Overview of Foundry Processes and Technologies:
Manufacturing Metal Castings

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OVERVIEW OF FOUNDRY PROCESSES AND TECHNOLOGIES

MANUFACTURING METAL CASTINGS

Definition

Metal casting enables the production of simple to complex parts that meet a variety of needs. The process consists of pouring molten metal into a mold containing a cavity of the desired shape. The most widely used method for small to medium-sized castings is green sand molding. Other casting and molding processes include shell molding, permanent molding, investment casting, plaster molding, and die casting. In addition, there are a number of innovative and relatively new casting methods such as lost foam casting and squeeze casting.[1]

Typically, castings are further processed by machining, which entails smoothing surfaces, drilling holes, cutting threads for fasteners, and other steps necessary for incorporation into an assembly.[2]

Figure 1. Casting a Bell. XVIII Century

[1] Metal Casting Industry of the Future. Annual Report 2000.
[2] Investigation No. 332-460. USITC Publication 3771. May 2005

Why Metal Casting is Important

A vibrant, competitive and energy-efficient U.S. metal casting industry is vital to the U.S. economy and national security. Cast metal products are found in virtually every sector of the economy. Almost 90 percent of all manufactured products contain one or more metal castings. Cast manufactured components include automotive parts such as engine blocks, transmission housings and suspension parts. Castings are also used in parts for pumps and compressors, pipes and fittings, mining and oil field equipment, recreational equipment, surgical equipment, and in many other areas. Figure 2 illustrates supply and end-use markets for castings. Markets for castings are increasingly competitive and customers for cast metal products are placing greater demands on the industry for high quality, competitively priced castings. In the industry's largest market, the automotive sector, customers are increasingly demanding light-weight, high strength cast metal components to respond to fuel economy requirements.

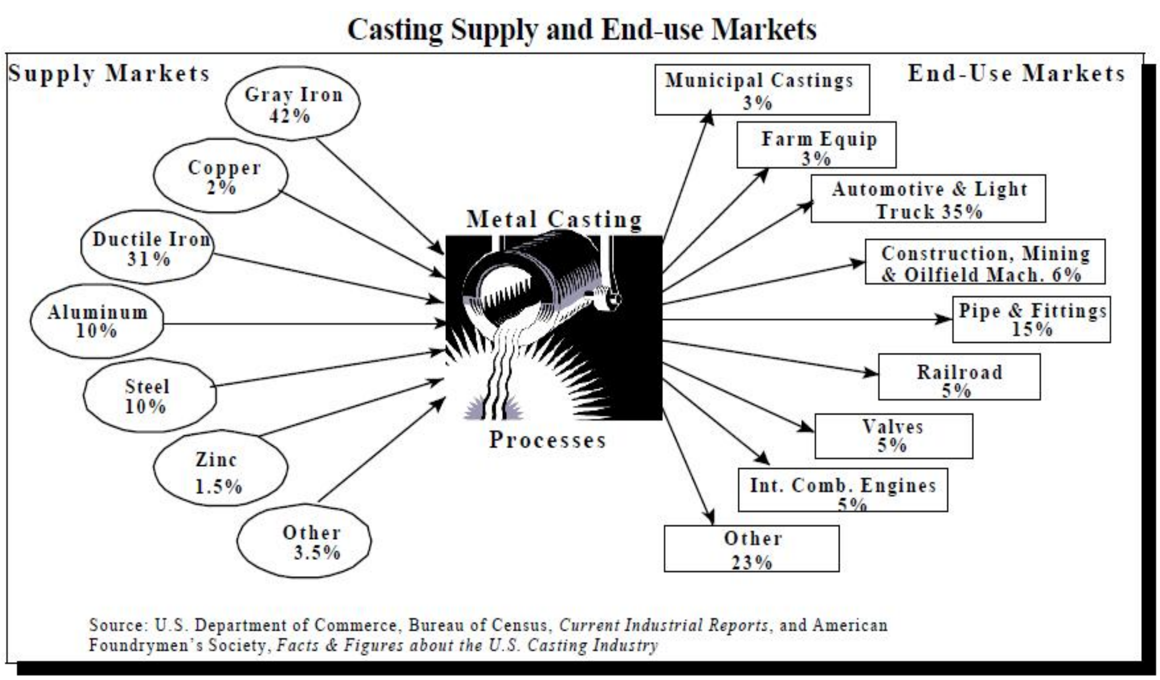

Figure 2.[1]

