Study of Centrifugal Casting of Cast Iron Rolls and its Problem Formulation at India Factory, Malerkotla, Punjab (India)

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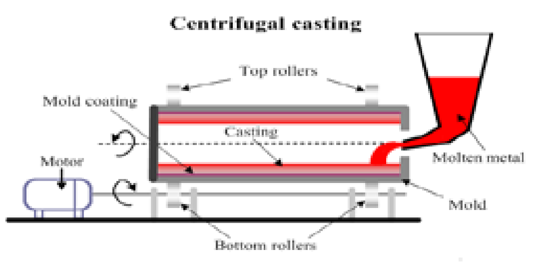
ABSTRACT *India Factory was established in 1970 and was the first company to introduce Chilled Rolls manufactured by centrifugal casting in India for Roller Flour Mills. Now the plant is manufacturing Chill Rolls for Roller Flour Mills, Solvent Extraction Plants, Vegetable Oil Mills, Feed Mills, Crushing, Grinding, Milling, Roller Mills, etc.*

A brief study is conducted about the present methodology, techniques and practices being adopted at the site and the problem formulation is suggested as per the rejection rates of products. The plant procedures and processes are carefully examined to check for any deviations from the standard principles and modifications/alterations for the present adopted methods are accordingly suggested to minimize rejections as far as possible.

Most of the rolled castings are produced by centrifugal casting; however some sand moulds with cores are also used for large and solid/hollow cylindrical profile castings. The chemical composition of the material is constantly examined via atomic spectroscopic techniques to assure the quality of the products as per the requirements and a simple 2D layout of the plant is shown to predict an efficient and effective process flow paths and material handling.

Introduction of Centrifugal Casting

Centrifugal casting or rotocasting is a casting technique that is typically used to cast thin-walled cylinders. It is noted for the high quality of the results attainable, particularly for precise control of their metallurgy and crystal structure. Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use.



Process

In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (300 to 3000 rpm) as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away. Casting machines may be either horizontal or vertical-axis. Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings.

Most castings are solidified from the outside first. This may be used to encourage directional solidification of the casting, and thus give useful metallurgical properties to it. Often the inner and outer layers are discarded and only the intermediary columnar zone is used. Centrifugal casting was the invention of Alfred Krupp, who used it to manufacture cast steel tyres for railway wheels in 1852.

Centrifugal force acting on a rotating body is, $C.F = mv^2/r$

Where m is mass, v is peripheral speed, r is radius.

Gravitational force, $G.F = mg$

Where g is acceleration due to gravity.

G factor = $CF/GF = mv^2/r.mg = v^2/r.g$

Solving further, we get, N = 4

Thornton suggested 50 – 100 G speed range for die cast (metal mould) and 25 – 50 G for sand cast pots and shaped castings. Too high speed results in excessive stresses and hot tears in outside surfaces.

Characteristics and Features of centrifugal casting

- Castings can be made in almost any length, thickness and diameter.
- Different wall thicknesses can be produced from the same size mold.
- Eliminates the need for cores and castings are relatively free from defects.
- Resistant to atmospheric corrosion, a typical situation with pipes.
- Only cylindrical shapes can be produced with this process.
- Size limits are up to 3 m (10 feet) diameter and 15 m (50 feet) length.
- Wall thickness range from 2.5 mm to 125 mm (0.1 - 5.0 in).
- Non metallic impurities which segregate toward the bore can be machined off.
- Less loss of metal in tundish compared to that in gating and risering in conventional sand casting.
- Production rate is high.

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- Can be employed to manufacture bimetallic pipes.
- Centrifugal casting process can be used for fabricating functionally gradient metal matrix composite material.

Benefits

Cylinders and shapes with rotational symmetry are most commonly cast by this technique. "Tall" castings (in the direction of the settling force acting, usually gravity) are always more difficult than short castings. In the centrifugal casting technique the radius of the rotation, along which the centrifugal force acts, replaces the vertical axis. The casting machine may be rotated to place this in any convenient orientation, relative to gravity's vertical. Thin-walled cylinders are difficult to cast by other means, but centrifugal casting is particularly suited to them. To the rotation radius, these are effectively shallow flat castings and are thus simple. Centrifugal casting is also applied to the casting of disk and cylindrical shaped objects such as railway carriage wheels or machine fittings where the grain, flow, and balance are important to the durability and utility of the finished product. Providing that the shape is relatively constant in radius, noncircular shapes may also be cast.

