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— Tracking Technologies —

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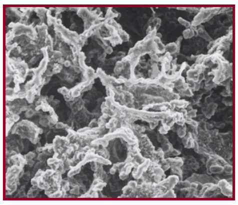

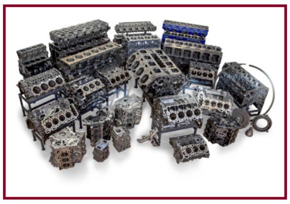

SinterCast Tracking Technologies – Industry 4.0 Process Control and Traceability in the Cast Iron Foundry Industry

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Abstract

In 2015, in support of the production of a new high volume Compacted Graphite Iron (CGI) cylinder block, the Tupy foundry in Saltillo, Mexico became the first foundry in the world to install the SinterCast Ladle Tracker® technology. Since the start of production, the gasoline engine cylinder block, produced with a 2.5 mm minimum wall thickness and within the narrow 0-20% ISO nodularity specification, has become the highest volume CGI engine in the world.

The SinterCast Ladle Tracker automatically tracks and logs the progress of every ladle at every step in the process, from furnace tapping through to pouring. The Ladle Tracker ensures that every step of the process is successfully completed within the allocated time and that all parameters such as ladle weight, temperature and chemistry remain within the specified ranges throughout the process. Nonconforming ladles are prevented from progressing to the next step of the process, and the pouring car is automatically locked-out. Only the iron within the specifications can be poured. In addition to the on-line process control, the Ladle Tracker system also identifies where ladles fall-out of the process, providing new insight for foundry managers to eliminate bottlenecks and to optimize the process flow.

The tracking capability has been extended to also track cores, flasks, castings and operators. The SinterCast Cast Tracker™ can provide complete traceability of each casting from the date of manufacture of the cores (inception), shelf storage time, pouring (birth event) and shake out. Together with the Ladle Tracker capability, Cast Tracker provides traceability of the moulding history and the liquid metal history. For the end-user, this novel capability provides complete traceability of each casting. For the foundry, Cast Tracker provides the detailed information (such as cast sequence) needed to determine robust correlations between defects and the process parameters.

Introduction

Advanced materials and improved foundry technologies are needed to meet the increasingly stringent design, performance and durability requirements established by automotive OEMs. Increasingly, CGI has become a material of choice for engine designers to satisfy performance objectives while reducing engine size and weight. In order to support the growing demand for CGI, foundries have adopted improved process control technology to ensure reliable high volume production, and to provide confidence to the OEM community. This paper provides an overview of the process control technology and traceability implemented by the Tupy foundry in Saltillo, Mexico for the high volume production of CGI cylinder blocks.

In preparation for the start of production of a new V6 gasoline engine cylinder block developed by Ford, Tupy installed the SinterCast System 3000 CGI process control technology to ensure reliable high volume production within the required 0-20% nodularity specification. The Saltillo System 3000 was the fourth SinterCast process control system installed by Tupy, in Brazil and Mexico. With the demand to produce up to 22 ladles per hour, with five ladles in-the-run and three forklifts for transport, Tupy also installed the SinterCast Ladle Tracker technology to monitor and control the movement of the ladles throughout the foundry. The Ladle Tracker system is based on the attachment of a radio frequency identification tag to each ladle, and the positioning of RFID antennas at key points in the foundry including: furnace tapping; base treatment; correction; temperature checking; and, pouring. As ladles progress through each step of the process, the tracking system collects data regarding temperature, weight, chemistry, CGI thermal analysis results, cored wire additions, and time to ensure that the correct actions are applied to each ladle and that only good ladles arrive at the pouring car. The system also implements an automatic fade clock that locks-out the pouring car after a fixed amount of time following the final addition of magnesium. In the production environment, the ladle tracking technology automatically applies and imposes management control limits rather than relying on the behaviour and discipline of the operators. The quantitative production records provided by the ladle tracking system have also identified bottlenecks in the process, allowing Tupy to implement new procedures that have significantly increased the overall efficiency of the process and the productivity of the moulding line.

Ladle Tracker Technology

The SinterCast Ladle Tracker monitors and records the progress of each ladle as it moves through the foundry. A radio frequency identification (RFID) tag (Figure 1) is affixed to each ladle and RFID reader antennae are installed at key locations throughout the foundry. Ladles are monitored at each of the three furnaces where iron for base treatment is tapped (two medium frequency induction melting furnaces and one channel induction holding furnace); at each of the wirefeeders used for base treatment and correction; and at each of the two pouring cars. Calibration of the antenna intensity and careful positioning is required to insure sufficient signal strength to energize the passive RFID tags. Where obstructions or ladle movement can interrupt the established connection between the ladle RFID tag and the antenna, a software locking mechanism has been specifically developed to hold the ladle in position until it is detected at exit. Locking a ladle in position insures that only one ladle can occupy a position and its status can remain positive (present and detected) despite the signal interruption. Antennae are connected to RFID reader boxes that interface with the process control technology through Ethernet connections.

