TECH FRONTIERS

Computers help produce quality casting

This article describes how the use of computers in a production foundry improves quality of casting. The casting production process is eco-friendly (green foundry), economic, and operates at reduced manpower (of 21 only). This foundry eliminates need for separate units for core preparation, ladle preparation, and laboratory. However, selected grades of scraps are used as charge materials which equalises (balances) sulphur, phosphorus content of melt. This process reduces melting time and energy consumption as well as casting defects and production costs

KUNAL KUMAR GHOSH

Kunal Kumar Ghosh is former Deputy Manager (Foundry), Braithwaite & Co. Ltd

NORMALLY, steel melting was done in electric furnace like arc or induction furnace due to its high melting point. However, the introduction of computers in the production line reduces the time gap in the process flow at different sections of a foundry and reduces production time. It also meets the demand for production of castings of intricate/complex shape. It (a) improves quality of casting, (b) reduces casting-rejections, (c) increases casting-yield, (d) reduces pollution, and (e) lowers the cost of production. This article discusses the process in detail.

Normally, a steel foundry consists of five shops:

- Pattern shop
- Moulding shop
- Melting shop
- Laboratory
- Fettling shop

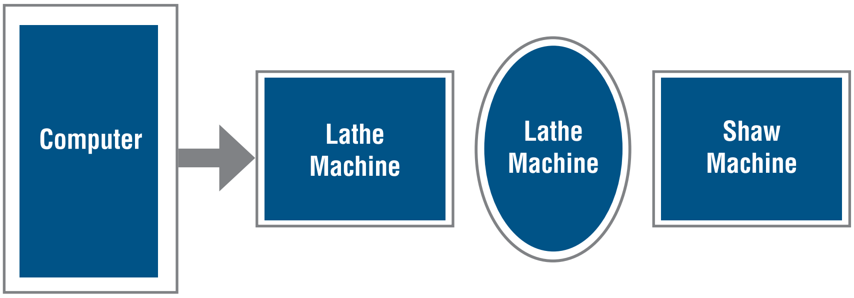
Whereas the modern steel foundry system contains four shops:

- Pattern shop
- Moulding shop (without core preparation)
- Melting shop (without ladle preparation)
- Fettling shop (casting by hammering machine)

PATTERN SHOP

Two persons are involved in making patterns where methoding is monitored by a computer (as shown in **Figure1**). The materials used for making patterns are: (a) good quality teak wood, (b) screw nail, (c) adhesive. Casting drawings are fed into a computer which monitors the methoding for the casting. Machines required for making patterns are: (a) lathe machine, (b) grinding machine and (c) saw machine.

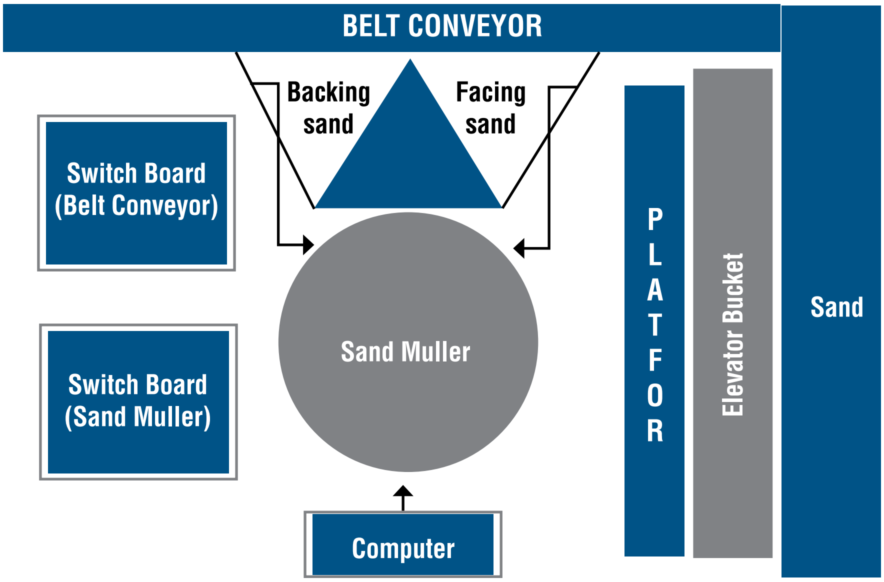
Figure1: Pattern shop



MOULDING SHOP

Sand dryers are used for heating sand to remove moisture at 180-200oC. This is an oil-fired furnace which takes one hour for drying. The capacity of the drier is 3 MT and sand is fed to the furnace in a batch using a crane. After drying, hot sand is cooled in air and then transferred to storage hopper by using elevator and belt conveyor. This process is controlled through computer and operated by one operator. From storage hopper sand is transferred to sand muller for mixing with suitable binders like (a) bentonite, (b) moisture, (c) molasses, (d) resins, and (e) hardeners, depending on the requirements for moulding or core-making. The capacity of the muller is 500 kg per batch.