Materials and Applications

Typical materials that can be cast with this process are iron, steel, stainless steels, glass, and alloys of aluminum, copper and nickel. Two materials can be cast together by introducing a second material during the process.

Typical parts made by this process are pipes, boilers, pressure vessels, flywheels, cylinder liners and other parts that are axi-symmetric. It is notably used to cast cylinder liners and sleeve valves for piston engines, parts which could not be reliably manufactured otherwise.

Theory of Atomic Emission Spectroscopy

Atomic emission spectroscopy (AES) is a method of chemical analysis that uses the intensity of light emitted from a flame, plasma, arc, or spark at a particular wavelength to determine the quantity of an element in a sample. The wavelength of the atomic spectral line gives the identity of the element while the intensity of the emitted light is proportional to the number of atoms of the element. In spark and arc atomic emission spectroscopy Spark or arc atomic emission spectroscopy is used for the analysis of metallic elements in solid samples. Both qualitative and quantitative spark analysis are widely used for production quality control in foundries and steel mill

Technique Used

Inductively coupled plasma atomic emission spectroscopy (ICP-AES), also referred to as inductively coupled plasma optical emission spectrometry (ICP-OES), is an analytical technique used for the detection of trace metals. It is a type of emission spectroscopy that uses the inductively coupled plasma to produce excited atoms and ions that emit electromagnetic radiation at wavelengths characteristic of a particular element. The intensity of this emission is indicative of the concentration of the element within the sample.

Mechanism

The ICP-AES is composed of two parts: the ICP and the optical spectrometer. The ICP torch consists of 3 concentric quartz glass tubes. The output or "work" coil of the radio frequency (RF) generator surrounds part of this quartz torch. Argon gas is typically used to create the plasma. When the torch is turned on, an intense electromagnetic field is created within the coil by the high power radio frequency signal flowing in the coil. This RF signal is created by the RF generator which is, effectively, a high power radio transmitter driving the "work coil" the same way a typical radio transmitter drives a transmitting antenna. The argon gas flowing through the torch is ignited with a Tesla unit that creates a brief discharge arc through the argon flow to initiate the ionization process. Once the plasma is "ignited", the Tesla unit is turned off. The argon gas is ionized in the intense electromagnetic field and flows in a particular rotationally symmetrical pattern towards the magnetic field of the RF coil. Stable, high temperature plasma of about 7000 K is then generated as the result of the inelastic collisions created between the neutral argon atoms and the charged particles. A peristaltic pump delivers an aqueous or organic sample into an analytical nebulizer where it is changed into mist and introduced directly inside the plasma flame. The sample immediately collides with the electrons and charged ions in the plasma and is itself broken down into charged ions. The various molecules break up into their respective atoms which then lose electrons and recombine repeatedly in the plasma, giving off radiation at the characteristic wavelengths of the elements involved. One or two transfer lenses are then used to focus the emitted light on a diffraction grating where it is separated into its component wavelengths in the optical spectrometer. In other designs, the plasma impinges directly upon an optical interface which consists of an orifice from which a constant flow of argon emerges, deflecting the plasma and providing cooling while allowing the emitted light from the plasma to enter the optical chamber. Still other designs use optical fibers to convey some of the light to separate optical chambers. Within the optical chamber(s), after the light is separated into its different wavelengths (colors), the light intensity is measured with a photomultiplier tube or tubes physically positioned to "view" the specific wavelength(s) for each element line involved, or, in more modern units, the separated colors fall upon an array of semiconductor photo detectors such as charge coupled devices (CCDs). In units using these detector arrays, the intensities of all wavelengths (within the system's range) can be measured simultaneously, allowing the instrument to analyze for every element to which the unit is sensitive all at once. Thus, samples can be analyzed very quickly. The intensity of each line is then compared to previously measured intensities of known concentrations of the elements, and their concentrations are then computed by interpolation along the calibration lines. In addition, special software generally corrects for interferences caused by the presence of different elements within a given sample matrix.

