Quality Output Through Procedure Verification At Texas Foundry

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Track: Product and Process Design

Abstract

Certain manufacturing procedures in necessitate the performance of manual operations at critical stages of product development. The resultant quality of products produced is a direct result of how efficiently these steps are performed by manufacturing personnel. This paper demonstrates how Texas Foundry, a major supplier of parts to the automotive industry, developed procedures to verify that certain critical steps in manufacturing were performed by foundry personnel. Through the use of these procedures, Texas Foundry was able to save approximately $50,000 in added costs per year.

Introduction

Foundries are an integral part of the history of mankind. While they are not the oldest profession, foundries have existed for thousands of years. The first known iron castings were made by the Chinese in the Sixth Century B.C. (Iron Castings Handbook). Saugus Iron Works (1643), near Lynn, Massachusetts, was America's first iron foundry. Today, in the United States alone, there are approximately 4,500 foundries, producing about 12 million U.S. tons of castings per year, totaling nearly $16 billion worth of shipments. Foundries are leading recyclers, since the bulk of molten metal comes principally from old car bodies and other scrap metals.

A foundry is a place where castings (either ferrous or nonferrous) are made from molten metal in accordance with specifications set out by the end-user. Ferrous foundries are those that produce castings made from some form of iron or steel. This type of foundry represent about $10 billion (63% of dollar value) and 10.8 million U.S. Tons (90% of tonnage) in annual shipments, and include gray iron, ductile iron, malleable iron and steel castings.

Texas Foundries, a division of Citation Corporation, located in Lufkin, Texas for sixty-five years is a ductile iron foundry that mainly produces castings for automotive and truck applications. Currently, production averages about 10,000 tons of castings per month. Texas Foundries has about 500 different active parts, which are supplied to twenty-six customers including the Big 3 automakers and some of their suppliers. Sixty-five parts make up 80% of the monthly sales volume. The majority of the production is comprised of safety critical braking and steering, suspension and drive train components. This paper addressed steps taken at Texas Foundries to insure that correct iron formulas were used in the casting process.

Process Overview

A simplified flowchart of the casting process at Texas Foundry is presented in Figure 1.

See Figure 1.

Metal Preparation

The first step is to purchase clean, high quality steel scrap. Steel scrap from stamping plants that has been shredded and bundled is the main raw material that is utilized. Each load is sampled for chemical composition. If unwanted trace elements are detected the load is rejected. If the chemical analysis is within the company specification the load is accepted and used by the melting department. Five coreless electric induction furnaces are utilized to melt about 40 tons of iron an hour. New steel scrap, internal "returns" consisting of feed material, scrap and runner systems, and carbon are added to the smelters. About 1 hour is required to melt 8 tons of iron in each furnace. When the operator determines the "heat" is ready to "tap-out", a sample is poured to check the chemical composition and the temperature is checked. If both are within specifications, the "tap" is transferred to a holding furnace. The holding furnace is utilized to level the slightly different chemistry levels between smelters, to maintain the temperature of the iron, and to provide a buffer during peak usage times.

Sand Preparation

This process consists of mixing sand with water and clay to produce molding sand. The molding sand is then packed and squeezed around a pattern to produce a mold that is a negative of the pattern. Two patterns are used, one for each half of the mold. The two mold halves are then matched together and the resulting cavity is filled with iron. Each pattern contains impressions of the desired part, a runner system to route the iron from outside the mold to the part cavity and a feeder to compensate for shrinkage that occurs during solidification of the iron.

Molding

Iron is transported in ladles from the holding furnace to the molding machine pouring line. At this point the iron pourer adds the required alloys. Before pouring the iron into the mold halves, the pourer skims the ladle to remove excess slag. After the last mold is poured, a test piece is poured to allow for a "nodularity" test. Nodularity is a characteristic of the form the carbon takes in the iron matrix. At least 90% of the carbon must be in the form of nodules or spheres.

Cleaning Process

When the castings have solidified, about 45 minutes after pouring them, they are removed from the sand. The sand is then filtered and reused and the castings are allowed to cool. When they are cool, the castings are separated from the runner systems and feeders. The castings are cleaned and sent to a station to have the hardness verified by a brinnel hardness check. If the parts are in range, they are sent to the finishing operation.

Finishing

Finishing consists of removing parting line "flash" via grinding or "shearing" on a press. "Flash" is the excess material formed when iron runs into the crack formed by the meeting of the two mold halves. "Shearing" is using a mechanical knife to cut the flash from the casting. Safety components are then subjected to an ultrasonic test that verifies 100% of the parts before shipping to customers.