Figure2: Process of sand mixing



Process of sand mixing

Facing sand forms the face of the mould. It is next to the surface of the pattern and it comes into contact with molten metal when the mould is poured. Initial coating around the pattern and hence for mould surface is given by facing sand. Facing sand has high strength refractoriness. Facing sand is made of silica sand and clay, without the use of already used sand. Different forms of carbon are used in facing sand to prevent the metal burning into the sand. A facing sand mixture for green sand of cast iron may consist of 25% fresh and 70% specially prepared and 5% sea coal. They are sometimes mixed with 6-15 times finer moulding sand. The layer of facing sand in a mould usually ranges between 20-30 mm. Normally 10-15% of the whole amount of moulding sand is the facing sand.

Core sand is used for making cores and it is sometimes also known as oil sand. Core sand is highly rich silica sand mixed with oil binders such as core oil which is composed of linseed oil, resin, light mineral oil and other bind materials. Pitch or flours and water may also be used in large cores for the sake of economy.

For making facing sand, resin (1.5-2 wt% of sand) is used. Sand and resin are mulled for 2 minutes followed by hardener (0.35-0.40% of resin) addition and then again mulled for one minute. So, total mixing time is three minutes for one batch of sand of 500 kg. For baking sand the process is the same; however, the binder is different. The sand is then sent to the hopper by elevator and belt conveyor. After this, the sand is transferred to moulding and core making machines. For making moulds, 70% baking and 30% facing sand are used. Sand is supplied from sand dryer by elevator and belt conveyor to sand mixer. The whole process (**Figure2**) is monitored by computer, along with other testing for param-

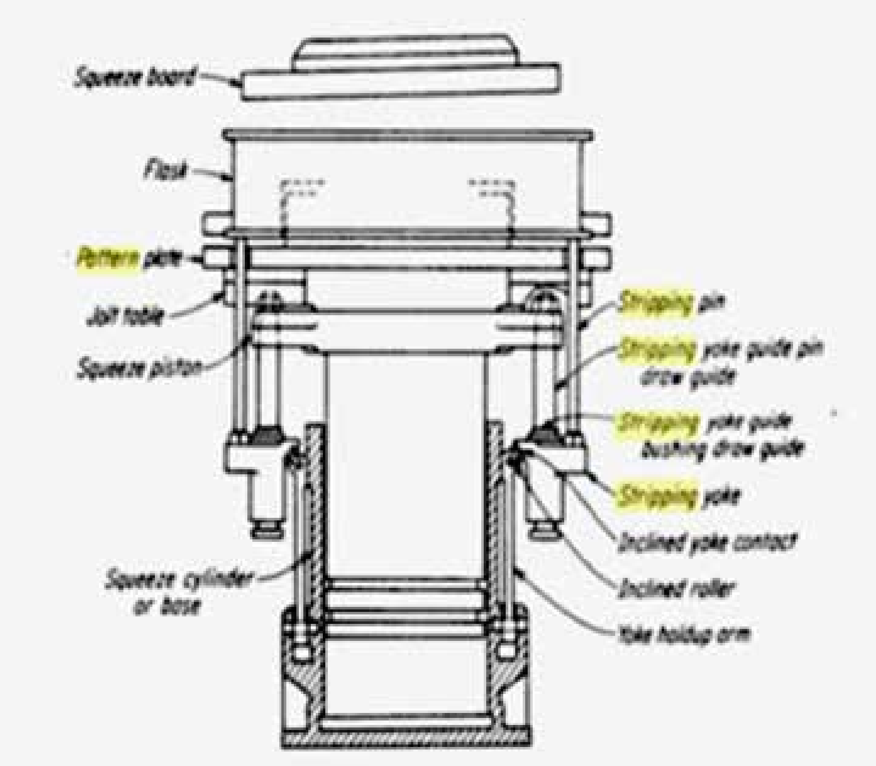
eters such as:
- Sieve Analysis
- Moisture
- Green strength
- Permeability
- Shear strength
- Flowability
- Collapsibility
- Shape of sand grains

This testing process is conducted by one operator.

