CASE STUDY

ALTERNATIVE FEEDER APPLICATION IN HIGH DENSITY, HORIZONTALLY PARTED GREEN SAND MOLDING FOR ALUMINUM

Abstract

As the green sand method migrated into fully automated molding processes, our aluminum foundry lost some of its ability to effectively feed areas of significant modulus that were not located conveniently near the parting line. For foundries who adopted the automatic molding process, they adapted to this impediment through the use of strategically placed mold chillers, blind risers, and costly cores to reduce the modulus of the problem areas. This conclusion, although, perhaps, justified by the popular opinion, did not reflect the opinion of Boose Quality Castings. Consequently, Boose Quality Castings decided that the time had come to find an alternative feeding method. With this in mind, BQC worked with our supply partner of feeders to form an alliance wherein we could sample widespread feeder sizes and applications to replace the aged ideas currently in use while exploiting our competitive advantage through the use of simulation modeling. The information developed through simulation and laboratory tests on the indicated samples as well as a cost justification based on yield, scrap loss, and production rate increases will be reported in this paper.

Introduction

Feeders are vital to the production of sound castings. The feeder offsets the shrinkage of the casting body during its solidification phase while eliminating the defects associated with isolated feed zones. Feeders, such as the ones used frequently in automatic molding, have a significant volume in relation to their feeding efficiency. In turn, this negatively impacts casting yield, material quality, and cosmetic appearance. To solve this inherent problem, BQC worked with our supply partners to implement the use of insulating sleeves into the automated molding process. Figure.1 details the cosmetic issues and material quality concerns created by the traditional risering approach.

Figure 1.

With insulating sleeves being applied in other in other molding processes, BQC felt that there should be documented information regarding their application to automatic molding. It was found that there is very limited data supporting insulating sleeves being applied in automatic molding. To that end, there has been limited data obtained on the application of insulating sleeves reported elsewhere, albeit in limited supply. The results of the investigation carried out on the effect of insulating sleeves in automated molding processes is reported here.

Prior Work

G. V. Kutumba Rao, M. N. Srinivasan, and M.R. Seshadri1 reported their study of the effects of plaster of Paris insulating sleeves on feeding of LM 6 alloy plate castings. It was concluded that the volume of the cylindrical feeder required for producing a sound casting is reduced by 75 % by using insulating sleeves. Through this prior work, BQC prioritized casting yield, scrap loss, and production increases to expand the investigation into the production floor.

EXPERIMENT DETAILS

Alloy Examined
A356 – 7% Si

Sleeve Material

The thermal sleeve used in simulation was produced with a commercially available insulating material and a preset geometry varying in volume. The final feeder geometry was established through a methodical simulation progression.

Simulation Tests
The simulation setup started with the baseline gating system used during production. The casting was poured with a standard down sprue and fed with a traditional feeder approach around the OD and directly into the center hub as shown in Figure 2.

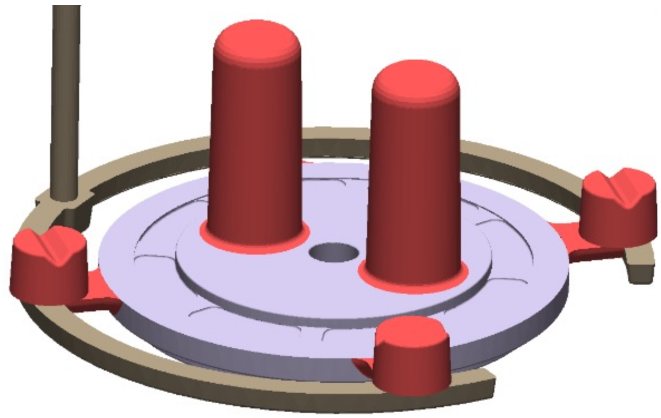

Figure 2. Baseline Geometry

The feeding modulus “feedmod” result (Figure 3.) of the baseline simulation revealed that the feedmod of the traditional riser contained an appropriate modulus at the furthest point from the casting. At the riser/casting interface, the feedmod began to equalize with the casting which allowed the feedmod to breech the casting surface. This made the baseline result susceptible to subsurface porosity and poor material properties.

