

RISER DESIGN BASICS FOR CAST IRONS



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ARTICLE TAKEAWAYS:

- Risers are design 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 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 feeding 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 feeding 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 cast irons and other alloys has to do with the mechanism involved in “piping”, or the onset of feeding behavior in the feeder. In practice, only one feeder should be used on each “feeding zone” in an iron casting; if multiple feeders are placed on the same zone of a casting, then typically one feeder will begin piping while the other feeders will not. Often, porosity will be seen at the contact point of non-piping feeders.

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

To correctly design a feeder 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 within 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 (M_c) 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 feeders should be placed and what size they should be (the Modulus of the feeder 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 and software, calculation of M_c was tedious and time-consuming; it required the foundry engineer to estimate volumes and surface areas by approximating various parts of the casting to relatively simple shapes. With modern casting simulation software, solidification of a casting can be simulated, often in a matter of minutes. The result data from this simulation can be converted to Modulus values within the casting. This means that Modulus data is now available at every point within 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). This point at which expansion begins is expressed as a percent of full solidification and is often referred to as the Shrinkage Time (ST) point.

Knowing the ST point for the iron in a casting, it is possible to calculate an equivalent Modulus value which then corresponds to the Modulus at which contraction of the iron stops and expansion begins. This Modulus value 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:



Figure 1.
Ductile iron control arm casting.

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

By plotting the value of MTR we are able to 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 can be understood as representing the Modulus value below which feeding of the casting from risers is no longer effective and the iron becomes self-feeding due to expansion. MTR is critical in designing the feeding system. The basic premise in all design work for feeding iron castings is that the expansion pressure must be controlled. This means that, 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 within 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 the correct feeding approach, we consider first of the all the ductile iron control arm as shown in Figure 1.

The foundry originally approached the feeding design for this iron casting by placing two symmetrical feeders as shown in Figure 2. This was, perhaps, understandable as the two sections to which these feeders were attached are the heaviest sections of the casting.

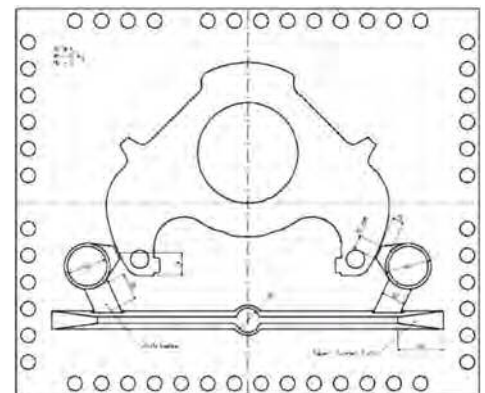


Figure 2.
Original pattern layout and feeder design.

During initial production of this casting, it was found that porosity occurred at one feeder contact on a consistent basis, as shown in Figure 3. The porosity was not always at the same contact, but on all castings one contact showed evidence of porosity and the other did not. No acceptable castings were produced with this pattern design.

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Figure 3. Feeder contacts with original design (2 feeders).



Figure 4. Areas of high modulus value in the casting.

To resolve this problem, it was decided to analyze this casting using the approach described previously to determine the feeding requirements. First, a solidification simulation of the casting without gating or feeders was performed. The data from the simulation was converted to Modulus data so that the feeding calculations can be performed. Figure 4 shows a plot of the areas of highest Modulus in the casting. From viewing this plot, the foundry engineer might be tempted to conclude that the original feeder design was correct, as there are two areas of high Modulus value in the casting and these are adjacent to the feeder contacts in the original design.

However, it is necessary to further analyze this casting to determine the Shrinkage Time and from this the Transfer Modulus (MTR) in order to understand the location and size of the feeding zones within the casting. Figure 5 shows the calculation performed within the software of values for both ST and MTR.

Analysis of the iron characteristics for this casting indicates that the value of the Transfer Modulus is 0.645 cm. Creating a plot of this value within the casting will indicate the location of feed zone(s); this is shown in Figure 6.

This plot shows that the entire casting is a single feed zone. The areas of higher modulus are connected by a section of the casting in which the Modulus is above the value of MTR, allowing liquid transport for feeding throughout the casting. This means that only a single feeder should be used on this casting. With the two-feeder design, both

feeders were connected to the same zone of the casting; when this is done, one feeder will pipe and the other feeder will not pipe, resulting in porosity at the contact of the non-piping feeder.

It should be noted that the computer simulation in this case took 16 minutes to perform, and within less than 5 minutes after that the calculation of ST, MTR, and the plot shown in Figure 8 were created. This means that with about 20 minutes of analysis, the correct feeder design was arrived at. Had this been done before the original pattern equipment was created, several months of time involved with production of defective castings would have been avoided. The costs involved were far greater than the cost of the software and training to perform this analysis.