Figure 1: RFID tags affixed to ladles [1, 2]

In the production environment, a solution was developed to protect the RFID ladle tags from heat, metal splash, impact and dust; while insuring that the tags were located in a readily readable location. Direct measurements found the outer surface temperature of the ladle peaked at 340°C while the tag must be kept below 120°C to preserve reading distance and usable life. A holder was developed to minimize the radiant heat from the ladle surface and from the convective heat rising from the base, keeping the peak temperature of the tag below specification. The reader antennae are also protected from heat and dust by a splash resistant refractory cloth and by placing the antennae in locations that enable reading while minimizing risk of physical and thermal damage. The design solutions have proven robust with no antennae failures in more than 25,000 ladle cycles and with RFID tag life exceeding one thousand cycles on many ladles.

The SinterCast Ladle Tracker documents the time of the ladle at every position; ensures that every ladle reports to every step in the process; and ensures that each step is completed successfully within the allocated time. The main features and process opportunities of the ladle tracking technology include:

Process Security: Real-time process control to ensure that every ladle reports to every station and that time limits are adhered to, including automated lock-outs at the pouring cars.

Process Optimization: Daily, weekly and/or monthly reports of ladle movement to identify where and why ladles drop-out of the process and to identify and resolve process bottlenecks.

Process Improvement: Establish production KPIs to link operator performance directly to productivity and to quantitatively measure process improvements.

Process Traceability: Ladle movement and process data (temperatures, weights, chemistries, thermal analysis results, and wirefeeder data) can be uploaded to the foundry database for process traceability and customer assurance. No process information is stored on the RFID tag.

Remote Office Display: Foundry supervisors and managers can view real-time process data on remote computers via internal network connections.

Stand Alone Capability: The technology can be installed independently in cast iron, aluminum, or steel foundries where metal handling, mold transfer and process efficiency can benefit from traceability and improved process flow.

Process Flow with the Ladle Tracker Technology

Melting of low-sulphur base iron is performed in two, 12 tonne medium frequency induction furnaces. Ladles are tapped directly from these melting furnaces or from a 30 tonne holding furnace that is filled by the melting furnaces during non-production periods. Up to five ladles are rotated through the process to maintain a steady supply of iron to the molding line. The ladle capacity varies between 1350-1750 kg, providing a maximum pouring capacity of 35 tonnes/hour. Ladles positioned at any furnace for tapping are detected and identified by ladle tracking as shown in Figure 2. A signal lamp provides operators with a confirmation that the RFID tag has been detected. When the iron has been tapped, the furnace operator registers the melt by pressing the registration button. Upon registration, the tapped weight and ladle ID are automatically input to the process control software.

Figure 2: Ladle tracking technology at tapping furnace [1, 2]

Ladles are transported to base treatment by forklift, where the iron temperature is measured and automatically input to the process control software. Ladle tracking identifies the ladle placed in the base treatment wirefeeder enclosure (the center enclosure in Figure 3), and ensures all process inputs are appropriately applied. The alloy calculator utilizes the thermal analysis results of previous ladles, together with the automatic inputs of iron weight, temperature and base iron sulphur content of the current ladle to calculate the optimal base treatment additions of magnesium, rare earths and inoculant. All input parameters registered to that melt ID must be within preset limits, as defined by the foundry management, to execute the base treatment. Non-conforming ladles are flagged early in the process.

Figure 3: Base treatment (center) and correction enclosures (north and south). [1, 2]

The operators are signaled to remove the successfully base treated ladles for thermal analysis sampling and transfer to either of the two available correction enclosures. The ladle tracking technology automatically determines into which correction wirefeeder the ladle has been placed, preventing any potential error in assigning corrective wire additions to a ladle. When the thermal analysis results are complete, the correction wire lengths are sent to the wirefeeder enclosure that contains the ladle with the matching RFID tag.

Ladles leaving correction are transported by forklift to one of two pouring cars. When a ladle enters the pouring car, ladle tracking identifies the RFID tag and illuminates the green signal lamp to indicate the ladle is approved for pouring (all process steps successfully completed; all input values; and, permissible pouring time within range), as shown in Figure 4. If all parameters are not within the specifications set by the foundry engineers, the red signal lamp will be illuminated and the ladle will be locked-out to prevent pouring. The time elapsed from completion of the correction step is recorded by the ladle tracking technology. When the time limit for pouring is about to expire, a warning indication is provided to the pouring car operator. This warning allows the operator to finish pouring the current mold. Thereafter, the red signal lamp illuminates and pouring is automatically locked-out (molds cannot be poured). This automatic lock-out insures that the foundry does not have to rely on operator discipline, thus providing control for the foundry and confidence for the OEM.