The metal casting industry is nationwide. There are 3,000 foundries located throughout the U.S. employing 225,000 people. The majority of metal casting facilities are small businesses. Eighty percent of foundries employ less than 100 people. Fourteen percent employ 100 to 250 people and six percent employ more than 250 people. Although the industry is found

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

nationwide, seven states account for nearly 75% of all casting shipments. These include Ohio, Indiana, Wisconsin, Alabama, Michigan, Pennsylvania, and Illinois.[1]

Alternative Processes

Machining, forging, welding, stamping, rolling, and extruding are some of the processes that could be alternatives to casting parts. However, in many situations there are quite a number of advantages to metal-casting processes.

Surely, sometimes conditions may exist where casting processes must have to be replaced by other methods of manufacture, when the alternatives may be more efficient. For example, machining procedures provide for well-finished surfaces and dimensional accuracy not obtainable otherwise; forging may allow developing high fiber strength and toughness in steel, etc. Thus the engineer is typically able to make a selection from a number of metal processing methods that is most suited to the requirements of the project.

Advantages of Metal Casting

There are a number of important advantages in the metal casting process:

- The most complex of external and internal shapes may be cast. As a result, many other operations (e.g. machining, forging, and welding) can be reduced or completely eliminated.
- Because of their physical properties, some metals can only be cast since they cannot be hot-worked into rods, bars, plates, or other shapes from ingot.
- Assembly effort may be reduced, as objects may be cast in a single piece which would otherwise require assembly of a number of parts and fasteners.
- Metal casting is well suitable for mass production, because large numbers of a casting may be produced very rapidly.
- Uncommonly large and massive metal objects may be cast when they would be difficult or even impossible to produce otherwise (e.g. a housing of a power turbine).
- Some mechanical properties are achieved better in castings than in machined parts (e.g. uniformity from a directional standpoint, strength in certain alloys, etc.).

Cast Materials

Cast iron, steel, aluminum, and copper accounted for 92 percent, by value, of metal castings produced in the United States in 2002, with cast iron alone, in its several variations,

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

accounting for about 38 percent; steel for 17 percent; aluminum for 32 percent; and copper for 5 percent.[1]

Iron

Cast iron and steel are alloys of the metallic element iron, but they differ in important ways. Cast iron contains over 2 percent by weight of carbon, and as a result has a lower melting temperature and requires less refining than does steel, which has a typical carbon content of 0.5 percent. Iron castings can therefore be produced with less costly and less specialized equipment than steel castings. Because cast iron shrinks less when solidifying than does steel, it can be cast into more complex shapes; however, iron castings do not have sufficient ductility to be rolled or forged.

Iron is the most commonly cast metal in the foundry industry, being not only relatively less costly to produce than cast steel, but also easily cast, readily machinable, and suitable for a wide range of cast metal products that do not require the superior strength and malleability of steel. The iron foundry industry comprises establishments that produce both rough and machined iron castings. Metal foundries produce molten iron by melting scrap iron, pig iron, and scrap steel in a traditional coke-fired cupola furnace, or in electric-induction or electric-arc furnaces. Molten iron is refined by adding alloying metals into either the furnace or a ladle. It is then moved to a pouring station for pouring into molds. Molten iron is cast by most molding processes, but is less suited for permanent molding and injection molding (die casting) because its high melting temperature increases wear on the casting surfaces of cast-iron permanent molds and steel dies. There are several important types of cast iron, each of which has physical properties that make it suitable for specific applications.

Gray iron.—Gray iron is the most widely cast metal and is easier to cast and less costly to produce than other types of cast iron because it neither requires special alloy additions necessary to produce ductile iron or compacted-graphite iron nor does it require annealing (heat treatment) of the rough castings as is necessary to produce malleable iron. The largest end use for gray iron castings is the motor vehicle industry. Gray iron is ideal for engine blocks because it can be cast into complex shapes at relatively low cost. Gray iron also is preferred for engine blocks because of its high strength-to-weight ratio, ability to withstand high pressures and temperatures, corrosion resistance, and greater wear resistance compared to aluminum. Gray iron is suitable for brake drums and disks because of its dimensional stability under differential heating. It is suitable for internal-combustion engine cylinders because of its low level of surface-friction resistance. It is suitable for gear boxes, differential housings, power-transmission housings, and speed changers in both automotive and non-automotive applications because of its high vibration-dampening capability.

