# RISER DESIGN BASICS FOR CAST IRONS

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**ARTICLE TAKEAWAYS:**

- Risers are designed to feed initial metal shrinkage
- Gates and Contacts should freeze off as graphite expansion begins
- One riser per feeding zone – Too many risers CAUSE shrinkage in cast irons

## DESIGN PRICIPLES FOR CAST IRON

The fundamental difference between gray and ductile cast iron and other alloys is the expansion that occurs as graphite precipitates during solidification. In most situations, the casting can become "self-feeding" after the onset of expansion and no further feeding is required. The object of designing a risering system for iron castings is to provide feed metal for the contraction of the liquid alloy as well as the contraction of the solidifying iron prior to the start of expansion; once the expansion begins, a well-designed risering system should control the expansion pressure to ensure that the casting is self-feeding during the remainder of solidification. This is in contrast to other alloys such as steel, where feed metal must be supplied to the casting during most or all of solidification and there is no expansion involved.

Another major difference between graphitic cast irons and other alloys has to do with the mechanism involved in "piping", or the onset of feeding behavior in the riser. In practice, only one riser should be used on each "feeding zone" in an iron casting; if multiple risers are placed on the same zone of a casting, then typically one riser will begin piping while the other will not. Often, porosity will be seen at the contact point of non-piping risers.

The requirement for a single riser per feeding zone is probably the design rule most often violated in iron foundries. We see designs where two or more risers are feeding the same zone within a casting, and the resulting casting exhibits porosity, often at the contact point of one of the risers. The tendency of many foundry engineers is to add more risers to try and resolve the porosity issue; in fact, this is exactly the wrong approach and will worsen the situation.

To correctly design a risering system, we must answer the question: Is this casting composed of a single feed zone, or are there multiple zones and, if so, what is the location and size of each zone? To make this determination, we introduce the concept of the Transfer Modulus.

Feed zones within the casting are defined by knowing where in the casting it is possible for liquid metal to flow from one point to another in response to expansion pressures. If there is no possibility of metal flowing from one area of the casting to another as expansion begins, then each of these areas forms a separate feed zone and each may require its own correctly-designed feeder (but no more than one).

The analysis of a casting begins with consideration of the Casting Modulus. This is defined as the volume:surface area ratio of various areas of the casting, and has been used for many years to estimate the order of solidification of different parts of the casting. The Casting Modulus (Mc) allows us to estimate which part of the casting will solidify first and which will solidify last. In steel castings, this information is immediately useful to indicate where risers should be placed and what size they should be (the Modulus of the riser should be greater than the Modulus of the casting). In iron castings, the Casting Modulus is used to estimate when expansion will begin, expressed as a percentage of complete solidification.

Prior to development of computers, calculation of Mc was tedious and time-consuming; it required the foundry engineer to estimate volumes and surface areas by approximating various parts of the casting with relatively simple shapes. With modern casting simulation

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software, solidification of a casting can be predicted, often in a matter of minutes. Data from this simulation can be converted to Modulus values in the casting. This means that Modulus data is now available at every point in a 3D representation of the casting; this also means that the Modulus data is more accurate, as effects such as local superheating of the mold material are accurately taken into account by the simulation, which is not possible with manual methods.

With the Modulus data for the casting, as well as the chemistry and temperature data, the point at which expansion begins can be calculated. Castings which have a higher Modulus (heavy section castings) will begin to expand earlier and will undergo more expansion than castings with low Modulus (light section castings). The expansion start point is expressed as a percent of full solidification and is called the Shrinkage Time (ST) point.

Knowing the ST point for the iron in a casting, it is possible to calculate an equivalent Modulus at which contraction of the iron stops and expansion begins. This is known as the Transfer Modulus (MTR), because it defines for us the areas of the casting where liquid metal transfer is possible. The calculation of MTR is as follows:

**MTR = SQR ( ST /100) * MC**

By plotting the value of MTR we can visualize the feed zone(s) in the casting. This allows us to determine the number of required feeders, using the rule of one feeder per feed zone.

