Autopour for Treated Ductile Iron: A Progress Report

W.J. Duca
Duca Manufacturing, Inc.
Boardman, Ohio

W.L. Powell
Waupaca Foundry, Inc.
Waupaca, Wisconsin

INTRODUCTION

As with many foundries, time necessitates change in products, iron types and methods. Unfortunately, when these changes are made, the major capital equipment must remain in use. Such was the case for this Wisconsin foundry. Designed and operated as a gray iron foundry for many years, ductile iron was introduced as a new direction. All major equipment, including vertical channel melting, automatic molding machines and pressure pour autpours were retained. Initial use of the autpours on treated ductile iron resulted in an inductor life of only a few weeks, causing serious production problems.

Was the problem that autpours of treated ductile iron was not possible, or can one not expect an autpours designed for gray iron to pour treated ductile iron without some redesign considerations? Foundry personnel believed that the latter situation needed to be addressed. The problem that had to be resolved was to determine how the autpours should be designed and operated so that they could pour treated ductile iron.

This paper discusses a joint project between Waupaca Foundry and Duca Manufacturing to design and develop a channel induction autpours furnace for pouring treated ductile iron.

BACKGROUND

The ductile base iron is melted in 30-ton vertical channel induction furnaces equipped with either 2500 kW or 3000 kW single-loop inductors. The channel melters have been modified in a number of ways including changing from a lip pour spout to a tea pour spout to minimize the amount of slag that enters the treatment vessel. A round channel loop replaced the square loop to minimize channel buildup.

The ductile base iron is converted into treated ductile iron in a tundish treatment ladle in 5000 lb batches as the ladle is filled from the melters. The iron is then transported from the melters to the autpours by monorail. Each autpours feeds a flaskless molding machine as shown in Fig. 1.

\[
5000\text{lb} = 2270\text{kg}
\]

Fig. 1. View of the autpours in operation.
Buildup Problem

When magnesium in treated ductile iron reacts with oxygen and other metal oxides, it forms an oxide compound with a very high melting point. When this reaction takes place within the autopour, the oxide compound remains as a buildup on the refractory lining. Because the buildup displaces molten metal, the capacity of an autopour will decrease as the buildup increases in the upper hearth.

A more serious problem is when the buildup closes the inductor throat area. The superheated iron in the inductor does not exit into the bath. The loop iron then continues to gain temperature, until the working temperature of the refractory is exceeded, causing the refractory to melt. This action is both rapid and irreversible, ending in an iron breakout.

The buildup situation is further complicated when the magnesium treatment alloy contains appreciable amounts of calcium. This is because calcium is more aggressive, with respect to oxygen, than magnesium, and because calcium oxide stiffens an oxide formation more than magnesium oxide does. One consideration was to look to a magnesium treatment alloy that was low in calcium. Such an alloy was jointly developed by the foundry and a treatment alloy supplier. This alloy has been used for the past four years.

Because the solution to the buildup problem revolves around ways to minimize and/or eliminate the formation of the magnesium and calcium oxide compounds, it became necessary to reduce the availability of oxygen within the vessel. This was accomplished by changing several items. The first and most obvious is changing the atmosphere from air to nitrogen. This not only reduced the amount of magnesium oxide formed, but it increased the fade time because the magnesium was consumed at a lesser rate. The second change involved the welding bar stock inside the furnace at all openings.

This provided a twisted path, limiting the indrafting of atmospheric oxygen.

Because not all of the oxygen can be eliminated, some of the magnesium and calcium will find and react with that oxygen. The resulting magnesium and calcium oxides are lighter than the molten iron. Therefore, they will preferentially rise and attach to the refractory in the upper hearth. To insure that the metal oxides will rise in the upper hearth, rather than remaining in the vicinity of the inductor, the height of the molten metal bath was raised. The capacity of the autopour was increased from 3000 to 7500 pounds.

THE AUTOPOUR INDUCTOR

Design

The original gray iron inductor was equipped with a standard throat design above the channel loop, as shown in Fig. 2. Because the throat acts as a collection vessel for refractory oxides, it was reasoned that the design of the channel loop for treated ductile iron should have no throat, as shown in Fig. 3. While this seemingly is a simple task, the longer iron loop presents a design challenge. Since a throatless inductor must be operated at higher volts per turn than a throat-type inductor, the cross-sectional area of the core for a throatless inductor must be larger than that for a throat-type inductor.

The original gray iron inductor was equipped with a channel that had a 3-1/2 in. (8.89 cm) square cross section. Because buildup is more significant when the channel loop has a small cross section and because the oxides build up in the square corners of a loop, it was reasoned that the design for a treated ductile iron loop should be round and large in diameter. The loop was fabricated by bending 5 in. (12.7 cm) OD steel tubing with a 1/2 in. (1.27 cm) wall into a U shape.

Fig. 2. Cross-section view of a conventional inductor.

