Effect of breaker core opening on carbon segregation

Abstract

This project was conducted to evaluate the effect of breaker core opening size on elemental segregation for top risered castings. The castings included cube castings and actual castings, both made from 8000 series, arc-melted carbon steel.

Castings made using the standard 50% opening breaker core based on the Washburn formula experienced under riser carbon segregation. Castings made using a full contact riser sleeve did not experience this problem.

Computer simulations were initially conducted to determine the optimal breaker core opening size for elimination of under riser carbon segregation. Opening sizes of 50%, 60%, 65%, 70% and full contact were simulated. The results showed a significant reduction in under riser segregation for the 65% and 70% cases.

Foundry trials were then conducted for the same breaker core opening designs on a casting with known segregation problems. The trials showed that the 70% opening was optimum for elimination of under riser carbon segregation for all castings tested.

For top-risered, segregation prone carbon steel alloys, breaker core opening size should be increased to between 65% and 70% of the riser diameter to minimize under riser segregation.

Introduction/Background

Elemental segregation can be even more detrimental to casting quality than inadequate feeding. Generally, inadequate feeding is visible to the naked eye as porosity, or at least visible via simple dye-penetrant tests. Elemental segregation (e.g. carbon) is generally not visible to the naked eye, and requires testing, such as etching, to determine if segregation is present. In practice, this problem is normally discovered in the form of under riser cracks or hard spots. Of course, this is of serious concern to foundries, and often results in scrapped castings or expensive repairs.

This type of segregation is normally associated with gross differences in the concentrations of alloy elements from one area of the casting to another, and is also referred to as macro-segregation. The degree of segregation increases with increasing carbon and alloy contents of the melt. The tendency of various elements to segregate in steel alloys is described in J. W. Halley's article, "Residual Elements in Steel"[1]. Several other excellent references can be found regarding segregation in steel castings[2-12].

One simple solution to reducing elemental segregation is to increase the pouring temperature of the melt, as outlined by Harold Bishop and K.E. Fritz[13]. This, of course, increases energy costs and may require larger risers to accommodate the increased volumetric feed metal demand, thus reducing yield.

Another solution would be to use full contact risers, thereby eliminating the use of a breaker core. Practically speaking, this is not a viable solution in many cases due to the increased cleaning costs. In most cases, a breaker core is desired for this application.

The focus of this project was to optimize breaker core opening dimensions for top risered castings made from segregation prone carbon steel alloys[1]. The goal was to minimize and/or eliminate elemental segregation found under existing riser sleeves with standard 50% opening breaker cores. The standard 50% opening breaker core design is based upon the Washburn formulation, shown in Figure 1.

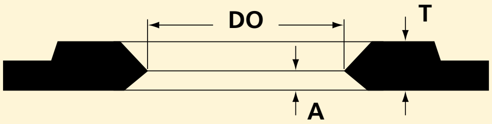


Figure 1: Washburn Breaker Core formulation.

$$D0 = 2.34 \times Mc \quad (1)$$

$$T = 0.56 \times Mc \quad (2)$$

$$A = T + 2.75 \quad (3)$$

where:

D0 = diameter of opening
T = maximum core thickness
Mc = geometric modulus of casting
A = height of break notch

Computer simulations using MAGMASOFT[14] were conducted on a matrix of cubes, and on a series of castings to estimate the optimum breaker core opening dimension. Molten metal trials were conducted in several foundries to validate the predicted results, and to determine the optimal breaker core aperture. In all cases, trials and simulations were conducted with low alloy, carbon steels prone to elemental segregation.

Results/Discussion

The molten metal trial and computer simulation results for the cube and castings were consistent and an optimal breaker core aperture design is recommended.

For all cases, the metal was 8000 series, arc-melted carbon steel. The base carbon level in the melt was approximately 0.28% (8627) for the cubes and 0.34% (8630) for the castings. The pouring temperature was 2880 F for the cubes and 2840 F for the castings. The top risers were insulated with exothermic/insulating insert sleeves in all cases. The molds are resin bonded sand in all cases.