Mould-making

The first step in the sand-casting process is to create the mould for the casting. In an expendable mould process, this step must be performed for each casting. A sand mould is formed by packing sand into each half of the mould. The sand is packed around the pattern, which is a replica of the external shape of the casting. When the pattern is removed, the cavity that will form the casting remains. Any internal features of the casting that cannot be formed by the pattern are formed by separate cores which are made of sand prior to the formation of the mould. Further details on mould-making will be described in the next section. The mould-making time includes positioning the pattern, packing the sand, and removing the pattern. The mould-making time is affected by the size of the part, the number of cores, and the type of sand mould. If the mould type requires heating or baking time, the mould-making time is substantially increased. Also, lubrication is often applied to the surfaces of the mould cavity in order to facilitate removal of the casting. The use of a lubricant also improves the flow of the metal and can improve the surface finish of the casting. The lubricant that is used is chosen based upon the sand and molten metal temperature. A diagram of a moulding machine is shown in Figure3.

Figure3: Moulding machine



Clamping

Once the mould has been made, it must be prepared for the molten metal to be poured. The surface of the mould cavity is first lubricated to facilitate the removal of the casting. Then, the cores are positioned and the mould halves are closed and securely clamped together. It is essential that the mould halves remain securely closed to prevent the loss of any material.

Pouring

The molten metal is maintained at a set temperature in a furnace. After the mould has been clamped, the molten metal can be ladled from its holding container in the furnace and poured into the mould. The pouring can be performed manually or by an automated machine. Enough molten metal must be poured to fill the entire cavity and all channels in the mould. The filling time should be very short in order to prevent early solidification of any part of the metal.

Cooling

The molten metal that is poured into the mould will begin to cool and solidify once it enters the cavity. When the entire cavity is filled and the molten metal solidifies, the final shape of the casting is formed. The mould cannot be opened until the cooling time has elapsed. The desired cooling time can be estimated based upon the wall thickness of the casting and the temperature of the metal. Most of the possible defects that can occur are a result of the solidification process. If some of the molten metal cools too quickly, the part may exhibit shrinkage, crack, or incomplete section. Preventative measures can be taken in designing both the part and the mould and will be explored in later sections.

Removal

After the predetermined solidification

time has passed, the sand mould can simply be broken, and the casting is removed. This step, sometimes called shakeout, is typically performed by a vibrating machine that shakes the sand and casting out of the flask. Once removed, the casting will likely have some sand and oxide layers adhering to the surface. Shot blasting is sometimes used to remove any remaining sand, especially from internal surfaces, and reduce the surface roughness.

Trimming

During cooling, the material from the channels in the mould solidifies attached to the part. This excess material must be trimmed from the casting either manually via cutting or sawing, or using a trimming press. The time required to trim the excess material can be estimated from the size of the casting's envelope. A larger casting will require a longer trimming time. The scrap material that results from this trimming is either discarded or reused in the sand casting process. However, the scrap material may need to be reconditioned to the proper chemical composition before it can be combined with non-recycled metal and reused.

MELTING SHOP

Process of steel melting

Pouring of steel melting by arc furnace capacity of 5 MT steel contain elements such as carbon, silicon, manganese, sulphur, phosphorus. Percentage of various elements present in steel after melting are carbon – 0.2, manganese – 0.5 to 1, sulphur – 0.004 (max), phosphorus – 0.004 (max).

Arc furnace is heated from the arc struck between the charge of bath and three large electrodes of carbon or graphite operating from a three-phase circuit. The height of the electrode above the bath is controlled electrically, voltage is low and current flow is high necessitating large bus bar and heavy lead-in cables from the transformers. Charging is usually done by removing the furnace top. The roof of the furnace is silica brick whereas the side walls are lined with magnesite brick or chrome-magnesite brick. Bottoms are rammed into place.

Arc furnace is heated from the arc struck between the charge of bath and three large electrodes of carbon or graphite operating from a three-phase circuit. The height of the electrode above the bath is controlled electrically, voltage is low and current flow is high necessitating large bus bar and heavy lead-in cables from the transformers. Charging is usually done by removing the furnace top. The roof of the furnace is silica brick whereas the side walls are lined with magnesite brick or chrome-magnesite brick. Bottoms are rammed into place

Melting and refining process

The general principle for controlling the refining operation in the basic electric furnace for greater flexibility is that most of the control of oxidisation comes from the charge itself. Lime is usually not added until pool of metal is formed and then it is added in small increments from time to time following meltdown. The heat may be handled in any of the following ways:

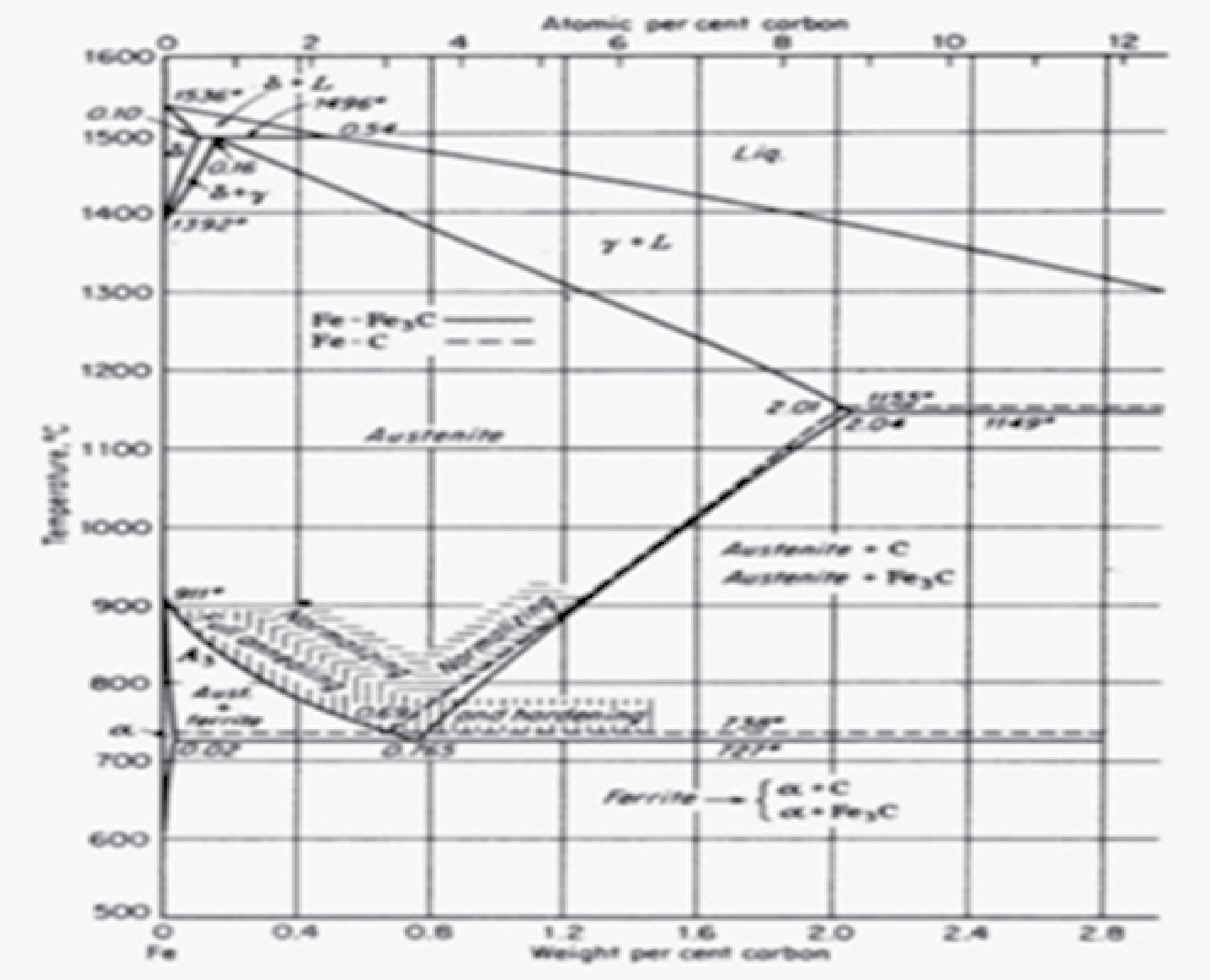
Charging: Purchased scrap and foundry return melt is charged for one to one-and-half hour. Slag is sufficiently basic and it is oxidised to remove the phosphorus to about 0.02% or lower. When the bath and slag have been adjusted to proper temperature and composition, the slag is removed. Once this slag is removed, a refining slag composed of lime is added. The variation is to deoxidise the metal after removing the first slag. Then add slaked lime (calcium hydroxide) as a flux and add Ca-Mn-Si alloy to steel bath of this refining slag. The removal of sulphur can be accomplished only by establishing the basic and reducing agent. In this case carbon is added to the top of the slag. The reaction is considered to be:

$$C \text{ (in steel)} + CaO + FeS \text{ (in steel)} + CO + Fe \quad (\mathbf{1})$$

The accurate composition of steel can be checked from the computer and then directly poured into the mould. Mould boxes are kept for three hours in the roller and then moved to the shake out machine. The whole operation (including testing of melting and pouring) is controlled through computer by three operators.