Other casting applications for gray iron include compressor housings for appliances and other equipment; construction castings and fittings (e.g. man-hole covers, storm grates and

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

drains, grating, fire hydrants, lamp posts, etc.); utility meter box covers; soil pipe and fittings; parts for pumps for liquids; and rolls for rolling mills, among other cast products.

Ductile iron.—Ductile iron (also called “nodular iron”) combines many of the engineering qualities of steel with the processing capabilities of iron. To produce ductile iron, magnesium is added to molten iron, which increases the ductility, stiffness, impact resistance, and tensile strength of the resulting castings. Ductile iron also offers flexibility in casting a wide range of sizes, with sections ranging from very thin to very thick. Ductile iron is a growth metal in the casting industry to the point of approaching gray-iron production levels. Ductile iron is primarily used for pipes, tubes, and fittings, and for automotive parts. Pressure pipe and fittings are cast with ductile iron primarily to resist fracturing from ground movement, shocks, and soil corrosion; these products are common in municipal water and sewage systems. For the automotive industry, ductile iron is cast into camshafts and crankshafts for internal-combustion engines. Other end uses for ductile iron castings are bearing housings, machinery components, construction and utility applications, and electric and electronic equipment components.

Malleable iron.—Malleable iron is cast iron with properties similar to those of ductile iron, however, malleable iron castings are produced by a method that requires a lengthy period of annealing in a special furnace to induce characteristics of increased strength, durability, and ductility; ease of machining; and high resistance to atmospheric corrosion. The lengthy annealing period increases the relative cost of producing castings of malleable iron compared to those of gray or ductile irons. In addition, technical requirements limit the thickness of a casting that can practically be produced of malleable iron. Malleable iron use declined, particularly for automotive parts, after widespread adoption of the ductile-iron process in the early 1970s. A major use for malleable iron is pipe fittings, particularly for applications that require resistance to shock and vibration or rapid temperature changes.

Compacted graphite iron.—Compacted graphite iron (CGI) exhibits properties that are intermediate between those of gray and ductile iron, and results from the addition of certain rare-earth elements and titanium to molten iron. Recent growth in CGI use was made possible by the development of advanced sensors and controls for the precise metallurgical additions to molten iron. CGI exhibits unique properties of medium to high strength, good thermal conductivity, low shrinkage, and medium dampening capacity while retaining much of the castability of gray iron to produce complex shapes and intricately cored passages. CGI also provides a better machined finish than gray iron. CGI exhibits slightly higher thermal conductivity, more dampening capacity, and better machinability than is possible with ductile iron. A drawback of CGI castings is the close metallurgical control necessary to obtain successive castings with consistent properties. The largest end use for CGI is internal-combustion engine blocks for both motor vehicles and other applications[1]

Detailed properties of specific cast irons could be found in the appropriate industry standards and references. Just to mention some of them:

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

ASTM A644 - 09a. Standard Terminology Relating to Iron Castings

ASTM A48 / A48M - 03(2012). Standard Specification for Gray Iron Castings

ASTM A126 - 04(2009). Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings

ASTM A159 - 83(2011). Standard Specification for Automotive Gray Iron Castings

ASTM A278 / A278M - 01(2011). Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)

ASTM A319 - 71(2011). Standard Specification for Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts

ASTM A436 - 84(2011). Standard Specification for Austenitic Gray Iron Castings

Steel

Steel castings are produced in a wide range of chemical compositions and physical properties. Steel castings are, in general, of higher strength and ductility than cast iron. Castings of alloy steel have high strength, and those of stainless steel are highly resistant to corrosion.

Steel castings are used extensively in the agricultural, construction, manufacturing, power generation, processing, and transportation industries. Typical products made from steel castings include bridge and building supports, compressors, mechanical components, pumps, tools, and valves. The railway rolling-stock industry is the largest consumer of steel castings in the United States, by volume.

Aluminum Alloys

Cast aluminum and aluminum-based alloys dominate the non-ferrous castings market, accounting for 74 percent ($6.0 billion) of total U.S. non-ferrous casting shipments in 2002. Aluminum-alloy castings contain varying amounts of silicon, copper, magnesium, tin, and zinc.

