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The Evolution of High Performance Feeding Aids to Improve Casting Quality

Abstract

Metal casters are constantly looking for ways to increase productivity and to improve casting quality and integrity in order to compete in an increasingly competitive market. Feeding aids and especially riser sleeves have evolved over the years to keep pace with those demands. This paper reviews those improvements in sleeve design and materials and details the latest advancements with current mini-riser technology.

Key Words: feeding, feeding aids, mini-riser, riser, sleeve, yield

Introduction

Risers are generally viewed as a necessary evil by metal casters. They are needed to prevent shrinkage cavities in the casting, but they also reduce the casting yield and require costly removal and clean-up. In order to function properly, the risers must have two primary attributes. They must have a modulus, i.e. volume to surface area ratio, such that they solidify later than the casting section they are intended to feed and they must have sufficient feed metal available to make up for the shrinkage volume loss in that section. These two criteria historically lead to a number of design guidelines for riser placement and geometry.

Initially, the risers were created in the mold as “natural” risers meaning that they were formed by the same mold material as the casting cavity and the gating system. This meant that the rate of heat loss from the riser surface was the same as for the rest of the casting and that riser modulus truly was the controlling factor. “Natural” risers are still in use today, but are more and more giving way to some type of feeding aid. A “natural” riser uses only a small fraction of its total volume to provide feed metal to the casting. The remainder is “wasted” although necessary to keep the

HOT TOPPING

A number of types of feeding aids have been developed over the years to improve riser efficiency by controlling heat loss from the riser or by providing an additional heat source to the metal in the riser. Hot toppings were probably the first type of feeding aid. Hot toppings are materials that are added to the tops of open risers after the casting is poured. They prevent radiant heat loss from the riser and provide additional insulation or heat to the riser surface. Insulating hot toppings include materials like rice hulls or expanded perlite or vermiculite that have low density and excellent insulating properties. Exothermic materials can also be used. These typically rely on the “thermite” reaction as the heat source:

$$4\ Fe2O3 + 8Al \rightarrow 4Al2O3 + 8Fe + \text{heat (2400C, 4500F)}$$

The thermite can be used alone or mixed with an insulating material. It not only provides heat and insulation, but is a source of liquid iron to provide additional feed metal into the riser.

While there are a number of different hot topping formulations and types, their use has been somewhat problematic because of their physical form. Most hot topping are granular or powder. They must be added after the casting is poured and are difficult to place accurately and safely. A recent development1 addresses those issues. Floating Cover Lids (FCL) have been designed as a replacement for traditional powdered hot top materials. They can be produced with both an insulating and/or exothermic refractory properties. The FCL’s are made from a Low Density Aluminum Silicate Ceramic (LDASC) material and are bonded with a phenolic urethane cold box (PUCB) resin system. They are made in round disk shapes which are sized to fit inside of traditional round open top risers. Other shapes can be made as needed for other riser shapes. Figure 1 shows several sizes of the round floating cover

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Figure 1. Several sizes of both insulating and exothermic floating cover lids are shown above.

The use of FCL's can dramatically improve the consistency of a riser's feeding efficiency. Many of the foundry variables are eliminated when FCL's are used, such as: how much topping was used, when was it applied and did it really cover the riser evenly. Tests in both the lab and in the foundry confirm the overall performance and consistency improvements when compared to the use of traditional hot topping compounds 1.. Figure 2 shows a FCL on a freshly poured mold.

Figure 2. The above photo shows a floating cover lid on a freshly poured riser.

RISER SLEEVES

Riser sleeves have created an even more dramatic improvement in riser efficiency. Riser sleeves can be either insulating or exothermic or with a combination of properties. They generally cover the cylindrical surface of the riser, i.e. the largest surface area, and in the case of insertable or ram-up sleeves can cover the entire area. As with hot topping, sleeves will reduce heat loss from the riser through insulation and heat additions.

One way to characterize a riser sleeve is to consider its effect on the relative modulus of the riser. By reducing the cooling rate of the riser, the risers solidify as if they were larger or had a higher modulus. This has given rise to the concept of a "modulus extension factor" or MEF. For instance, if a sleeved riser solidified the same as a "natural" riser with twice the modulus, the sleeve would be given a MEF of 2. If a sleeve had an MEF of 1.5, the sleeved riser should solidify in the same time as a natural riser with a modulus that is 1.5 times bigger. Generally speaking an exothermic sleeve will have a MEF that is larger than for an insulating sleeve, allowing the use of smaller risers and improved yield.