A matrix of 80 cube castings was defined to cover a range of cube sizes, riser sizes and breaker core apertures. Solidification only computer simulations were conducted for all 80 cubes. Molten metal trials were conducted on 40 of the cubes. A representative example of the results is shown in Figure 2.

Carbon segregation is clearly shown as the discoloured regions in the casting photos in Figure 2. The discolouration is a result of the etching procedure. Significant carbon segregation is shown underneath the riser for the 50% breaker opening case. At 65% opening, the carbon segregation has moved into the riser neck, and is completely contained in the riser for the full contact case.

After evaluating all of the cube casting computer simulation and molten metal trial results, it was determined that the optimal breaker core aperture is between 65-70%.

The **second** part of the study involved actual castings made from 8630, low alloy, arc-melted carbon steel. A computer model of the casting and gating is shown in Figure 3.

Figure 3 shows one casting, but the configuration is actually a two on, symmetrical pattern.

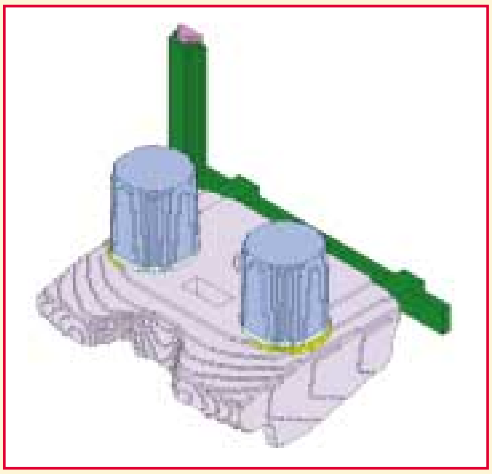


Figure 3: Computer model of casting.