The strength-to-weight ratio of aluminum is among the highest of all metals, which has enabled lighter weight aluminum to find a niche in almost every segment of the transportation industry—particularly in aerospace where aluminum castings are used for such applications as engine and airframe parts.[1]

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

Detailed properties of specific aluminum alloys could be found in the appropriate industry standards and references. Just to mention some of them:

ASTM B26 / B26M – 12. Standard Specification for Aluminum-Alloy Sand Casting

ASTM B85 / B85M – 10. Standard Specification for Aluminum-Alloy Die Castings

Copper Alloys

Copper castings include those of copper-based alloys, such as brass (copper with zinc as the primary alloying metal) and bronze (a large family of copper alloys with tin, aluminum, manganese, or another metal as the primary alloying metal). Copper castings have high corrosion resistance, good electrical and thermal conductivity (especially pure or near pure copper castings), and good tensile and compressive strength (certain alloys are nearly as strong as many stainless steel alloys), are non-sparking, and exhibit low friction and good wear resistance when in contact with other metals and materials. In addition, they maintain these properties at extremely low temperatures. Copper castings are especially amenable to post-casting operations such as machining, brazing, soldering, polishing, and plating. Typical applications for copper castings include valves that control the flow of liquids and gases; plumbing fixtures such as faucets; power plant water impellers; architectural applications (e.g., door hardware); ship propellers; bearing sleeves; and electrical circuit parts (e.g., circuit breakers).

Detailed properties of specific copper alloys could be found in the appropriate industry standards and references. Just to mention some of them:

ASTM B824 – 11. Standard Specification for General Requirements for Copper Alloy Castings

ASTM B22. Specification for Bronze Castings for Bridges and Turntables

ASTM B61. Specification for Steam or Valve Bronze Castings

ASTM B62. Specification for Composition Bronze or Ounce Metal Castings

ASTM B66. Specification for Bronze Castings for Steam Locomotive Wearing Parts

Casting Methods

Sand Casting

Sand casting is the most common method of metal casting, accounting for approximately 75 percent of all metal cast. It consists of forming a cavity in sand with a pattern, filling the cavity with molten metal, allowing it to cool and solidify, and then releasing the casting by breaking away the sand. Patterns are full size models having the shape of the exterior of the casting to be produced and may be made of wood, brass, aluminum, or other material. The choice of material for a pattern depends on the expected number of times it will be used and the cost of producing it. If the casting has features such as a hollow interior or internal holes, inserts ("cores") are used.

There are two basic types of foundry sand available, green sand (often referred to as molding sand) that uses clay as the binder material, and chemically bonded sand that uses polymers to bind the sand grains together. Foundry sand is typically sub-angular to round in shape.

Green sand consists of 85-95% silica, 0-12% clay, 2-10% carbonaceous additives, such as seacoal, and 2-5% water. Green sand is the most commonly used molding media by foundries. The silica sand is the bulk medium that resists high temperatures while the coating of clay binds the sand together. The water adds plasticity. The carbonaceous additives prevent the "burn-on" or fusing of sand onto the casting surface. Green sands also contain trace chemicals such as MgO, K_2O, and TiO_2.

Chemically bonded sand consists of 93-99% silica and 1-3% chemical binder. Silica sand is thoroughly mixed with the chemicals; a catalyst initiates the reaction that cures and hardens the mass. There are various chemical binder systems used in the foundry industry. The most common chemical binder systems used are phenolic-urethanes, epoxy-resins, furfyl alcohol, and sodium silicates.

In the casting process, molding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as byproduct, new sand is introduced, and the cycle begins again. A schematic of the flow of sands through a typical foundry can be found in Figure 3. [1]

Sand molds, especially for large castings, frequently require special facing sands that will be in contact with the molten metal. Facing sands are specially formulated to minimize thermal expansion and are usually applied manually by the molder.