Some of the earliest riser sleeves used an insulating material that was mixed with a binder, perhaps a greensand mix with clay and water or oil and starch similar to a baked core, and the mix could be rammed up around the riser "bob" on the pattern to create a sleeve. While effective, this was time consuming and not very efficient. In 1947 exothermic compounds were developed which improved the feeding performance.

Pre-formed exothermic sleeves were first developed in 1948 and were produced from a water-based slurry containing binder and a refractory fiber. The sleeves were formed by drawing a vacuum on a fine mesh form to deposit the fibers on the form and to remove the water. The sleeves were then baked to remove excess water and develop strength. Figure 3 shows the vacuum form and finished fiber sleeves.

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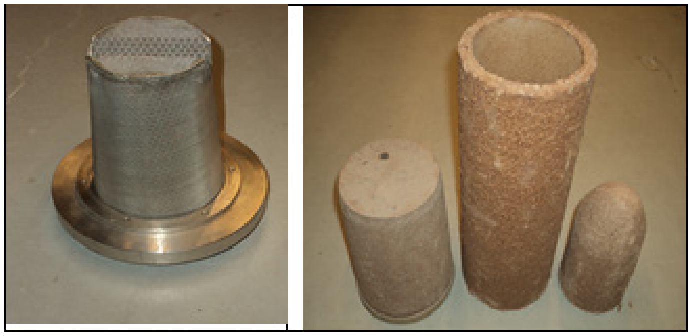

Figure 3. The vacuum form is shown on the left. Finished fiber sleeves are shown on the right.

Fiber sleeves can be produced in several grades from insulating to highly exothermic depending on the amount of exothermic material added to the slurry. The sleeves normally have a rough exterior surface. This is suitable for ram-up applications and provides good interference with the mold material to hold the sleeve in place. The surface of the sleeve can also be ground to provide a smoother surface and tighter dimensional control for insertable applications.

The next step in the evolution of high performance sleeves was the introduction of blown sleeves made from low density alumina-silicate (LDASC) "microspheres" using the coldbox process. These sleeves provided a number of advantages2. . Since the sleeves are formed in coldbox tooling, they are more dimensionally accurate than standard fiber sleeves. They also show more uniformity in composition from sleeve to sleeve. As with traditional fiber sleeves, the LDASC sleeves can be produced in a range of compositions from insulating to highly exothermic. They can be used in traditional ram up applications or as insertable sleeves.

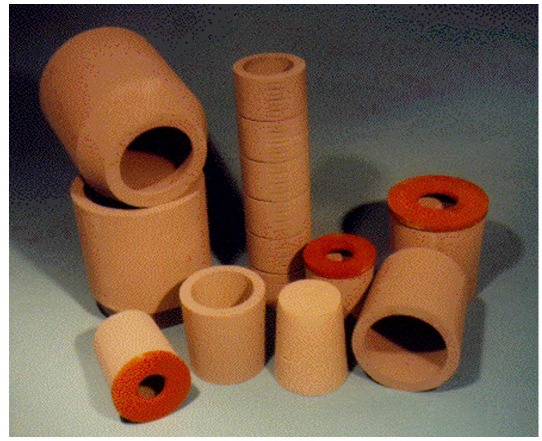

Figure 4. Different styles of LDASC sleeves are shown above.

The LDASC sleeves were first introduced in 1997 and over the years have seen a number of improvements. One of the more significant improvements had to do with the formulation of the exothermic package. As indicated earlier, all the exothermic feeding aids rely on the thermite reaction with powdered metallic aluminum and iron oxide. However, other chemicals are typically added to enhance the reaction. Cryolite (Na3AlF6) or similar fluoride compounds are often added as "initiators" for the reaction. These compounds flux or clean the surfaces of the aluminum particles to give faster and hotter reactions.

While experimenting with formulations specifically for ductile iron, it was discovered that the sleeved risers can experience a loss of nodularity 3.. Further investigation showed that the graphite degradation was related to pickup of aluminum from the sleeve into the riser. Examples of the graphite degradation in the sleeved risers are shown in Figure 5.

Potentially, this could create areas of flake graphite on the surface of ductile iron castings and resultant loss of physical properties. Figure 6 shows a large ductile iron casting with flake graphite from the sleeve on the machined surface.