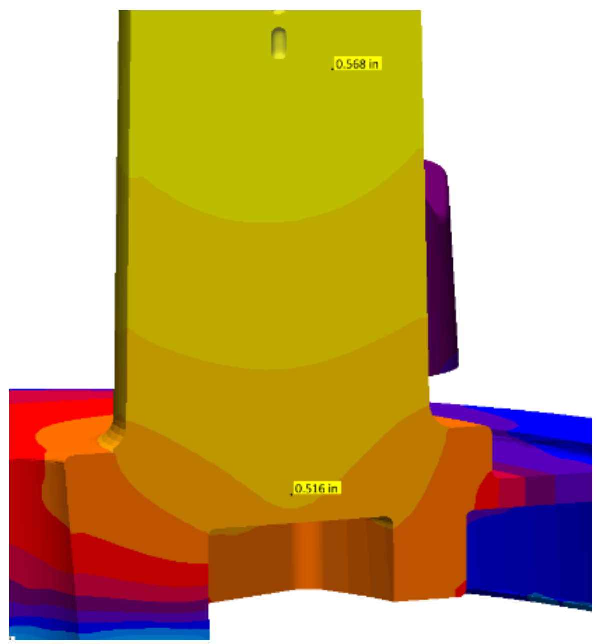

Figure 3. Feedmod result – Geometric modulus that also considers thermal factors such as chills

Feedmod can help with understanding the thermal conditions within the casting and select appropriately sized feeders. The highest values should appear in the feeders and gradually become smaller within the casting. In comparison to the geometrical modulus (V/A), the thermal modulus takes “sand edge” effects and chills into account, which leads to a decrease or increase in the effective casting surfaces available for cooling and thus to different solidification times. Therefore, a more precise evaluation is possible with the thermal modulus than with the geometrical modulus. The feedmod result was further supported by the Hot Spot FS Time results shown in Figure 4. Hot Spot FS Time confirmed that even though the riser had a significant volume, the volume still wasn’t enough to keep the Hot Spot out of the casting geometry. The ‘Hot Spot FSTime’ result indicates hot spots with the help of the critical percentage of solidified metal. Predicted hot spots within the casting are dependent on the restriction of the macroscopic feeding capability during solidification by the alloy-specific solidification pattern; AKA “Feeding Effectivity”.

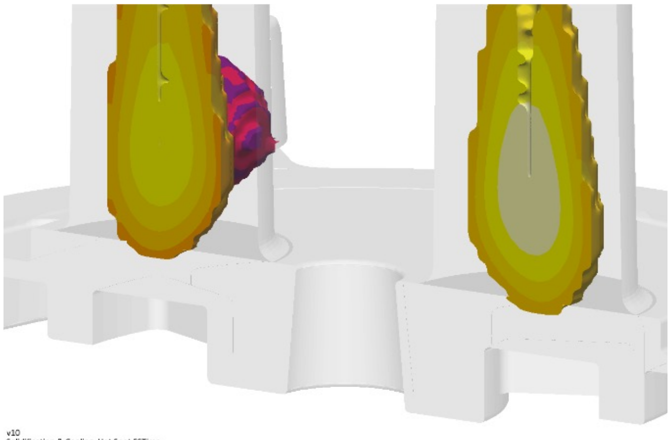

Figure 4. Hot Spot FS Time – Large riser still wasn't enough and hot spot breeches casting

The iteration 1 geometry shifted away from the large traditional feeders and focused on optimizing the feedmod, Hot Spot FS Time, and casting yield results. Insulating risers replaced the traditional uninsulated ones while maintaining the same feeder location as shown in figure 5.