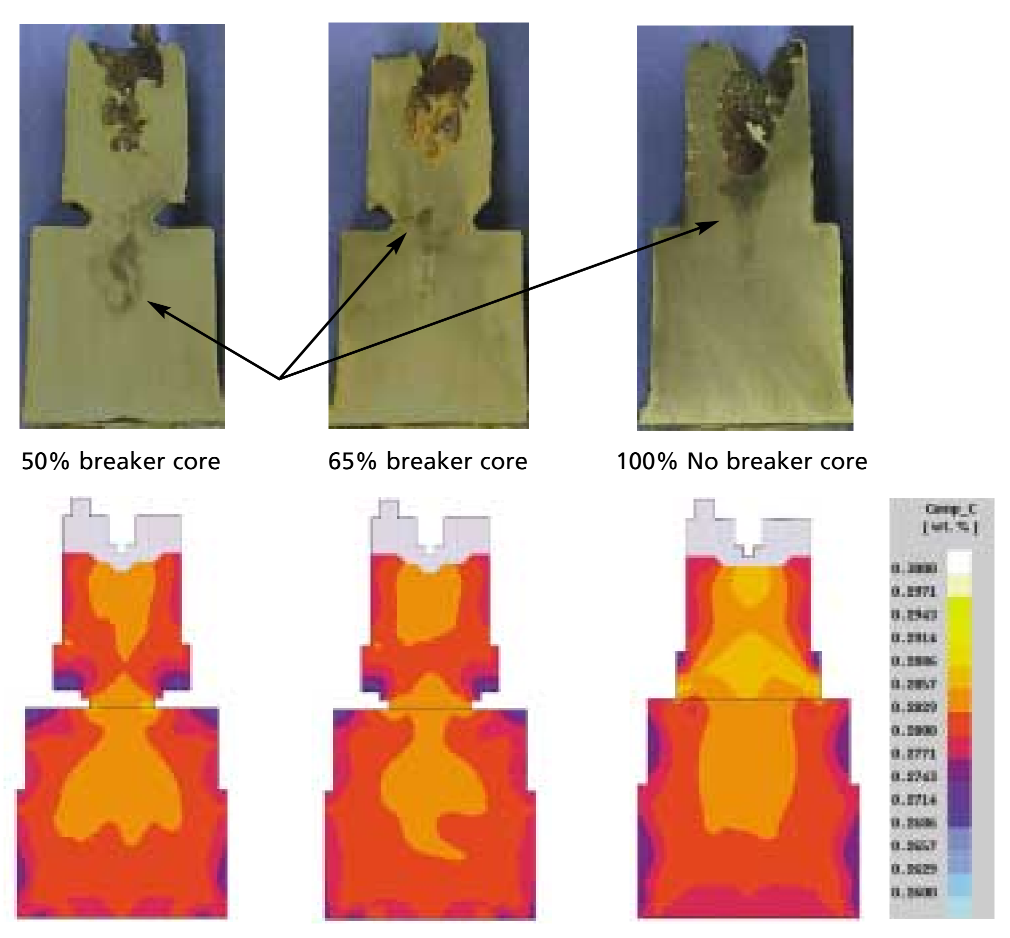


Figure 2: Segregation results from Cube Trials and computer simulations.

In practice, the castings were top risered with two exothemic/insulating insert sleeves with standard 50% breaker cores attached. Riser sleeve size was chosen to adequately meet the modulus and volume demands of the casting section.

Initial production trials of the casting resulted in sound castings. Several of these castings were sectioned and etched, as shown in Figure 4.

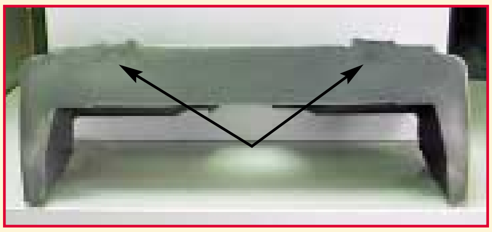


Figure 4: Section of etched casting with 50% breaker core.

The arrows point to discoloured sections below the risers. These discoloured sections are the result of carbon segregating to levels in the metal matrix significantly above the base chemistry, as exposed by etching.

Breaker core apertures of 50% (standard), 60%, 65%, 70% and full contact (no breaker core) were modelled using computer simulation, and elemental segregation was evaluated as shown in Figure 5.

The clear areas shown in Figure 5 represent areas of the casting that have carbon levels less than or equal to the base chemistry of 0.34% carbon. Areas of colour represent carbon levels between 0.34% and 0.36%.

Carbon segregation decreases significantly as breaker core opening increases until the breaker core reaches 70% opening. Only a small carbon segregation reduction is shown when the opening is increased from 70% to 100% (no breaker core), thus 70% appears to be the optimum in this case.