The value of MTR represents the Modulus value below which feeding of the casting from risers is no longer effective and the iron becomes self-feeding due to graphite expansion. MTR is critical in designing the risering system. The basic premise in all design work for feeding iron castings is that expansion pressure must be controlled. Assuming the mold is rigid enough, all contacts with the casting (gates and riser contacts) should be solid enough to ensure that the expansion pressure is contained in the casting after the onset of the graphite expansion. This leads to another simple rule: The Modulus of the feeder contact neck should be equal to MTR. This ensures that feeding of the liquid contraction will be able to occur, and also that the expansion pressure will be contained in the casting due to freezing of the feeder contact at just the correct point in solidification.

## CASE STUDY

As an example of both the incorrect and correct approach to feeding cast irons, we examine a 210 Kg ductile iron ring casting, shown in Figure 1. This casting is a bearing connector for a wind power generator.

**Figure 1.**
Ductile iron bearing connector (210 Kg).

The foundry making this casting approached riser design as a steel casting rather than an iron casting. Figure 2 shows two alternate riser designs which were being used to produce this casting. The original design specified five risers with insulating sleeves. When the results of this design were unsatisfactory, the design was changed to include six risers.

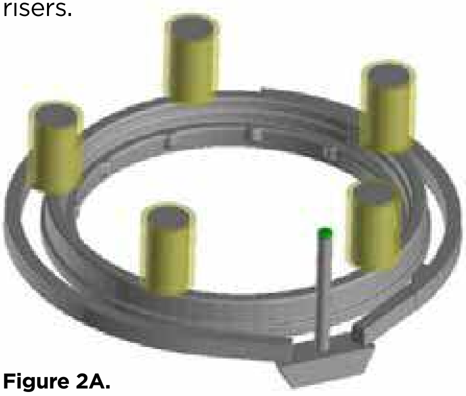

**Figure 2A.**
Original design with five risers

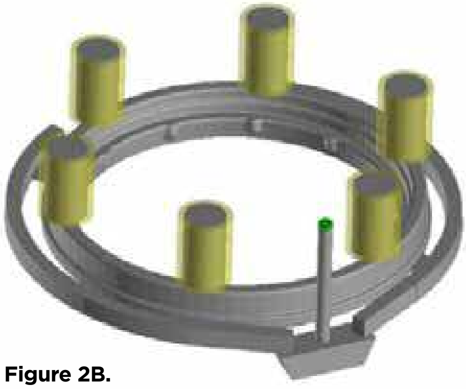

**Figure 2B.**
Redesigned process with six risers.

This is typical of the approach to design and problem solving that one might find in a steel foundry; if a casting cannot be successfully produced with a given set of risers, the typical decision is to add more risers. This approach did not resolve the problem, instead the quality of the casting was worse. This casting represented the most expensive scrap problem of all production castings in the foundry.

Examination of the defective casting showed that porosity was exposed on the top surface of the casting after machining 6 mm of iron off the surface, as shown in Figure 3.