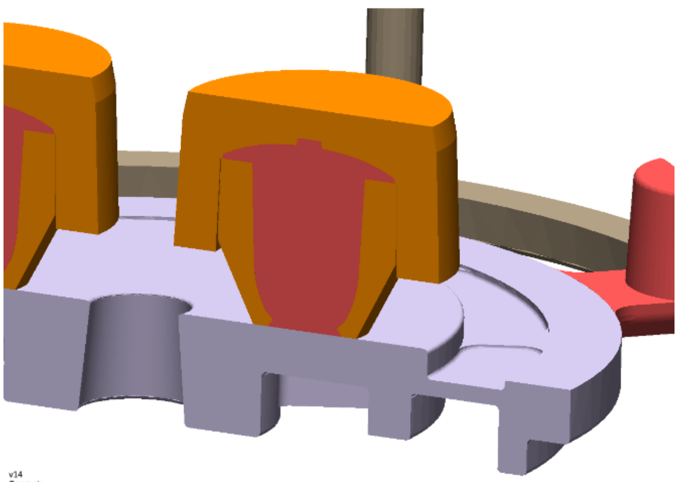

Figure 5. Iteration 1 Geometry

The feedmod result (Figure 6.) of the iteration 1 simulation revealed that the feedmod of the insulated riser contained an appropriate modulus throughout the feeder. As discussed in the baseline results, feedmod helps the user understand the thermal conditions within the casting and select appropriate feeders. The highest modulus values should appear in the feeders and gradually become smaller within the casting. At the riser/casting interface, the feedmod division remained strong which allowed the feedmod to break freely from the casting surface. The iteration 1 result showed an insignificant potential for subsurface porosity and improved material properties.

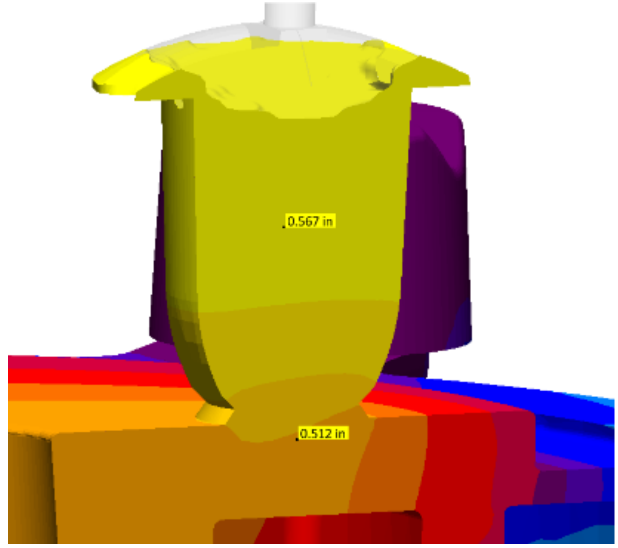

Figure 6. Feedmod result – Geometric modulus that also considers thermal factors such as chills

As with the baseline simulation, the feedmod result was further supported by the Hot Spot FS Time results shown in Figure 7. Hot Spot FS Time confirmed that even though the feeder volume was considerably reduced, the feeder geometry and insulating material maintained the modulus separation sufficiently while keeping the Hot Spot out of the casting geometry.

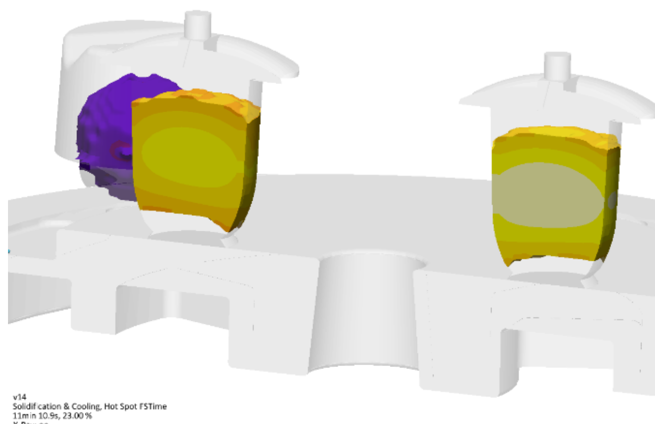

Figure 6. Hot Spot FS Time – Feeder effectively feeds casting

RESULTS & DISCUSSION

Solidification Time

The solidification time of the traditionally fed casting versus the solidification time of the insulated approach is shown below in figures 7 and 8. A linear relationship exists between the solidification time and feeder volume when insulated.

Figure 7. shows that the traditional feeder solidified in ≈ 650 seconds whereas the insulated feeder took ≈ 660 seconds to solidify as shown in figure 8. The volume of the insulated feeder is less than half of its traditional counterpart with the insulating material expanding the solidification window beyond traditional capacity.