After this information was presented to the foundry, the pattern was revised to reflect a single feeder as shown in Figure 7.

It should be noted that the feeder in this case is not connected to the casting at one of the areas of high Modulus. This illustrates the point that in iron castings, the location of the feeder is not as critical as in steel castings. This is due to the expansion pressure which acts throughout the casting once precipitation of graphite begins.

Finally, Figure 8 shows a photograph of the contact area with a single feeder. In this case there is no porosity at the feeder contact, and no porosity elsewhere within the casting. Thus, a simple and quick analysis of the casting has produced the correct feeder design for making a sound casting.

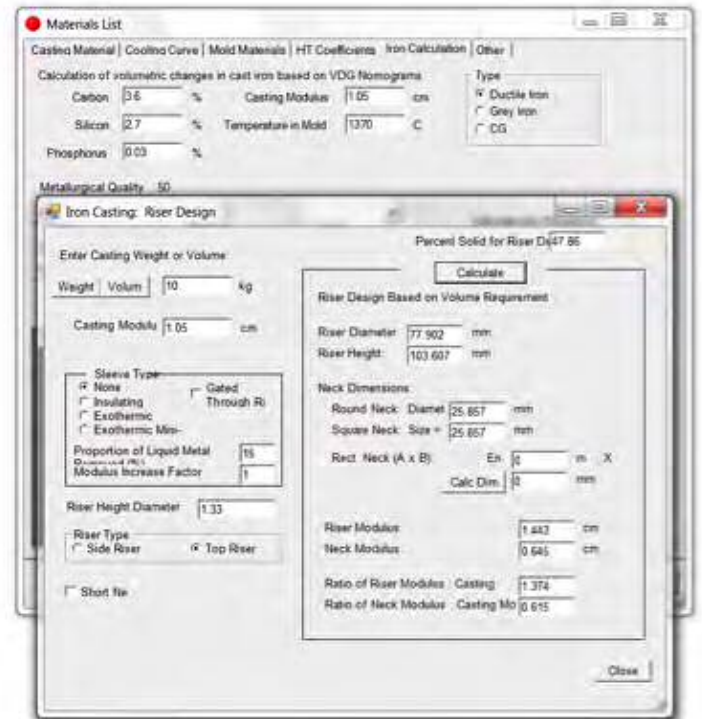
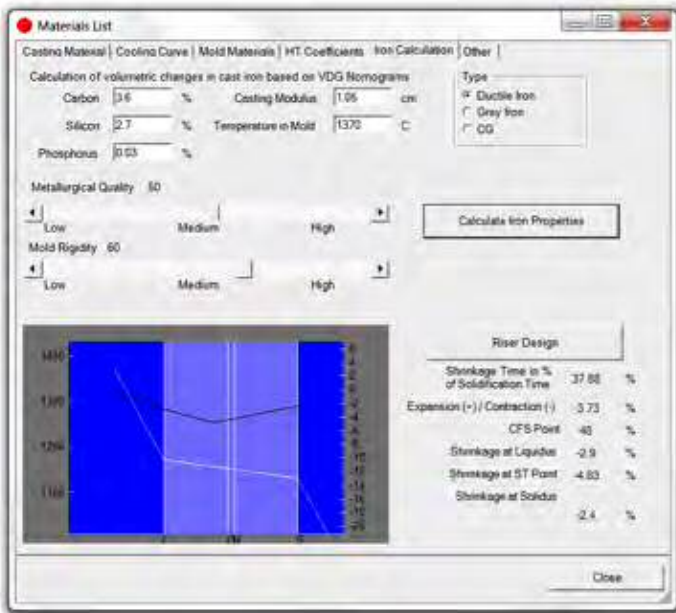


Figure 5. Calculation of Shrinkage Time and Transfer Modulus for the Casting



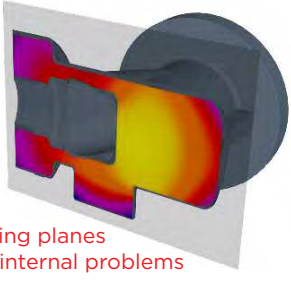
Figure 6. Plot of transfer modulus of 0.645 cm in the casting.



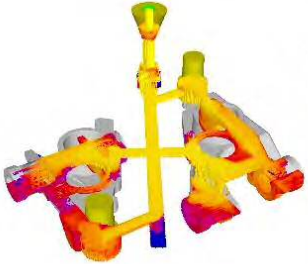
Figure 7. Photo of revised pattern with single feeder.



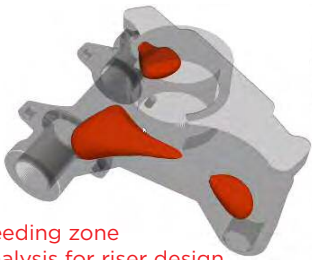
Figure 8. Photo of the contact area with a single feeder.



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