Iron Foundry Benefits from New Nodularizing Process

A gray iron plant has successfully incorporated ductile iron casting with the help of a revolutionary magnesium addition system.

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Today's market is placing new demands on both foundries and the industries that rely on their castings. In addition to toughening quality standards, delivery schedules and price expectations, there is a call for metalcasters to provide a more diverse range of alloys and services.

For 72 years, Blackhawk Foundry, Davenport, Iowa, has been supplying highly engineered gray iron castings to the agricultural, heavy equipment, diesel engine, hydraulic pump and transmission industries. Interested in diversifying to better serve existing customers and expand into new markets, Blackhawk began in 1991 to look seriously at adding ductile iron production to its capacity.

An implementation team was designated and it chose the fall of 1993 for the first prototype production. From the outset, Blackhawk officials realized it was vital that the nodularizing needed to make ductile iron blend with existing daily gray iron production.

The foundry melts with a 78 x 60 in., acid-lined, water-cooled cupola. The furnace features recuperative hot blast and O₂ enrichment, and is capable of a melt rate of 19 tons per hour. Iron is then duplexed into two 16½-ton channel holders.

Several compatible ductile treatment methods were evaluated by the foundry's planning team. They ultimately chose a newly patented nodularizing process developed by Materials & Methods, Ltd., Ardingly, England, and Globe Metallurgical Sales, Inc., Cleveland, Ohio.

A small amount of magnesium (Mg) is added to molten iron to produce ductile iron. The introduction of this Mg to the melt promotes the spherical formation of graphite during casting solidification, characterizing the metal as ductile iron.

The Process

The process, known as Sigmat, consists of pouring low sulfur-base iron (less than 0.02%) through a tightly sealed box containing the nodularizing alloy (Fig. 1). The iron flow rate, controlled by the entrance and exit diameters, is matched to the cross-sectional area of the reaction chamber so that the alloy is consumed sequentially to recover a maximum amount of Mg. This ratio of pouring rate to cross-sectional area is one of the method's governing principles.

Factors that led Blackhawk to choose this "flow-through" process included:

- quick processing time (treats 1 ton of metal in 60-90 seconds);
- low temperature losses due to the small box size;
- flexibility in the treatment batch weight;

The unit treats one ton of iron in 60-90 seconds.
The foundry determined that Mg recovery was very dependent on temperature (Table 1). Also, for the relatively small batch sizes evaluated, a pour rate of 20 lb per second appeared to yield a higher Mg recovery than 25 lb per second.

In these tests, Mg recovery and nodularity were not adversely affected by sulfur levels of up to 0.029%. Above that, alloy usage had to be increased to maintain nodularity.

**Current Status**

Full ductile iron production began at Blackhawk in January 1994. One eight-hour shift per week is dedicated to ductile iron production at about 80 tons a shift. A larger box was built and batch size increased to 1500–2700 lb as more molding lines were added to meet production demands. A 1500 lb batch is delivered to an automated 22 x 28 in. molding line and batches varying from 1500–2700 lb are delivered to the plant's seven matchplate lines.

A lot of work has been done in evaluating dam heights and exit hole dimensions to control the iron flow rate through the box as it relates to box performance (Mg recovery rates, slag buildup, fumes escaping from the box). An optimum pour rate has been determined to be 33 lb per second for the larger box.

Magnesium recovery is fairly high—60–70% with treatment temperatures at 2700–2750°F—in spite of the telephercar ladle's less than ideal geometry. The surface area to volume ratio of the ladle is substantially greater than that of a conventional ductile treatment ladle, causing increased Mg and temperature losses.

Slag buildup at the box's exit hole has at times caused concern. It may be attributable to the flow rate evaluations, as well as to the fact that Blackhawk has consistently run at the top of the weight range the boxes are designed to handle. This slag buildup contributes to lower Mg recoveries and the burping back of magnesium gases trapped in the box through the entrance hole.

As production has increased in both the number of treatments per hour and the total treatments per shift, overheating of the box has also become a problem. Consequently, an air line is now inserted into the alloy fill hole between treat-

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**Initial Evaluation**

Prototyping of ductile iron castings began in October 1993. The unit was placed directly under one of the two channel holders and 700–1200 lb batches were treated directly into the telephercar ladles. The ladles were then subdivided to feed several molding lines.

In these early trials, Blackhawk used a nodularizer containing an average of 3% Mg to pour 100-70-03, 80-55-06 and 65-45-12 grades from a single base iron. The as-cast ferritic grade was produced with extremely low postinoculation levels of 0.10% ladle and 0.10% mold. Because the iron flows over the nodularizer, it exits the box with a high level of nucleation, thereby dramatically reducing postinoculation requirements. The various pearlitic grades were produced by alloying with copper or copper ferromanganese additions.

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*Fig. 1. In these cross sections, #1 is the empty box at the start of the process while #2 shows the inserted MgFeSi. In #3 and #4, the yellow denotes base iron flowing in, red iron being nodularized, and brown is the completed ductile as it flows into the ladle.*

*Fig. 2. The telephercar ladle carrying the ductile iron has to clear the shakeout conveyor as it's way to the pouring dock.*

*The box lid is taken off and any built-up slag is removed.*

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Box Maintenance

After a production shift of 80-90 treatments, the boxes are taken out of service for refractory maintenance. The lid is removed and any built-up slag is removed. Alloy chamber dimensions are then checked before a new alloy dam is placed in the box, and entrance and exit holes are chipped out and remilled to proper size.

Blackhawk has not yet established a schedule for completely recasting the boxes, since it is evaluating various refractory materials. Under consideration are castables from 60% conventional alumina to 90% low-moisture, high-density alumina.

Future Considerations

The process of testing and refining the operation for future production growth continues. Among the possibilities being considered is fabricating a larger box to accept batch sizes of 3500-4500 lb, and increasing production to 100-120 tons per shift.

Table 1. Mg Recovery Is Largely Dependent on Treatment Temperature

<table>
<thead>
<tr>
<th>Temperature in °F</th>
<th>% of Mg Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2800</td>
<td>40-50</td>
</tr>
<tr>
<td>2700-2800</td>
<td>50-60</td>
</tr>
<tr>
<td>&lt;2700</td>
<td>&gt;60</td>
</tr>
</tbody>
</table>

Blackhawk continues to evaluate the flow rate to alloy recovery ratio, as well as new alloy compositions to increase Mg recovery. The foundry may also begin to use a fluxing agent to keep the box clean for longer operations.

Since the operator's ability to accurately cut off iron flow into the box has some effect on Mg recovery, Blackhawk is continually studying ways of attaining more consistent batch weights and treatment times. Production of 60-40-18 grade ductile cast iron from the same base iron is also being considered.

Since its installation in January, the process has been helping Blackhawk produce clean, cross-free, high-quality ductile iron. A low inoculation rate has been all that is needed to produce carbide-free microstructures in sections as small as 1/4 inch. Alloy usage has been in the 1.5-1.7% range, depending on sulfur levels, base iron temperature and flake time requirements. Blackhawk officials feel that investing in the process has helped the foundry successfully expand into the ductile iron market.

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