Mold coatings or washes, are used to obtain better casting finishes. The coating is applied by spraying, brushing, or swabbing to increase the refractory characteristics of the surface by sealing the mold at the sand-metal interface.[2]

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[1] Foundry Sand Facts for Civil Engineers
[2] Recommendations for Control of Occupational Safety

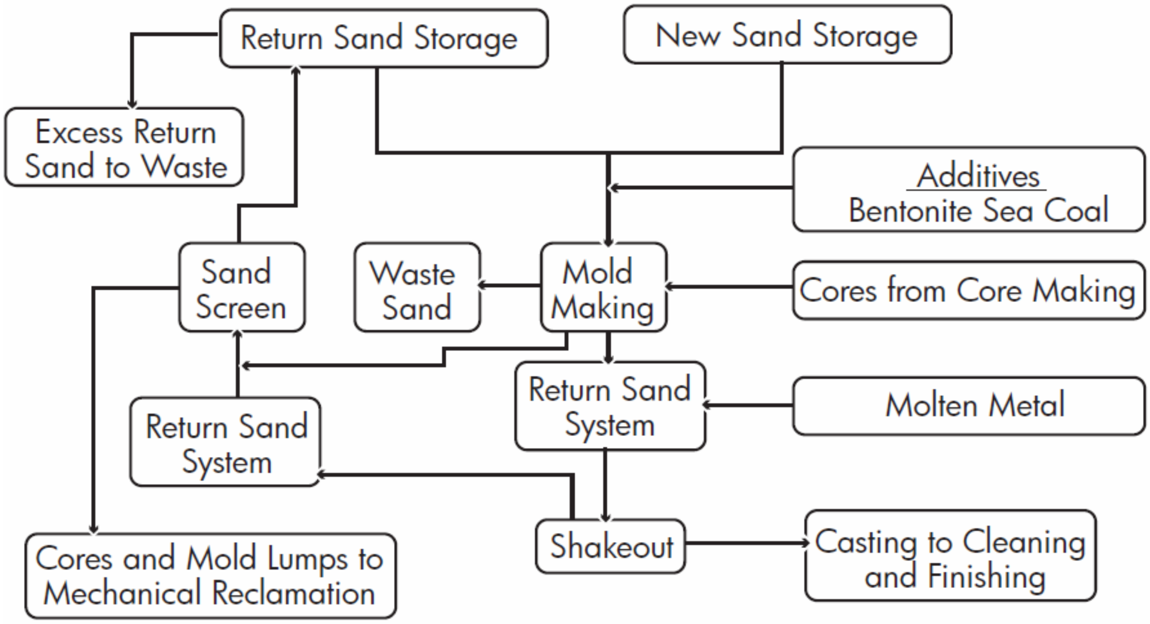

Figure 3. How Sand is Reused[1]

Shell-Mold Casting

Shell-mold casting is a variation of sand casting in which sand containing a resin binder is cured by heat. The pattern is heated and impressed into sand. The sand cures in contact with the hot pattern, after which excess sand is removed, leaving a shell mold. Shell molding castings can be used for any metal, and the process generally produces castings of greater dimensional accuracy at a higher rate of production than standard sand casting. Typical parts produced by shell casting include connecting rods, gear housings, and lever arms.

Investment Casting

Investment casting is a process also known as the “lost-wax” process, or “precision” casting; it is very old and was widely used even in ancient Egypt. The process is suitable only for small castings and is capable of producing castings of very-close dimensional tolerance, with excellent surface finish and detail. Typical parts made by the investment casting process include golf-club heads, orthopedic implants, costume jewelry, dentures, and turbine-engine blades. In this process, an expendable wax pattern is made for each casting to be produced by using a special wax that is melted and injected, under pressure, into a metal mold. The patterns are assembled onto wax pieces that will form runners and channels for molten metal to enter the mold cavity. The wax pattern assembly is dipped into a slurry of a refractory coating material that will produce a uniform coating after drying. The pre-coated assembly is placed in a flask and a fluid aggregate containing an inorganic binder is poured around it. The molds are allowed to air set. After setting, the flasks are heated in an oven, at which time the wax is melted out and may be reclaimed and reused. The heating process

[1] Foundry Sand Facts for Civil Engineers

completely eliminates the wax and gas-forming material from the mold. When the mold is at a suitable temperature, molten metal is poured into the mold. After cooling and solidifying, the mold material is broken away from the castings. The individual castings, each an exact metal replica of the wax pattern, are broken or cut from the central runners, and, because of the precision of the process, often require very little finishing.[1]

Figure 4. Bronze, Investment Casting, Ancient Rome, V-VI B.C.