Figure 4: Ladle tracking at the semi-automatic pouring line. [1, 2]

Ladle Tracker Feedback

A status window for ladle tracking lists each ladle position and indicates the presence of a ladle by the affixed RFID tag. Color coding defines the status of each ladle, with green indicating that the ladle has been registered and accepted at that position, yellow signifying that the ladle has been registered but is waiting for completion of a sample or other data, and red meaning that the ladle has been rejected, either for an out-of-range value, incorrect positioning or for exceeding a time limit. The feedback screen can be viewed remotely on any foundry computer on an attached network or on a mobile PDA. The remote viewer allows managers and supervisors to view current results in real-time and to scroll back through past results from any convenient foundry network location, or remotely.

Foundry engineers can connect to the system from any foundry network location to manage and set the production parameters of each casting and to download results and summary reports. Summary reports can be independently created on a daily, weekly, monthly or on-demand basis. The ladle tracking summary report is customized for the foundry to detail the timing of ladles passing through the process. The report data can also be exported in a text stream, in real-time, to a foundry controlled database.

Reports of the average start time at each measurement position, and elapsed times for each step in the process, allows the production performance to be measured and bottlenecks to be identified and resolved. The timing data are organized by furnace, correction and pouring locations to accurately identify when and where ladles drop out of the process. Ancillary data such as ladle weight, temperature and sulphur can be used to further identify the reasons why ladles may drop out of the process, creating a powerful tool for productivity improvement. RFID tag life statistics are included in the summary reports to assist with maintenance. Log reports detail maintenance alerts or errors. The comprehensive communication interface between the casting process control technology, ladle tracking, and foundry process inputs insures that operational security is achieved and system benefits are maximized.

Cast Tracker

Cast Tracker provides complete traceability of each casting from the date and time of core production (inception), shelf storage time, pouring (birth) and shake out. Together with the Ladle Tracker technology, Cast Tracker links the moulding history to the liquid metal history. For the OEM end-user, this novel capability provides complete traceability of each casting. For the foundry, Cast Tracker provides the detailed information (such as cast sequence) needed to determine robust correlations between defects and process parameters.

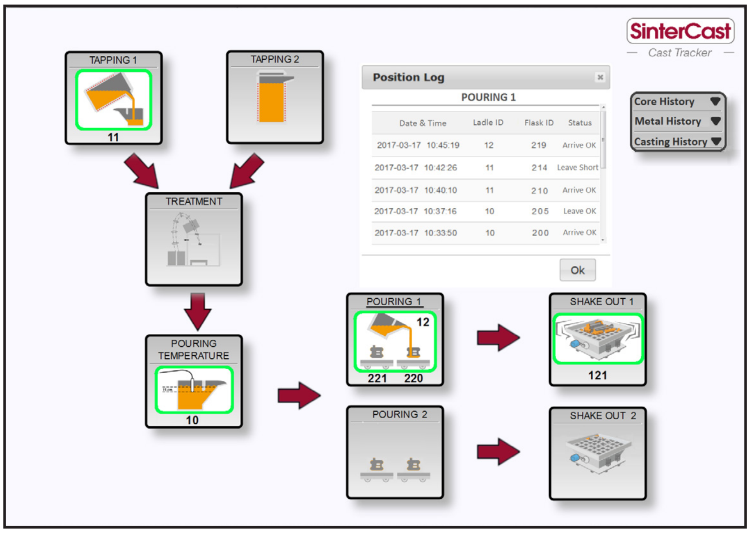

Figure 5: Real-time position monitoring and tracking with Cast Tracker

Additional features for Cast Tracker beyond the Ladle Tracker features include:

- *Core Traceability:* Inputs for core marking that define the date and time of manufacture (inception); determination of shelf storage time; and, identification of the mould in which the cores are set.
- *Mould Tracking:* RFID tags or 2D optical matrix plates on each flask match the mould with: - the marked cores identified by printed bar codes or sand etching - the ladle identification, the liquid metal history and the cast sequence within the ladle- shakeout time
- *Casting Traceability:* Synchronisation of the coremaking, mould identification, and metal history data (including pouring times and temperatures), ultimately relating each component to the entire process history.

You Can't Control What You Can't Measure

Summary

Building on more than ten years of high volume Compacted Graphite Iron series production at the Tupy foundries in Brazil, Tupy and SinterCast designed and installed a bespoke CGI process at the Tupy Saltillo foundry in Mexico prior to the start of production of the world's first high volume CGI petrol engine cylinder block for Ford Motor Company. The high throughput, with capacity to process up to 22 ladles per hour, using multiple furnaces, multiple treatment stations and multiple pouring cars, also required the development of a novel ladle tracking solution to ensure that every ladle completes every step in the process flow, within the boundaries set by the foundry engineers. It has been successfully used in production since 2015, controlling more than 100,000 ladles. Following the positive experience in Mexico, including, reduced scrap and improved efficiency, Tupy invested in the technology for its foundry in Brazil in 2018.

References

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