Metal Grades Produced At Texas Foundry

Texas Foundries offers customers four grades of ductile iron. The molecular defining characteristic of ductile iron is carbon that takes the shape of nodules within the molecular iron framework. Carbon is introduced into the molecular framework by exposing the molten base iron to magnesium. Magnesium boils when exposed to molten iron at 2600 degrees. The vaporized magnesium eventually evaporates (after about 15 minutes) and the iron reverts back to the base-grade iron. The base-grades produced at Texas Foundry are in accordance with the Society of Automotive Engineers for grade D4512, D4018, D5506 and D7003. For D4512, the "D" designates ductile iron, the "45" designates the yield point in thousands and the "12" designates the percent elongation before breaking**.** D4018 is a D4512 derivative that has been softened by heat-treating. D5506 and D7003 are produced by modifying the grain structure in the base metal through the introduction of copper alloy. Normally 0.50% copper is required to achieve the D5506 grade and 0.75% copper is required to achieve the D7003 grade. Residual copper in the base metals (D4512 and D4018 grades) normally runs at 0.20%.

Problem Description

Each order of ductile iron produced at Texas Foundry has a method card that indicates what metal type is required, what alloys are needed and any other special instructions. During the pouring process, the iron pourer must retrieve the required alloy(s) and add them to the ladle during the molding process. The addition of magnesium results in a bright flash. If this flash does not occur, the ladle’s trolley rail is blocked automatically until the ladle is removed. The subject of this paper will be to confirm, that copper has been added to pouring ladles during the casting process. Copper is manually added by the iron pourers, for various grades of iron produced by Texas Foundry. Like any manual operation, however, it is possible that the iron pourer could forget to add the copper to the ladle. To verify that copper has been added to the ladle, a sample coupon or actual castings must be checked. A sample coupon is a test slug poured in a coffee cup sized mold by the iron pourer. Several methods are available for these checks.

Testing For Copper Alloy

To check a sample coupon for the presence of copper, an eddy current tester is utilized to check a sample coupon that is poured from each ladle. The eddy current tester is only 80% accurate on D5506 and 95% accurate on D7003. To check a casting for copper, two possible nondestructive tests are available. Hardness, which correlates with copper level, can be verified with a Brinnel Hardness Test. This requires no set up and takes 1 minute per part to check and is performed before finishing. Forty minutes per hour is available with current personnel for this method. The other method, an eddy current test, requires a 20-minute set up and takes 10 seconds per part and must be done *after* the parts are processed.

It was determined from historical records that approximately 2760 ladles were poured each week per molding line of which 60% had copper. A 99.5% accuracy rate for all 1656 (2760 X 0.60) ladles containing copper yielded 8.28 incorrect ladles. This level of error was unacceptable; therefore, top management decided to use an error rate of 99.99%. This level of error yielded 0.17 bad ladles per week or one ladle every six weeks. Management also decided that catching bad parts was not sufficient, consequently this project investigated feasible methods for verifying that copper was added and also identified methods of preventing the fabrication of castings that did not contain the specified amounts of copper alloy.

Prevention Costs

The four major categories of cost that are associated with quality management are prevention, appraisal, internal failure, and external failure. Prevention costs are associated with preventing defects before they happen. These costs include the costs of redesigning the process to remove the causes of poor quality, redesigning the product to make it simpler to produce, training employees in the methods of continuous improvement, and working with suppliers to increase the quality of purchased items or contracted services. In order to improve quality, firms have to invest additional time, effort, and money.

Poor quality at Texas Foundry was associated with copper not being added to the ladles of iron to produce the strength and hardness of the parts in accordance with customer specifications. After some discussion with the iron pourers and reviewing the process flow diagram, it was the iron pourers' responsibility to know what job was currently being produced, and to follow the method card in adding specific alloys. However, the researchers identified some tools that were used to help insure this happens:

1. A monitor was installed at the pre-pouring station that indicated the job and specifics of the cast-iron currently being processed. The screen shows the job and the metal type. This was completed with a one time cost for the screen of $500. No additional personnel were required to maintain and operate the monitor.

2. A mechanical buzzer device was installed where the iron pourer must hit a specified button when the copper alloy is picked up. If the operator does not hit this button a buzzer will immediately sound to remind him to get the copper alloy. This was completed with a one-time installation cost of $1500 and requires no additional manpower to operate.

3. The copper must be placed on a tray prior to dispensing magnesium alloy. Cost is negligible and additional personnel are not required.

4. The holding furnace tap-out man verifies and logs that the iron-pourer had the copper (tap-out man cannot be issued any magnesium alloy until the log is completed and the iron-pourer has added it to the iron during the filling process). This was done with current personnel and had no implementation costs. A stop is in place to prevent the iron-pourer from proceeding to the line if the magnesium flash is not detected (no flash if magnesium is not added). This stop had a one-time installation cost of $3200. Additional operational costs were not necessary.