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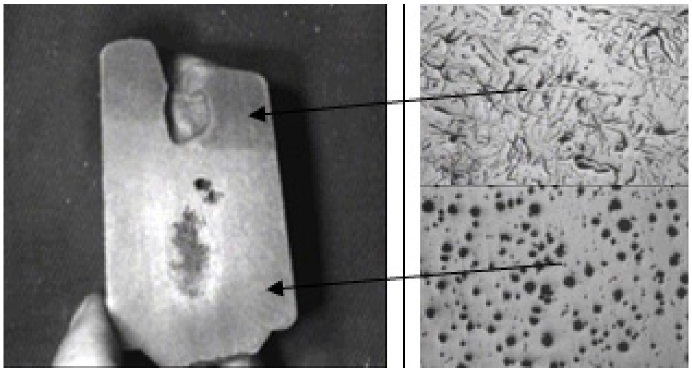

Figure 5. The photo on the left is a polished riser showing flake graphite on the top and nodular graphite on the bottom.

Figure 6. A large ductile iron casting (left) contained flake graphite below an exothermic sleeve (right).

About the same time, another problem arose with exothermic sleeves used on ductile iron. A ductile iron foundry was experiencing what they called “fish-eye” defects on ductile iron castings that were produced in greensand following production runs of high risered and sleeved castings. It was thought that fluorine from the cryolite in the sleeves was somehow contaminating the greensand and causing the defects. An example of the “fish-eye” defect is shown in Figure 7.

Figure 7. These are “fisheye” defects on ductile iron castings.

A number of tests were conducted at the foundry to determine the true cause of the defects. Batches of sand were intentionally contaminated with pure cryolite, broken un-burned sleeves, and broken burned sleeves. It was discovered that the burned sleeves were responsible.
It was further theorized that it was the aluminum fluoride from the exothermic reaction that was responsible, both for the “fish-eye” defects and for the degradation of graphite in the ductile iron.

To eliminate the problem, it was necessary to eliminate the cryolite and any other fluoride compounds in the exothermic mixes. This was finally accomplished by using a mix of other reactive metals as “fuel” and other reactive salts to initiate the exothermic reaction. Fluorine free formulations have now been in use for a number of years with good results in the foundry.

Development of the Mini-Riser

While the LDASC, coldbox sleeves were being developed and improved, other parallel developments were also occurring. The development of mini-risers in the early 1970’s at the Rexroth Foundry in Lohr, Germany was a significant step forward on the continuous improvement path of the feeding systems. These new risers provided an incredible 70% efficiency in feeding a casting while reducing the overall size of the feeder so less space was needed to apply them as seen in Figure 8. The basic principle was still the “thermite reaction” where aluminum burns with iron oxide, releasing heat up to 2,400 C (about 4250 F).

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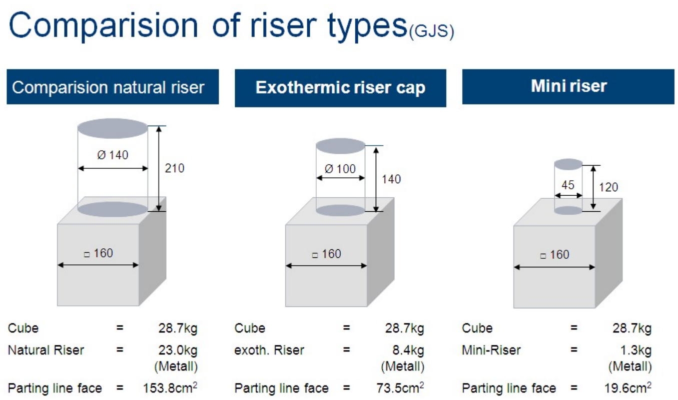

Fig. 8. Diagram showing differences in feeding efficiency and contact area for various riser types.sleeve (right).

The volume of a natural riser of 23 kg in this example is decreased to 8.4 Kg by using an exothermic cap and to 1.3 Kg by using a mini-riser. The fettling surface is decreased from 158.8 cm2 to 73.5 cm2 by using an exothermic cap and even to 19.6 cm2 by using a mini riser. This is a remarkable optimization of the yield of the casting which allows for much better performance of the molding line and can reduces the cost associated with rework and grinding.