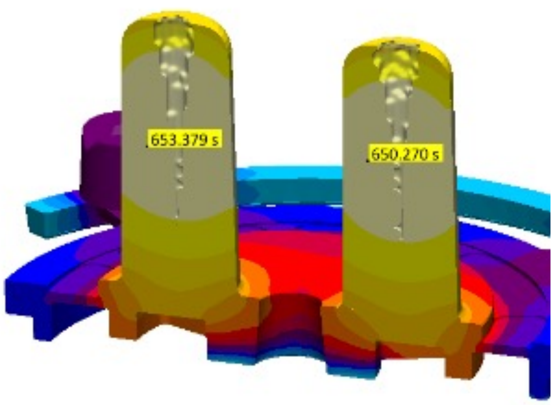

Figure 7. Solidification Time

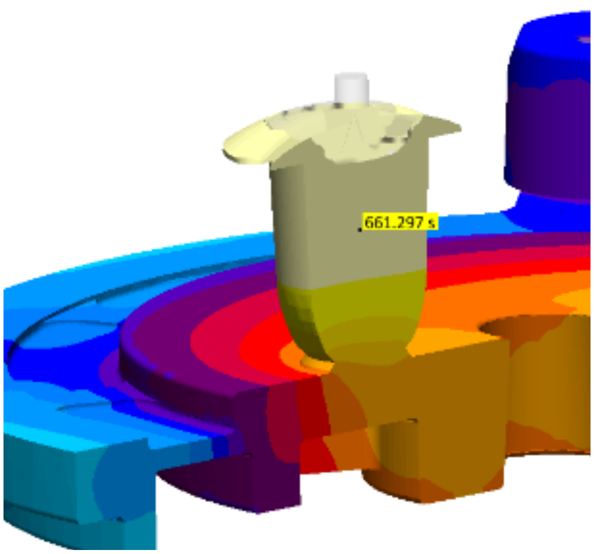

Figure 8. Solidification Time – Insulation extends solidification time.

Sand Burn-On & Mold Temperature

The iteration 1 simulation also predicted improvement to casting finish and surface quality through decreased mold temperatures. Figure 9 predicts a significant sand burn-on result at the feeder / casting interface due to the green sand mold material being superheated during the solidification phase. The surface porosity shown in Figure 1. correlates well with the data presented in figures 9 & 10.

Figure 10. further supports the predicted sand burn-on by showing that the maximum mold temperature exceeded 1000°F at 100 seconds into the solidification phase.

Comparative images to the insulated feeder approach are provided in figures 11 and 12.

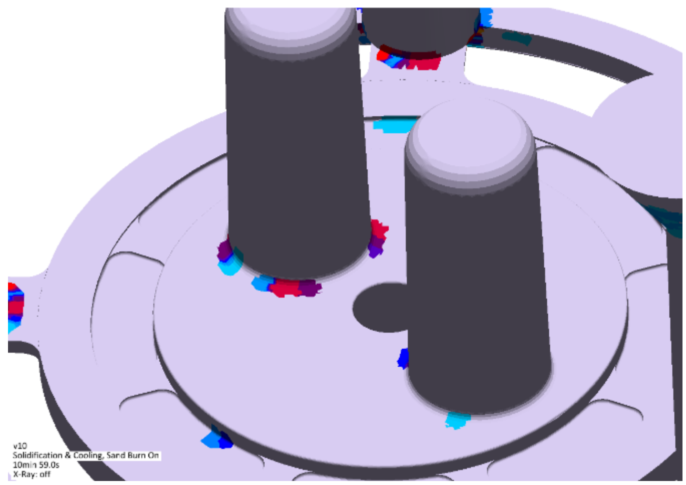

Figure 9. Sand Burn On – Time over Temperature result indicating areas of overheated mold material at feeder/casting interface.

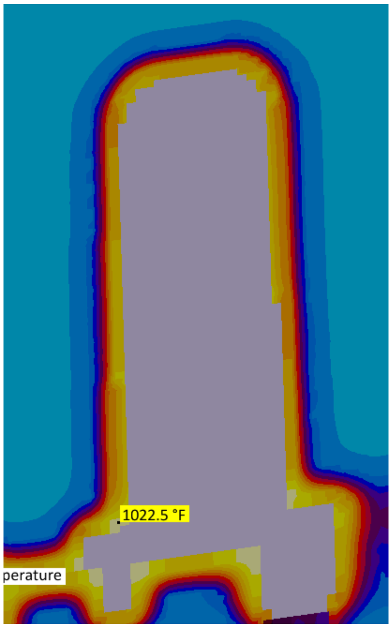

Figure 10. Mold Temperature – Mold temps exceed 1000° F.