These preventative steps will insure that iron specifications requiring copper will be met with greater consistency.

Appraisal Costs

Appraisal costs are incurred in assessing the level of quality attained by the operating system. Appraisal helps management identify quality problems. As preventive measures improve quality appraisal cost decrease, because fewer resources are needed for quality inspections and subsequent searches for causes when problems are detected. Assessing the level of quality at Texas Foundry is a two-step process. A test coupon is poured from each ladle, which is primarily used to examine for nodularity (strength and hardness), but can also be checked for the copper level. This process however is affected by other factors such as coupon density and surface finish, resulting in a 90% effective rate. It can only be used if the difference in the copper alloy addition and the copper residual in the base iron is greater than .2 percent. This test can be done with current personnel and equipment. It offers the opportunity for an immediate response and the questionable parts can easily be caught and the actual castings can be verified, so it is used despite its limitations.

The addition of copper is highly correlated to metal hardness. Using the hardness check as a verification process then is very effective. Two methods are available to check hardness: A brinnel machine (direct), or an eddy current machine (indirect). The direct method is labor intensive and is normally utilized on small batch jobs. The eddy current test is more appropriate for checking 100 percent of large batch castings.

The number of parts that require checking is developed in the following way: the line runs 12 hour per day with copper added to the ladles, 300 molds are poured per hour, with an average of 6 parts per mold which total 21,600 pieces per day. If only one part from each ladle is checked to insure that copper was added then the problem can be looked at as 23 ladles per hour (13 molds per ladle). Thus, it would be necessary to check 23 parts per hour, one from each ladle. If one ladle is bad, on average there would be 78 (6 parts per mold x 13 molds per ladle) defective parts.

Internal failure costs result from defects that are discovered during the production of a product or service. They fall into two major cost categories: yield losses, which are incurred if a defective item must be scrapped and rework costs, which are incurred if the item is rerouted to some previous operations to correct the defect or if the service must be performed again. Internal failure costs could result in all parts having to be scrapped and reprocessed. The cost of one bad ladle discovered at molding would be approximately $450.00 and if discovered after a job was completed would be approximately $ 1,010. 00.

External failure costs arise when a defect is discovered after the customer has received the product or service. Also external failure costs can include warranty service and litigation costs. Defective products can injure and even kill consumers who purchase them. External failure could be very costly to Texas Foundries because the majority of the production in which copper is added is comprised of safety critical braking and steering components to car manufacturers and their suppliers. If the customer finds one defective part in a shipment then the entire shipment has to be tested and verified on site. This cost can range from $5000 to

$20,000 depending on customer location, number of questionable parts and the stage of processing of the parts.

To achieve an acceptable quality level of 99.99% it was determined that a sample size of 500 pieces per hour would be required to meet the required quality level. This would require 1.75 hours of sampling per hour of production, resulting in the addition of 2 people at an annual loaded cost of $32,000 per person and greatly reduce through-put and hinder process flow.

An alternate method that was acceptable to management was to perform a Brinnel check on a sample casting from each ladle. This will create 23 minutes of extra work per hour for current personnel, using an average of 23 ladles per hour and one minute per casting to perform the check, in addition to the manpower required to pull the pieces. Additional costs were not required for this option.

Conclusion

Doing the job right the first time is the only real solution. The company can make tools available to personnel to help insure that the processes are followed and the job is done correctly. Investments of $5200 were made to help personnel follow the establish procedures.

However, due to the importance of having the correct metal type, the company has decided that the process must be verified. The earlier suspect parts are uncovered, the smaller will be the cost for the failure. A rough check is performed in the lab that will detect most of the failures. This is accomplished with current equipment and personnel immediately after pouring the molds. A final check is performed before finishing on a sample piece from every ladle using current equipment. If a bad piece is detected the entire lot will be sorted. The final sampling method will be by the brinnel non-destructive method before the parts are released to the finishing department. This process required additional labor of 6 hours each shift or 12 hours per day, at a loaded cost of $14 per hour or $50,400 per year.

In the last six months, Texas Foundry has experienced external failure costs of nearly $52,000 and internal failure costs of $5,050. These costs do not include potential loss from losing future business that could occur if quality problems resulted in removal from customer supplier lists. If the last six months represent a typical period, annual failure costs of $114,100 could be expected verses prevention costs of $50,400 variable costs and one time fixed costs of $5,200. In short, investing $5,200 in prevention tools and spending an additional $50,400 per year in additional labor costs, failure costs can be minimized in the future.

Figure 1 – Ferrous Casting, Process Diagram