In order for the riser to deliver this elevated temperature and maintain proper feed metal, the mini riser has ingredients like sand and/or other insulating materials to slow down the reaction and achieve lower temperature losses for a longer duration during solidification. This allows the volume of liquid iron in the riser to be significantly reduced by replacing heat loss with exothermic material. This type of mini riser was first developed and used in Germany under cooperation with Rexroth foundry and is still widely used today in various shapes and forms.

Once the mini-riser was developed, the optimizations didn't stop there. The first step was the introduction of spring pins which create a sand layer between the riser and casting in order to avoid contact of the exothermic material and the sand. The purpose of this was to increase the surface quality of the casting that can be compromised

by the reactions of the exotherm during solidification. The introduction of breaker cores made in Croning (shell) sand, which are in direct contact with the casting, reduces the fettling costs even more. However, as more modern, high pressure molding lines with higher compaction of the molding sand became more popular, the risers with breaker cores had achieved their limit. The breaker cores can be destroyed by the pressure of the molding sand which can create sand inclusion defects in the casting. The use of breaker cores also can wear down the pattern surface, which can

Fig. 9. This photo shows the footprint of the breaker core on a casting coming from the pattern.

SPRING PIN RISERS

The spring pin and riser combines the advantages of both types by using exothermic breaker cores. This exothermic breaker core reduces the riser neck and creates together with the spring pin a sand layer between the riser and the casting. There is no footprint on the pattern and the riser can be easily knocked off, although part of the riser neck is sometimes left behind after knock off and additional work must be done to remove it and finish the casting

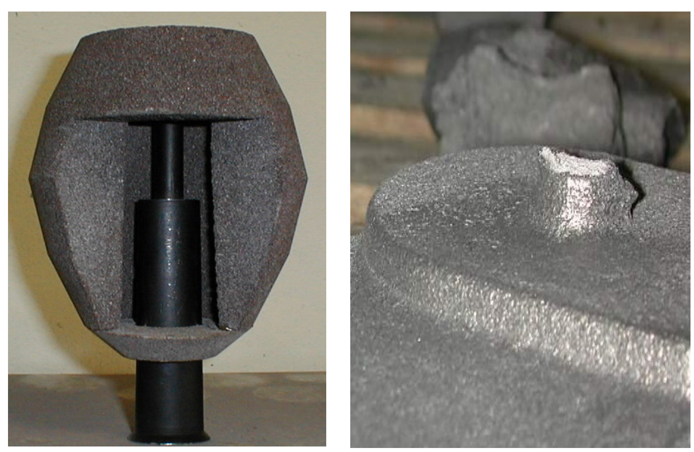

Fig. 10. The photo on the right shows a mini-riser on a spring-pin prior to molding. After knocking off the riser, part of the riser neck is sometimes still on the casting and must be removed as shown in the left-hand photo.

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Optimized Exothermic Formulations

Another important improvement in mini-riser development was the merging of the LDASC coldbox technology to the mini-risers. These formulations allowed for the production of lightweight sleeves without the use of the ceramic fibers that are typically incorporated in traditional slurry feeders, some of which have been deemed hazardous in the European Community. The original mini riser was quite heavy because of the use of sand as the ceramic in the sleeves. Replacing the sand with LDASC reduced the weight by nearly 75%. With less refractory, less exothermic material was needed to get the sleeve to the same temperature. The fluoride free formulations developed for ductile iron applications could also be incorporated in the mini-risers, thus reducing the possibility for aluminum contamination and nodularity degradation.

The Mini Riser with Metal Neck

To use the advantages of these principles and to exploit the potential to its fullest, the mini riser with a metal breaker neck was developed. This riser is positioned on a spring pin with a conical metal tube, which builds up an accurate riser neck. The riser moves down and slides over the metal tube while the sand is compacted. The result is a very small riser neck with an optimal breaker edge to make knocking off and fettling very easy. Many foundries eliminated fettling completely after knocking off the riser due to this advancement in feeding technology. Due to the downward-moving riser, the molding sand under the feeder is very well compacted and the casting has a perfect contact surface (See Fig. 11). This type of system is very common today and nearly all feeder suppliers use some variation of this type of feeder system which provides a similar benefit to the metal caster.