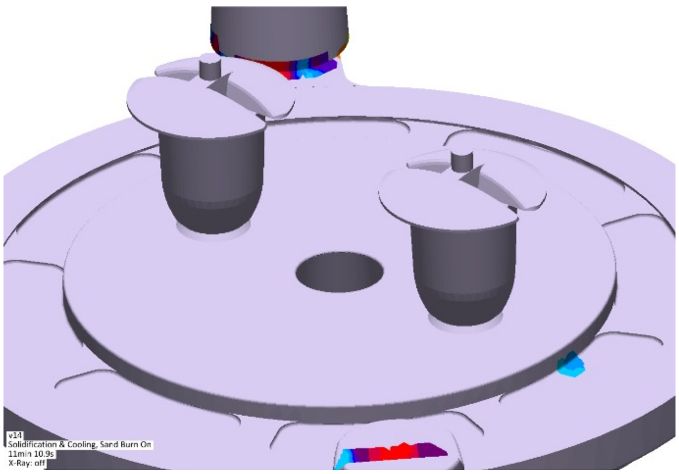

Figure 11. Sand burn On - Time over Temperature result showing zero areas of overheated mold material at feeder/casting interface.

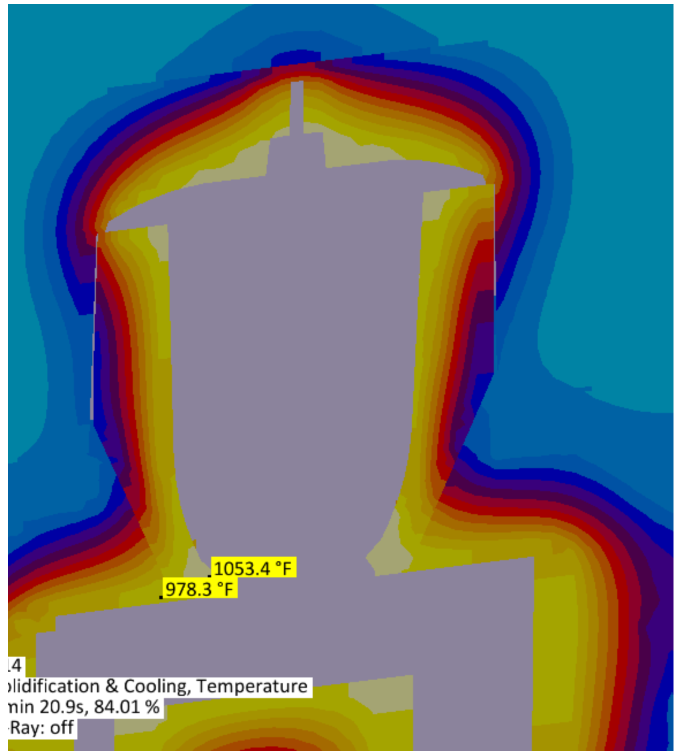

Figure 12. Mold Temperature – Insulating sleeves keep mold temps 50° F below uninsulated temps.

Functional Testing

To validate the effectiveness of the simulation results and their interpretation, radiographic testing was performed on a sample casting. Acceptance standard SAE AMS 2175 Edition A Table 6, Grade C was used to qualify the material with ASTM E1742/E1742M-18 controlling the radiographic process. There were no failures and zero areas of concern.