Procedure of Centrifugal Casting of Cast Iron Rolls at India Factory

- First of all scrap is melted in induction furnaces. The furnaces were two in number and of 800 kg capacity each. This molten metal can be taken to the moulds with the help of laddles which are carried away by a heavy duty EOT crane as shown below

- Time to time samples are taken from furnace and checked in atomic emission spectrometer used with argon gas at about 5 bar pressure to produce the required spark to determine the contents in the sample as well as their concentration.
- The roller dies of various diameters are available. Thus castings of various diameters can be obtained as per the desired size.
- First of all roller die is placed over the set of rolls. The rolls are driven by a set of belts being driven by a diesel engine. The variation in speeds is obtained by the provision of gears. A centrifugal mould on belt driven rollers is shown below

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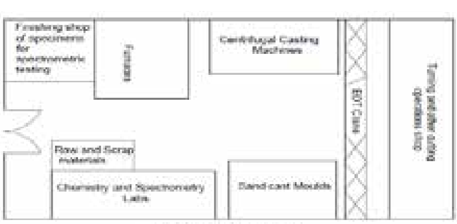
- Roller dies are placed over the set of rolls. If the molten material is directly poured into the metallic mould, it would likely to weld itself with the mould and would become impossible to remove the solidified ingot. In order to prevent it, the metallic die is coated with ceramic material that can use colloidal silica as a bonding agent. The water must vaporize rapidly, leaving behind a coherent refractory layer which can withstand erosive effects of molten material and act as release agent for the finished ingot.
- The rollers which are produced are made up of dual cast iron. Dual cast iron consists of two layers, the outer layer is harder one and inner layer is comparatively softer.
- The outer layer of casting is made hard and tough by adding chromium and manganese with brinell hardness number BHN 550.
- For inner layer which is softer, silicon, which acts as a softening agent is added and brinell hardness number obtained of softer inner layer is BHN 300.
- After mixing the required agents in melted material. Firstly outer layer which is harder one is poured from one side of roller die with the help of hopper like structure as shown below

- After pouring the harder layer in the roller die from one side, its allowed to rotate for some time and then next layer of molten material containing silicon is poured from other side of roller die.
- It takes about 20 to 25 minutes to cast one roll.
- After the roll is prepared, its allowed to cool down to harden and then the casting is sent to turning shop with the help of EOT crane for the required turning operation.
- The roller dies are cooled to 90 degree centigrade before the next run of casting another roll.
- Engines instead of electric motors are preferred for driving the set of rolls for centrifugal casting to get the required high power and speeds.

Simple Plant Layout of India Factory



layout of India Factory Punjab

Results And Problem Formulation

The rejection rate of rolls at India factory was near about 4 to 5 percent. The main causes of rejection were presence of cracks, scales over the surface of rolls. Other causes of rejection were hot tears, segregation and banding.

Hot tears: Hot tears are developed in centrifugal castings for which the highest rotation speeds are used. Longitudinal tears occur when contraction of casting combined with the expansion of the mould, generates hoop stresses exceeding the cohesive strength of the metal at temperatures in the solidus region.

Segregation: Centrifugal castings are under various forms of segregation thus pushing less dense constituents at centre.

Various types of Non destructive techniques such as dye penetrant testing are used to detect cracks.

Conclusion

The defects such as hot tears and segregation were developed because no required data was available with the industry about revolution per minute required for casting of particular diameter of rolls in the roller die. Without any prior knowledge about RPM required for particular diameter rolls, only past experience was used for casting rolls.

Presence of cracks and scales were observed due to manual errors. Pouring time of molten material may be inadequate due to which scales and cracks were formed since there were no provisions for constant pouring of material and manual approaches were used for pouring.

The contents for the dual cast iron rolls during casting may not be of required amount.

Future Expansions

Certain suggestions regarding these defects were given to the industry. It was suggested that the rejections will be minimized to the least value by using appropriate rpm of centrifugal moulds. Some mathematical model may be used to get the optimal rpm of the moulds in order to have defect free castings. Arrangement for pouring should be precised to facilitate uniform and constant mass flow rate which will aid in the prevention of inclusions and scales. Further, advanced refractory ceramic material layers that can withstand high temperatures without melting and decomposing and with high thermal insulation should be applied to metallic moulds instead of simple clay products which ultimately cause undesirable properties in castings.

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