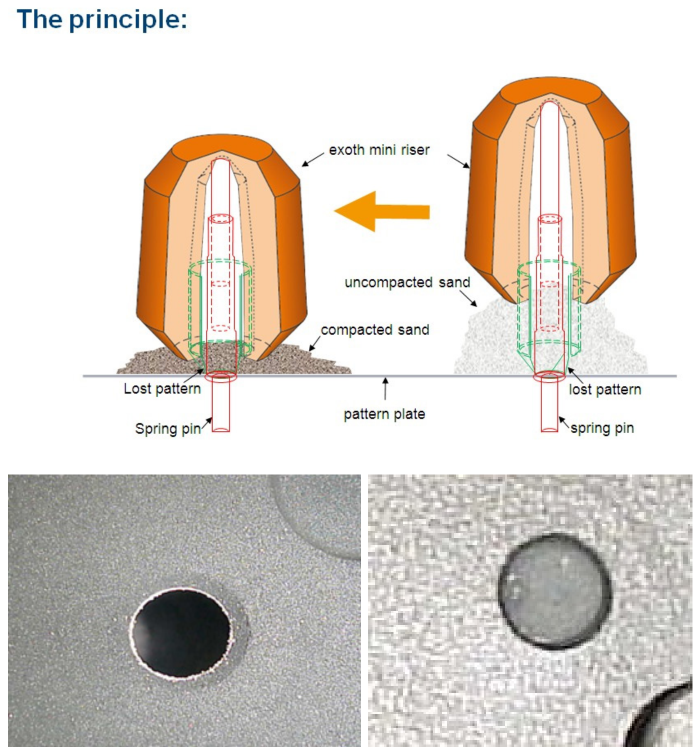

Fig. 11. The top diagram shows the compaction principle for using a mini riser with telescoping metal breaker neck. The lower photos show the casting results.

The successful implementation of the mini riser with metal neck did not end the desire for improved feeding systems. The next development was a two-part riser that carries the metal tube as a loose part inside which automatically falls into place during application of the riser on the spring pin or post2. The fact that the riser itself is made in two parts allows for customized solutions with various feeding volumes, depending on the needs of the foundry. However, the biggest advantage is the ease of use as it is nearly impossible to make any application mistakes during riser

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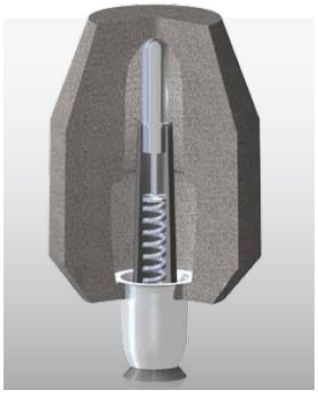


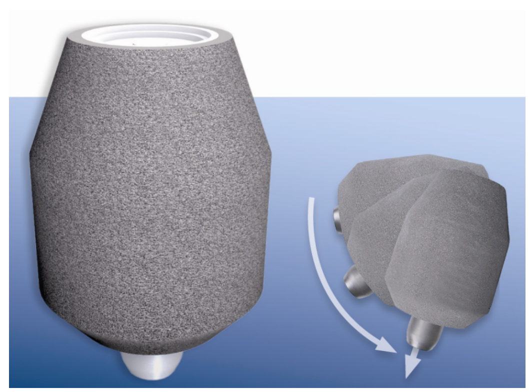
Fig. 12. This is a diagram of a mini riser with a loose metal neck for improved application when using spring pins on the pattern.

At the same time as the above mini riser was being implemented another patent technology was being developed. This time the target was to create an optimal, reduced contact breaker edge without the need for a separate breaker core (See Fig. 13). The breaker edge geometry is integrated in the exothermic sleeve and a plastic cap is placed in the top of the riser to keep sand out of the riser when it is rammed up. Using this design it was possible to produce the riser in a more economical manner than some other two and three piece riser systems. The type of riser can be used with or without a spring pin.

Fig. 13. This reduced contact mini riser was developed with no breaker core.