RNDT, Inc. Nondestructive Testing Services ♦ 228 Maple Ave. ♦ Johnstown, PA 15901 ♦ 814-535-5448

RADIOGRAPHIC EXAMINATION REPORT FORM

Customer	Specification	Acceptance Standard	NDE Procedure No.
Boose Quality Castings 402 Schaeffer Road Lebanon, PA 17042	ASTM E1742/E1742M-18	SAE AMS 2175 Edition A Table 6, Grade C	RNDT-RT-1742, Rev. 4

Part Name	Part Thickness	Drawing Number	Material
UC048C1 End Plate, Output	Various	20040-048C1	Aluminum

Radiation Source	Curies	Kv	Ma	Focal Spot Size	Technique Used	Focal Film Distance	Exposure Time
X-ray	N/A	See RSSS	See RSSS	3 mm	See RSSS	42"	See RSSS

Film Type	Film Size	Film Technique	Penetrameter Type / Size	Material	Penetrameter Location	Shim Material	Shim Thickness
See RSSS	See RSSS	See RSSS	ASTM E1025 / See RSSS	Aluminum	Step Wedge	Aluminum	See RSSS

Film Processing	Intensifying Screens	Front	Center	Back	Radiographer	Film Reviewer
Automatic	None	None	None	None	Tony Raco	Erik Korenoski

As Cast		Gas Holes 1/4"	Gas Holes 3/4"	Gas Porosity (round) 1/4"	Gas Porosity (round) 3/4"	Gas Porosity (elongated) 1/4"	Gas Porosity (elongated) 3/4"	Shrinkage Cavity	Shrinkage (sponge) 1/4"	Shrinkage (sponge) 3/4"	Foreign Material (less dense) 1/4"	Foreign Material (less dense) 3/4"	Foreign Material (more dense) 1/4"	Foreign Material (more dense) 3/4"	Microshrinkage (feathery) 1/4"	Microshrinkage (feathery) 3/4"	Microshrinkage (sponge) 1/4"	Microshrinkage (sponge) 3/4"	Crack	Other	Surface	Film Artifact	No Apparent Casting Defects	Accept	Reject	Comments
Item Identification	Zone																									
SN-1	A - B					3	2																	X		
	B - C					3	2																	X		
	C - D					3	2																	X		
	D - A					3	2																	X		
N/A																										

Signature: [signature] III
NDT Inspector SNT-TC-1A Level

Date: 6/20/2022

Lab	Field
X	

P.O. Number 19018, Item 2
Job Number J22-1600

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Casting Yield

As expected, the casting yield varied significantly between the insulated feeder and the traditional one. The traditional feeding system produced a 46.83% yield ratio that still struggled to effectively separate the feedmod and Hot Spot FS Time from the casting geometry.

With the insulated feeding system, the yield ratio increased to 60.39% with no concerns of feeding performance or reduced material properties. Production rate increases and scrap/re-work reduction

The substantial reduction of riser volume using an insulated feeder allowed BQC to move this product to a smaller flask molding line where molding rates are up to 5 times faster. The last production run prior to the work center change was produced with a cycle time of 1.5 - 2 minutes per mold. The 1st production run after the work center change was produced with a cycle time of 45 – 50 seconds. The production run-rate increase was also coupled with decreased scrap percentage. The scrap percentage fell to 1.9% from 4.19%.

The cost savings through decreased cycle time and scrap fallout offset the cost of the insulated feeder while increasing profit margin. The increased margin made BQC more competitive while helping to preserve cost structure for the customer during a tumultuous market with supply chain disruptions outside of the casting supply chain.

Figure 13. shows the improved final casting finish after the smaller insulated feeders were applied.

Summary/Conclusions

The results of the analysis of insulated riser applied in automated molding processes indicated the following:

1. There is a linear relationship between the solidification time and the volume required to feed the casting modulus when using an insulated feeder.
2. In both the traditional and insulated feeders, the feeder size is dependent on casting modulus with the feeder to casting modulus remaining equal between insulated and non-insulated.
3. The insulated geometric feeder modulus promotes a more pronounced modulus separation between the feeder and casting when compared to the traditional feeder.
4. Riser piping was more effective when an insulating feeder is applied.
5. The volume of the feeder required for producing a solid casting is reduced by 60% when using insulated sleeves.
6. Proper application of insulated feeders increases the yield of the casting system to 60.39% from 46.83%.

References

1. G.V. Kutumba Rao, M.N. Srinivasan, and M.R. Seshadri, and A. Ramachandran. AFS Transactions 75-57.

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Brandon Boose - V.P. of Manufacturing, Boose Quality Castings

Definitions/Abbreviations

BQC Boose Quality Castings
Feedmod Feeding Modulus