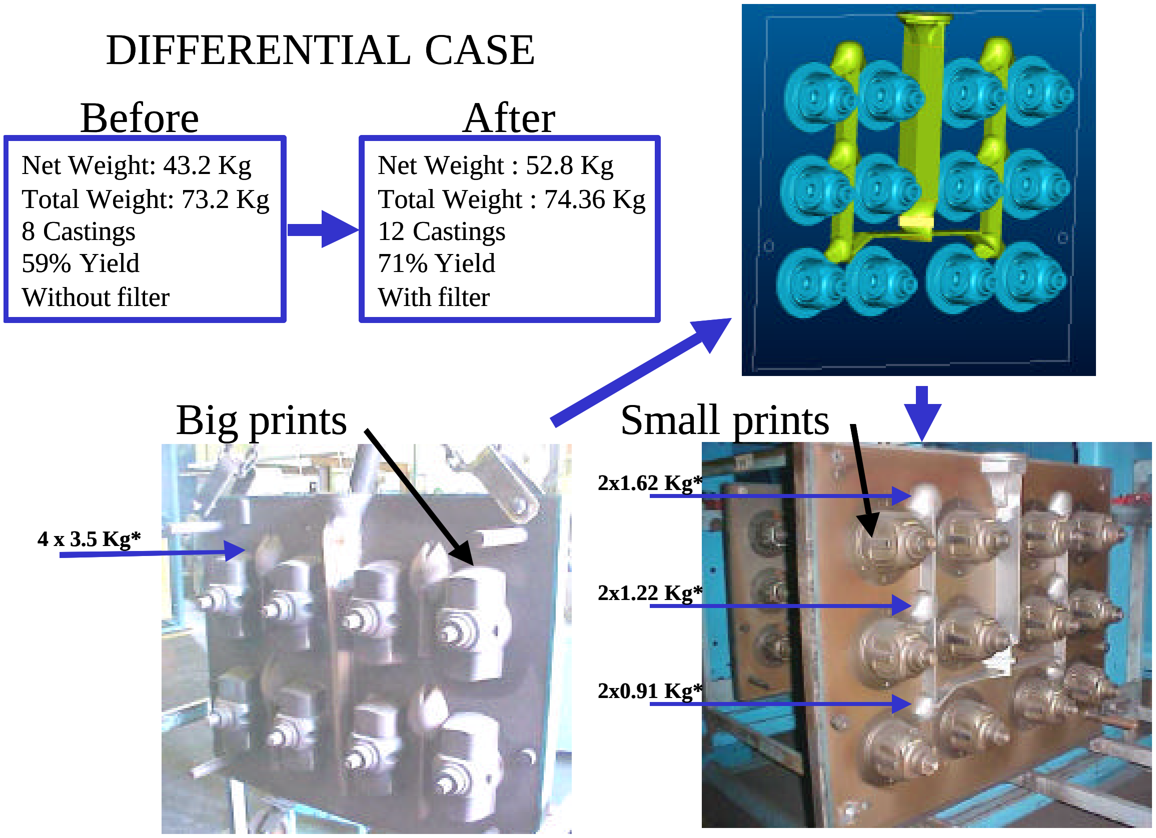
(*) Only riser weight

Disa line 2070

Figure 3: Illustration of a carrier housing casting.

Example B Differential Case Casting

Figure 4 shows the initial and final gating designs for a differential case casting. Initial yield was 59% with only eight castings per mold. The runner and in-gate cross-sections were calculated based on Reynold's numbers (as outlined in Table I). In addition to placing a ceramic foam filter, extensive redesign of the hot risers were performed. The hot risers at the middle level were 10% smaller as compared to the hot risers at the top level and 10% larger than the bottom level. The design, thus, used the advantages of metallostatic pressure at the lower levels. The average weight of the riser reduced from 1.2 Kg to 0.8 Kg. The final yield was 71% with 12 castings per mold.



DIFFERENTIAL CASE

Before

Net Weight: 43.2 Kg
Total Weight: 73.2 Kg
8 Castings
59% Yield
Without filter

After

Net Weight : 52.8 Kg
Total Weight : 74.36 Kg
12 Castings
71% Yield
With filter

(*) Only riser weight

Disa line 2070

Figure 4: Illustration of differential case casting.

CONCLUSIONS

Ten principles to improve yield in ductile iron castings have been outlined. Process improvements for scrap reduction are important. Process control is essential for consistent quality. The focus of this paper has been to suggest the possible benefits of cost reduction that can be achieved by yield improvements.

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