Shake out machine: Casting and baking sand will be ready. The baking sand is transferred by belt conveyor and elevator to hopper for sand mixing at muller. And the casting is transferred to the hammer machine. This process is monitored

Figure4: Usual temperature range for annealing, normalising, and quenching



through computer by one operator.

Hammer machine: The cleaning sand is received from casting and cutting, through riser, runner, and gating. The casting is then transferred for the heat treatment and through riser, runner, and gating and sent to the furnace.

Heat treatment

Heat treatment requires cast steel casting to be brittle and to possess poor mechanical properties. Heat treatment of steel casting is necessary in order to render them serviceable. The main objectives of heat treatment are:

- Refinement of the coarse structure of the cast metal
- Relief of internal stresses
- Development of desired physical and mechanical properties.

The heat treatment of steel casting depends on the following factors:

- Chemical composition
- Grain size
- Shape and size of the section
- Desired mechanical properties

The principal heat treatment process depends on the nature of casting:

- Annealing
- Normalising
- Quenching and Tempering

Annealing: This process consists of heating the casting slowly in a furnace to a temperature slightly above the critical range (900oC) for about one hour and then cooled in the furnace itself. Certain alloy steel requires higher annealing temperature and holding time in order to affect solution and diffusion of alloying elements. Annealing relieves casting stress, refines the coarse structure, and makes the product homogenous in chemical composition. It improves the mechanical ability, makes the product tensile and yield strength, and increases ductility.

Normalising: Normalising is similar to annealing except that a higher temperature may be used and the casting is cooled in air. Normalising gives higher strength and hardness than annealing.

Quenching and tempering: Mainly required for manganese steel and alloy steel for water quenching and oil quenching. Rapid cooling will repress the transformation of steel to a ferrite-pearlite product and will produce martensite instead. Martensite is the hardest product obtainable for a given carbon content. Reheating martensite to a subcritical temperature (tempering) will produce a dispersion of fine carbide in ferrite and will lead to a gradual softening and toughening of the steel. Thus the quenching and tempering provides a mean of controlling the properties of given steel within rather broad limits. Furthermore, this treatment gives the best combination of properties obtainable. In other words, a steel tempered to a given tensile strength (or hardness level) will have the highest ductility, toughness or yield strength as compared with other methods of heat treating leading to the same hardness. Requires austenite for CMS crossing. In this process CMS is heated at 1050°C in annealing furnace for five hours. After cooling the furnace, within 30 seconds remove to water tank. Treated in cold water and kept for 30 minutes and passing the heat at 5°C. Then casting is removed and rested on floor. The whole operation is monitored through computer by one operator.

The usual temperature range for annealing, normalising, and quenching is shown in **Figure4**.

Shot blasting: Cleaning the casting after heat treatment by a single operator.

Grinding and chipping: After shot blasting, salvaging of the castings is required. This process consists of welding, grinding, and chipping of the casting as required. The process is monitored by a single operator.

Total manpower required is 21 (**Table1**). Work done in the foundry (on shift) is 500 MT steel productions.

Table1: Manpower at different shops in a foundry

Sl No.	Head	Manpower
1	Foundry Engineer	1
2	Foundry Supervisor	1
3	Pattern Shop: Pattern Maker	2
4	Moulding Shop: Moulder Closer Sand Dryer Operator Sand Mixer Operator	
5	Melting Shop: Melter Charger Operator	
6	Shake Out Machine Operator	1
7	Hammer Machine Operator	1
8	Heat Treatment Furnace Operator	1
9	Shot Blasting Machine Operator	1
10	Grinding, Chipping and Welding Operator	1
11	Crane Operator	1
12	Electrical Maintenance	1
13	Mechanical Maintenance	1
Total manpower		**21**

Conclusion

The new process has the following benefits compared to conventional process.

- Increased production rate
- Casting yield improved
- Riser volume is reduced
- Reduction in gas porosity and improves quality of castings
- Less scrap generation
- Cost effective production process
- Increased profit compared to conventional processes
- Reduced pollution compared to previous processes.

Reference

1. Heine, RW, CR Loper, PC Rosenthal, Principles of Metal Casting, McGraw Hill India, 2nd Edition, 1976