Fig. 3. Cross-section view of an inductor for treated ductile iron.
**Inductor Positioning**

Typical American auto-pours have the inductor located on the bottom while most European auto-pours have side- or angle-mounted inductors. Because everything possible should be done to encourage the oxides to float to the surface and to have as much distance from the iron surface as possible, it was reasoned that the inductor should be located on the bottom of the auto-pour.

**Inductor Assembly**

The throatless design requires some changes in the normal inductor installation procedures. The technique begins as any normal refractory installation. The inductor case is set on its side and fitted with the bushing. A copper, water-cooled bushing is employed to achieve maximum cooling of the inductor refractory. A dry alumina refractory is then installed using a hand-held vibrator. When the refractory is at the proper height, the inductor loop is set atop the refractory and bolted to the ramming plate. The balance of the refractory is then installed in the inductor case.

After installing the side plate, the core and coil assembly is lowered and bolted in place. The inductor is then set upright and the butt leg is attached. The ramming plate is removed, and the bolting flange on the end of the channel U-section is burned away.

The inductor is then moved under the auto-pour, by means of an inductor cart, jacked upward and bolted to the upper case. A steel tube is then set atop each of the exposed tubes in the inductor case and welded in place. A tie bar of sufficient size to handle the startup current in the loop is then welded between these two tube extensions to complete the loop (Fig. 4). An alumina refractory is then dry vibrated about the tube to form the auto-pour bottom.

**Inductor Startup**

The upper case is fired with a gas torch. When the upper case temperature reaches 2000°F (1093°C), electrical power is applied to the inductor. Temperature rise in the loop is controlled at about 100 degrees per hour. When the loop reaches temperature, 6000 lb of molten metal is introduced into the auto-pour. A prescribed sintering cycle is maintained for four hours, after which the bath temperature is raised to the required pour temperature, a chemistry sample is taken, and appropriate adjustments to the chemistry are made.

**AUTOPOUR OPERATION**

**Pulsing**

Because metal oxides tend to build up in the channel when an inductor is operating at a fixed power level, it was decided to pulse the power from low to high. This established an aggressive stirring action to flush out unwanted metal oxides from the loop. Typically, furnaces are pulsed 1–2 times per hour. However, this can lead to increased buildup by establishing high melting point oxides, followed by excessive temperatures loss.

To prevent this, a short pulse time was employed. The pulsing takes place every six minutes, with the power level changing from 35 to 350 kW so that the time-ratied power equals the 95 kW hold power of the auto-pour.

**Power Supply**

The 350 kW power supply is of the tapped autotransformer design. Four power levels are available at 35, 70, 135 and 350 kW. Because of the pulsing requirement, air contacts would not survive the repeated cycling. Consequently, vacuum contacts were employed for tap changing. In four years of operation, no vacuum contacts have failed. The power supply is equipped with digital meters and operates from a programmable logic controller. Capacitors are employed for power factor correction.

**Pouring**

Originally, the molten iron was pressure-poured directly from the auto-pour into the mold. Unfortunately, the repeatability of the pour left something to be desired. The pour control problem was resolved by using the pressure to move the molten metal from the auto-pour into an unheated launder equipped with a stopper rod. The metal level in the launder is maintained by laser control, which provides for very accurate level control. The metal in the stopper rod launder is maintained at a height of 4–6 in. (10–15 cm) to prevent oxide buildup on the stopper rod.

The auto-pour can operate for up to 22 hours before it must be shut down for stopper rod maintenance and cleaning. This is done by reducing the pressure on the vessel so that the molten iron in the launder will drain back into the main vessel, allowing ease of stopper rod maintenance.

**Slagging and Cleaning**

Because there will always be some metal oxides accumulating on the upper side walls of the auto-pour and atop the molten metal, the top inspection hatch is opened on a daily to every-other-day basis to remove this oxide formation. This is accomplished by using a long chisel bit and a small slagging spoon. After every three months of
operation, the removable top cover is removed so that the autopour can be thoroughly cleaned of any unwanted metal oxide buildup on the lining. Removal of the metal oxides on a continual basis has been found to be one of the most important factors to successful operation of an autopour used on treated ductile iron.

Fade

The autopour operates with minimal magnesium fade when the molten metal is replenished with 5000-lb batches on a regular basis. However, when the hatch is opened or when the autopour has been held for some time, the residual magnesium level goes below the control limits. The iron is then treated with a nickel-magnesium alloy so that the magnesium level can be restored without altering the silicon level.

PERFORMANCE

The first autopour was put into operation in April of 1989 and ran for 12 months. It was restarted in April of 1990 and ran for 10 months and 6 days. It was restarted in February of 1991 and has been running 20 months to date.

The second autopour was put into operation in May of 1990 and has been running for 29 months to date. This autopour is scheduled to be shut down due to upper case refractory wear. The electrical characteristics of the inductor have remained virtually unchanged from the day it was started.

A third autopour was put into operation on May of 1992 and has been running since.

CONCLUSION

Although existing channel induction autopours designed for gray iron are inoperable when used to hold and pour treated ductile iron, they should not be discarded. Proper updating of these autopours can lead to successful and profitable holding and pouring of treated ductile iron.