Lost-Foam Casting

Lost-foam casting is a technique similar to investment casting in that it uses an expendable pattern, one made of polystyrene foam rather than wax. The pattern is coated with a refractory material and then encased with sand, forming a one-piece sand mold. As molten metal is poured into the mold, the foam vaporizes and metal takes its place. This process can produce complex shaped castings without any parting line flash. However, the cost of the expendable patterns adds to the processing cost. Such parts as pump housings, manifolds, and auto brake components may be produced by this method.

Permanent-Mold Casting

The permanent mold process involves the pouring of molten metal into reusable metal molds of a higher melting temperature than the metal being cast. The process is used primarily for nonferrous (e.g., aluminum or copper) castings. The advantage of permanent mold casting is that rather than making a new, expendable mold for each casting, the mold can be used

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

many, often thousands, of times. Shapes and sizes are limited in this method, however, and initial tooling costs are high. The process is economical only for high-volume production. Typical products of this process include gears, splines, wheels, and auto engine pistons.

Centrifugal Casting

Centrifugal casting involves the pouring of molten metal into a rotating cylindrical mold. Centrifugal force causes the metal to flow to the outer wall of the mold, where it is held until it solidifies. Typical products produced by centrifugal casting include cast-iron pipe, propeller shafts and mill rolls. (Cast-iron pipe is one of the most significant applications of metal castings, accounting for about 25 percent, by weight, of all cast-iron production.)

Die Casting

Die-casting is similar to permanent mold casting except that the molten metal is injected into the mold under high pressure, resulting in very uniform parts with good surface finish and dimensional accuracy. Die casting molds, which are called “dies” in the industry, are costly because they are made from hardened steel and often require a long cycle time and technical expertise for their production. Die casting is limited to the nonferrous metals; harder, higher-melting-point metals (e.g., iron and steel) would destroy the dies.

Obtaining the Casting Geometry

The customer or user of a casting is normally responsible for its design. The foundry may provide assistance in the design, through its practical knowledge of casting limitations and requirements, and often through application of computer simulation of metal flow and solidification characteristics.

Pattern Making

Once a design has been received, the casting producer must design and build the necessary tooling to produce the casting. For a sand casting, the tooling consists of dies for any required cores and patterns to make sand molds. The patterns incorporate placement of cores and include shapes forming channels in the mold through which molten metal flows to completely fill every cavity of the finished mold. The size, shape, and location of these channels, called sprues, gates, and risers, are essential parts of the pattern design process. The design process is aided by computer simulation programs that are used to predict the flow of metal in the mold. Separate patterns (these are usually called molds) are manufactured to produce cores. Some casting producers have in-house pattern-making capabilities, while others outsource such services. The production of patterns requires significant capital investment and skilled labor.[1]

[1] Investigation No. 332-460. USITC Publication 3771. May 2005

Figure 5. Preparing Model for Mold Making[1]

Mold Making

The mold-making process is one of the key production steps in a sand foundry, usually occurring in the area where molten metal is poured. The extent of automation of mold making depends upon the size, complexity, and number of castings to be produced. For U.S. and foreign foundries producing high-volume production runs, molding machines are fully automated. These machines feed sand into a flask around a pattern, automatically remove the pattern, position the mold for insertion of cores, close the mold, and convey it to the metal-pouring station.

In the sand-casting-molding process, there are many opportunities for application of automation and robotic technology. Since the production of molds can be very labor-intensive, foundries, especially those in the developed world, invest heavily in mold-making technology to remain competitive, particularly for the production of high-quantity orders, such as those for automotive applications.[1]

[1] OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries

Figure 6. Sand-Clay Mold on Conveyor[1]

[1] Success Story: Harrison Steel.

Core Making

Cores are forms, mostly made of sand or sand-clay mixtures, which are placed into a mold cavity to form the interior voids and surfaces of castings. Most of the techniques used to make a sand mold also apply to making a sand core. The quality of sand-clay mixtures that are used to produce cores normally is better than the quality of standard sand-clay mixtures used to produce molds as they are subjected to higher temperatures and stresses during metal pouring and solidification.