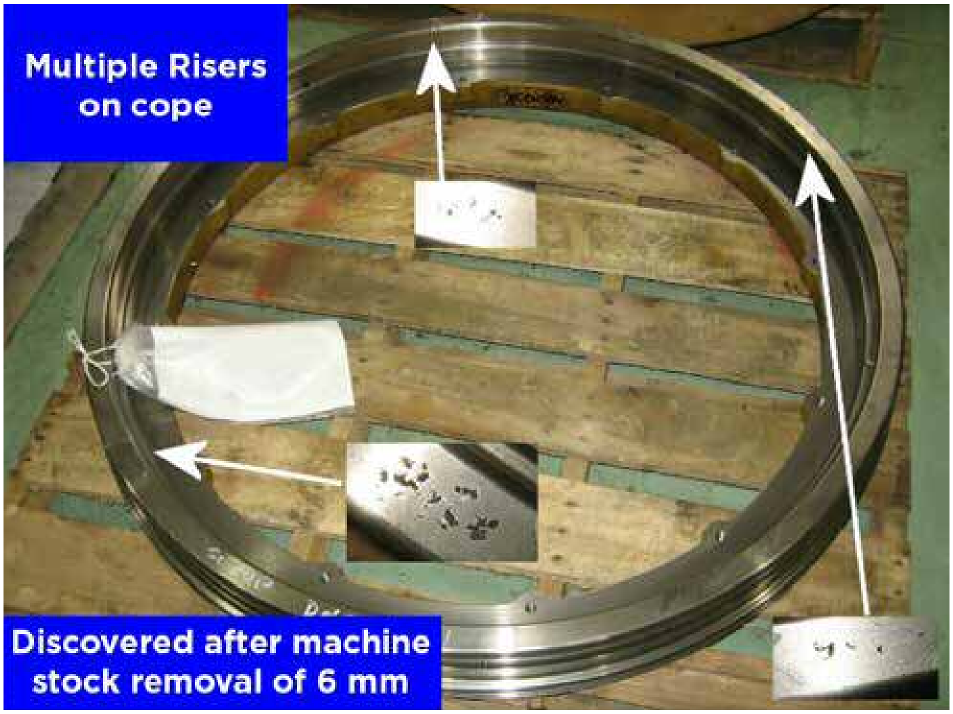

**Figure 3.** Appearance of porosity on machined surface.

Close-up inspection of the areas of porosity showed what appeared to be primary shrinkage as shown in Figure 4. A very strong clue to the cause of this porosity is that these defective areas were found at the location of the risers on top of the casting (which were removed after casting shakeout). This suggests the phenomenon which has been discussed earlier in this paper, that multiple risers are being used on a single common feed zone and only one riser is showing piping behavior with shrinkage formation under the non-piping risers.

**Figure 4.**
Porosity on machined face, under riser location.

An analysis of this casting was performed, involving a solidification simulation and calculation of the MTR. The value of MTR was determined to be 0.96 cm. A plot of MTR in the casting is seen in Figure 5.

**Figure 5.**
Plot of MTR at a value of 0.96cm.

This image shows very clearly that the entire casting consists of a single feed zone, and that only a single riser should be used on this casting. The final revised design for this casting is shown in Figure 6.

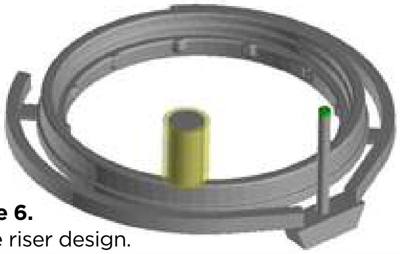

**Figure 6.**
Single riser design.

When this design was adopted in the foundry and the riser and contact were sized correctly, the result was a shrinkage-free casting. It is worth noting that the cores which were originally used by the foundry to create the riser-casting contacts were intended for production of steel castings, where the contact diameter was 50% of the riser diameter. Consideration that the Modulus of the contact should be equal to MTR resulted in a much smaller contact diameter. In this case the foundry produced cores which were specialized for this particular casting to ensure the correct contact size.

The analysis of this casting to produce the correct riser design required 15 minutes of time. The foundry could have saved considerable costs over a long period of time had they performed this quick and simple analysis before finalizing the production design for the casting.

## SUMMARY

Understanding the solidification mechanisms of graphitic iron alloys in terms of expansion/contraction behavior, feeding mechanisms and control of expansion pressure is critical to correct design of risering systems. Quick and simple analysis is available which will help the foundry engineer to design the production process correctly at the beginning of production, thereby avoiding major costs involved in producing defective castings.

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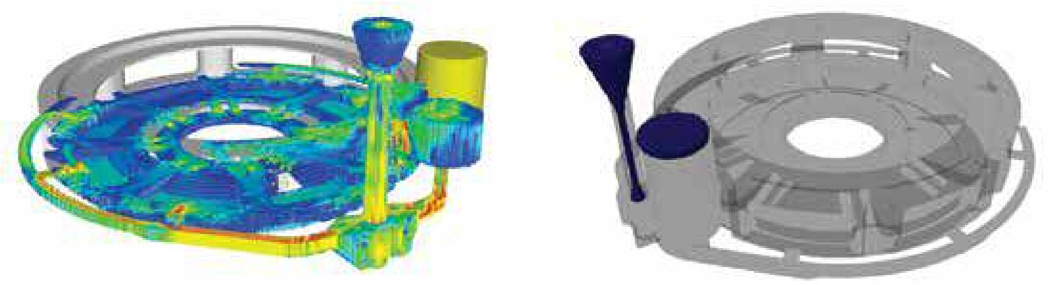

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