Synergies of Existing Riser Technologies

Although several great risering improvements had been developed for foundries to employ, recent developments have brought together the benefits of several technologies to create a new generation of riser. This new mini riser combines the best advantages of the existing riser technologies discussed previously in this paper. The metal breaker neck technology reduces the fettling costs and allows for a very small contact area to put the riser on very complicated casting geometries. By using the telescoping metal necks, the riser is very easy to handle for the foundry operators and gives several volume variations leading to many different possibilities for use. Last but not least is the production process and the plastic cap that can help reduce overall cost of the feeding system while offering the benefits of light weight risers and high performance feeding (see Fig.14). These feeders are in approval stages in several European foundries at the moment and the initial test results



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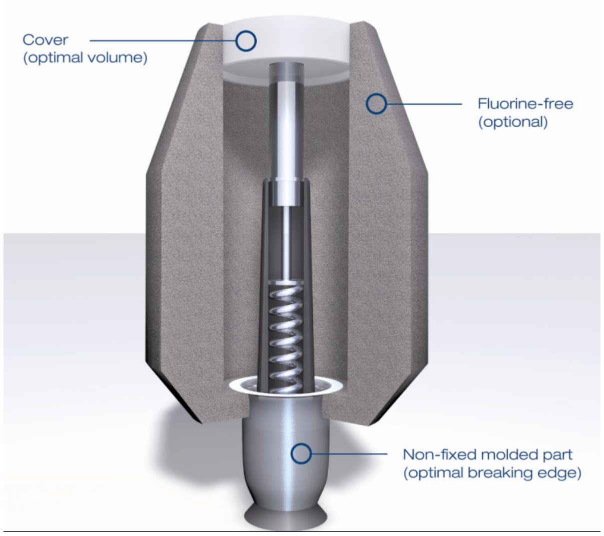

Fig. 14. This shows the combination of three high performance risers into one.

Health and Sustainability: Improvements in Feeding Aids

As much as high performance and ease of use is important to foundry workers today, the health and safety of the worker should be first and foremost. All these mini risers discussed in this paper have the benefit of being free of carcinogenic fibers to protect the health of the people using them. Much like the LDASC sleeve products described earlier, these mini risers are also now produced without fluorine, another hazardous material. Eliminating the fluorine from the feeders will ultimately reduce the amount of fluorine in the molding sand so that surface defects created by fluorine are avoided as seen in Figure 15.

Fig. 15. This casting shows surface defects caused by fluorine.

Fluorine free exothermic feeder formulations improve the productivity of the foundry. With a lower amount of fluorine in the molding sand, surface defects can be avoided and the casting quality enhanced. Fluorine free mini risers can also help to reduce graphite degeneration around the feeder neck in ductile iron castings (See Fig 16).

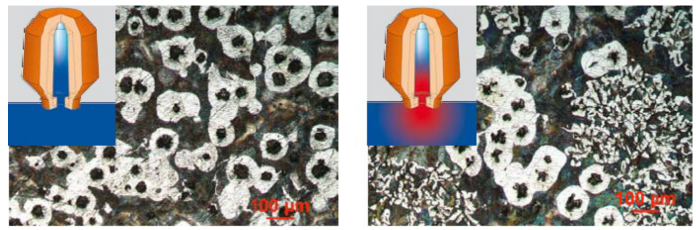

Fig. 16. The nodular iron structure can be compromised by increased levels of fluorine in the riser as shown in the photomicrograph on the right.

Fluorine can also become a problem in the disposal of spent foundry sand. By using fluorine free risers, the content of fluorine in the old molding sand is much lower so that the disposal of the sand at the waste disposal site is acceptable. Ultimately, incorporating fluorine free risers into the feeding process can mean an economical advantage for the foundry and a step in the right direction to protect the environment on the way to a sustainable

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Conclusion

As can be seen from the long history of development and improvements in the performance and functionalility of feeding aids, the need for continuous improvement is not limited to process-related initiatives. Foundry consumables can also be a tool implemented by the metal caster to not only improve casting quality and performance, but also reduce overall costs in a safe and efficient way.

The more recent improvements in feeder design has led to new mini riser products that combine several of these optimal benefits into a single product. Now, the metal caster is able to reduce the size and weight of the riser along with the risers "footprint" left on the casting. Today's advanced mini riser technologies consider-

The invention of fluorine free technology that first began in the larger LDASC has also now been carried over to the smaller, more efficient mini risers. Not only can you eliminate the graphite degredation sometimes caused in ductile iron by fluorine-containing riser sleeves, but you get the added benefit of improved ergonomics (lower weight), precision dimensions, and a reduced environmental footprint.

Through a perfect blend of functionality, performance, and cost reduction todays' new mini risers have raised the expectations of what risers are capable of to a new level. It is this type of novel solution to several issues facing foundries today that allows the metal caster to produce world class castings at a much lower

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