Metal Melting and Pouring

Another key production step is metal melting. The type of melting furnace depends upon the type of metal to be cast and the volume of molten metal required. Raw materials, consisting of scrap, including significant amounts of internal scrap; virgin materials such as pig iron (in iron or steel foundries) or ingot (for copper or aluminum foundries); and alloy materials are placed in a melting furnace. Any necessary refining, such as oxidizing unwanted contaminants in the metallic charge, or dissolving such contaminants through the use of slags, is done in the melting furnace. Molten metal is then poured from the melting furnace into a ladle and moved to a pouring station, where it is poured into molds.

A variety of technologies are available to produce molten metal. Iron foundries often use cupola furnaces, which are fueled with coke, as their primary melting facility. Cupola melting is an old technology, but one that has seen incremental improvements over the years. Cupolas are most suited to high-production, continuous operations. Other iron foundries, as well as steel foundries, choose either electric-arc or electric induction furnaces, which are more suited to batch-type and intermittent operations. Non-ferrous foundries may use electric-induction furnaces and, due to the lower melting temperature of the metals, have additional options in gas- or oil-fired reverberatory (open-flame) furnaces. Typically, a foundry will also use an electrically heated holding furnace to maintain temperature in molten metal, transferring large amounts of molten metal from the melting furnace to the holding furnace, then taking smaller amounts to the pouring location as needed so that a constant pouring temperature can be maintained for all similar castings.

Metal casting is an extremely energy-intensive process. As such, energy expenditures can account for a large portion of the cost of a casting. Foundries take great care in selecting which type of furnace to install for their individual casting needs, since the purchase of a furnace is a long-term commitment that requires a significant capital investment. With increasing energy costs, many foundries have put more effort into mitigating these costs through hedging energy costs in financial markets; utilizing curtailment programs, in which foundries consume the most energy during lower-priced, off-peak hours to reduce energy costs; forming cooperative buying groups to leverage purchasing power to obtain lower energy prices; and self-supplying energy via energy co-generation.[1]

[1] Investigation No. 332-460. USITC Publication 3771. May 2005


Figure 7. Metal Casting in Foundry[1]

[1] OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries

Figure 8. Ductile Iron is Poured into Molds[1]

Shake-out

After the casting has solidified (e.g. in a sand mold), the mold is broken away and the casting is removed. At this point, various cleaning methods, such as shaking or shot blasting, may be used to remove all of the sand or other molding material, including that which was in the cores and the internal parts of the casting. Metal that has solidified in the sprues, gates and risers is broken or cut off of the castings and returned to the melting area for remelt. Sand is recovered and processed for reuse.[2]

[1] Success Story: Harrison Steel.
[2] Investigation No. 332-460. USITC Publication 3771. May 2005

Figure 9. Large Castings Being Removed from Mold[1]

[1] OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries

Figure 10. Castings Being Removed from Molds[1]

Final Processing of Rough Castings

Unwanted protrusions, such as those where the casting was broken away from the gates and risers, and thin flash, where separate parts of the mold abutted, are cut or ground away. After such limited processing, a rough casting is ready for shipment or further processing. If a large number of a single casting is to be produced, the producer may invest in special tooling, e.g., a die, to cut off the flash, thereby automating the process and reducing the direct-labor input while also increasing the uniformity of the rough castings.

[1] Success Story: Harrison Steel.

Figure 11. Grinding Castings[1]

Figure12. Grinding Castings[1]

Machining of Castings

Some castings are used as rough castings and require no further processing. However, many castings are extensively machined or ground. Such machining may include drilling of holes and machining of surfaces to closer dimensional tolerances or smoother surface finish than can be achieved in a rough casting. Some foundries perform these finishing operations in-house while others may outsource the finishing. In many cases, however, rough castings are shipped to customers who perform the finishing operations.

[1] OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries

Figure 13. Machining Castings on Lathe[1]

Figure 14. Machining Castings on CNC[1]

Computer Technology

The greatest technological advances occurring in the castings industry are those associated with electronic computing advances. The application of process control to the industry has revolutionized everything from predictive design to process sensing and control to on-line quality testing. Computers play a major role in reducing the time needed to produce castings and increasing the efficiency with which foundries interact with their customers. An increasing number of customers are sending part geometry to foundries via the exchange of