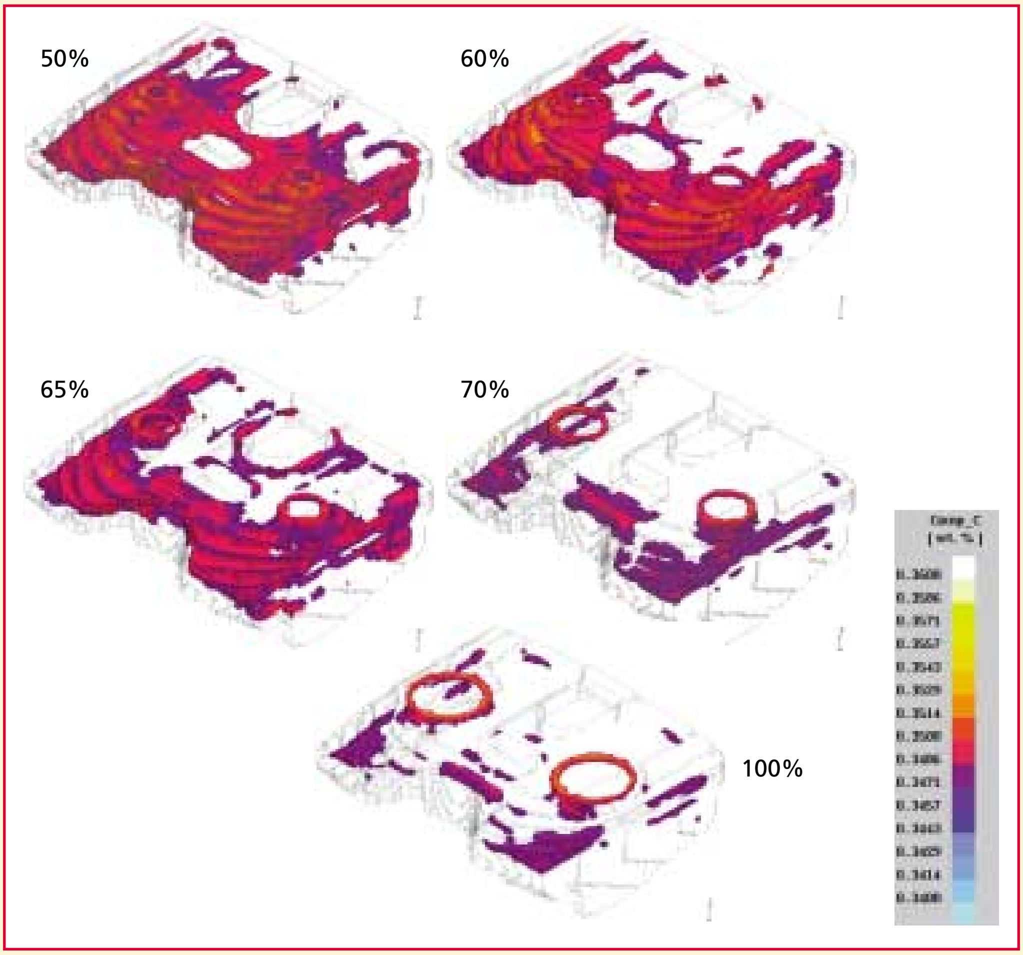
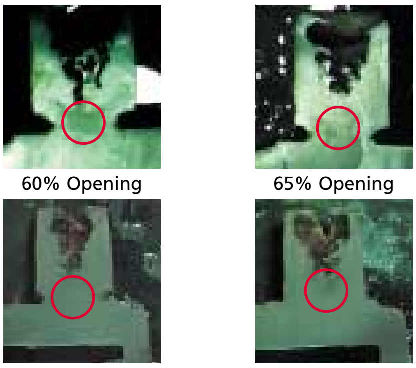


Figure 5: X-ray of predicted carbon segregation in casting.



60% Opening
65% Opening
70% Opening
Full Contact

Figure 6: Actual casting carbon segregation trial results.

The casting trial results agree well with the simulation results. The 60% and 65% breaker core opening cases show the carbon segregation moving from the casting into the riser neck. The 70% breaker core opening case shows the segregation safely residing in the riser, similar to the full contact case.

Based on the results of the cube and casting computer simulations and molten metal trials, the optimum breaker core opening to minimize/eliminate elemental segregation in these castings would seem to be 70%.

Summary/Conclusions

Breaker cores are designed to be thermally transparent, such that they do not adversely affect the feeding characteristics of the riser sleeve. Many studies have been conducted over the years to prove this concept, including the work done in this project.

The key objective of this study was to determine the effects of breaker core opening on elemental segregation. Breaker core opening has a significant effect on the location and extent of carbon segregation in 8000 series, arc-melted steel.

Computer simulations and molten metal trials were conducted on a range of castings to quantify the effect of breaker core opening on the characteristics of carbon segregation. The results from the simulations and the trials would seem to be conclusive.

The optimum breaker core opening to minimize/eliminate elemental segregation in the castings analyzed is between 65% and 70%.

Further study is required to determine if the breaker core opening angles and dimensions have any effect on elemental segregation.

References

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