[1] OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries

computer-aided design (CAD) files, whereas traditionally, casting geometry was obtained from blueprint drawings. Technologies such as rapid prototyping allow foundries to make 3-D models and patterns directly from CAD data, reducing both time and costs, as well as increasing dimensional consistency. Several computer modeling and software design programs predict metal shrinkage, cooling rate, and resulting physical metallurgy properties without the need to cast a test model. These advancements can transform what could have been an 18-month design process that included multiple drawings and mold models into a few weeks, and help reduce the cost of actual pattern-making and molding. Further, new software versions allow users to “tune” the predictive program to actual results, thus allowing the effects of natural process inconsistencies, hindrances, impurities, or other unknowns to be factored in. The installation of sensors and controls linked to computer monitors and analysis tools, which can improve metal casting productivity and quality by continuously monitoring output, is another use of computers in castings facilities. Similar modeling power is enabling cupola production to become predictable. Models that incorporate both the chemistry and physics of the process have allowed average waste rates of cupola melts to decrease by as much as half.

Other Advanced Technologies

An important use of technology in some foundries is x-ray spectrography during the testing phase to determine strengths and weaknesses of castings. Automated machines also are playing an increasing role in performing repetitive tasks, which can reduce the cost of labor.

Another example of advanced technology is the SinterCast process for the production of compacted graphite iron castings. Real-time thermal analysis determines the solidification behavior of each small amount of molten iron to be treated. The results enable the control system to calculate proper addition rates of magnesium and other additives prior to the casting. The key was development of patented thermal analysis Sampling Cups which quickly and automatically determine the required additions, practically eliminating casting process variation, and delivering consistent product.[1]

A recently developed approach to dry-sand molding is the “V Process” which uses unbounded sand with vacuum. The dry-molding sand is made rigid by vacuum packing it on a plastic film during mold production. The plastic film is vacuum formed against the pattern; the flask is positioned and filled with dry unbonded sand and then covered with a plastic film and made rigid by drawing a vacuum through the sand.[2]

Safety and Environmental Concerns

Foundries’ working environment subjects workers to a variety of hazardous conditions, such as extremely high temperatures, chemical additives, and repetitive motion, which can result in harmful, if not lethal, accidents and exposure. Consequently, federal and regional agencies regulate worker health and safety and impose industry standards to protect the labor force. These standards may require the installation of exposure-control technologies

[1] Investigation No. 332-460. USITC Publication 3771. May 2005
[2] Recommendations for Control of Occupational Safety

such as ventilation fans, and require workers to wear full environmental suits or fire-resistant clothing and use air-purifying respirators.[1]

The physically demanding tasks performed during foundry operations may be responsible for the musculoskeletal disorders (MSDs) developed by workers in this industry. Foundry workers have higher MSD injury rates than workers in general industry and construction.

Injuries to the low back and upper limbs are common MSDs among foundry workers. These may arise from doing work repetitively or for prolonged time periods, exerting excessive force to move or grip objects, or using vibrating tools such as chipping hammers and hand-held or rotary grinders. Early symptoms of MSDs include pain, restricted joint movement, soft tissue swelling, numbness, and tingling. MSDs typically develop gradually, over time, as a result of intensive work.

For many foundry operations, the number and severity of MSDs resulting from physical over exertion, as well as their associated costs, can be substantially reduced by applying ergonomic principles. OSHA recommends that employers develop a process to systematically address ergonomic issues in their work environments and incorporate it into their existing safety and health programs. [2]

Respiratory disorders, particularly silicosis, are among the most commonly reported occupational health effects in foundry workers. An increased risk of lung cancer among foundry workers has been shown in a number of studies. Studies of health effects show that in addition to being at risk for developing certain chronic respiratory diseases, foundry workers may be exposed to health hazards which could result in carbon monoxide poisoning, metal fume fever, respiratory tract irritation, dermatitis, and other illnesses. Therefore, the appropriate recommendations for control of occupational safety and health hazard should be closely followed by all employers.[3]

[1] Investigation No. 332-460. USITC Publication 3771. May 2005
[2] OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries
[3] Recommendations for Control of Occupational Safety

List of References

1. Foundry Products - United States International Trade Commission. Investigation No. 332-460. USITC Publication 3771. May 2005

http://www.usitc.gov/publications/332/pub3771.pdf

2. Foundry Sand Facts for Civil Engineers. US Department of Transportation. Federal Highway Administration. First Printing, May 2004 FHWA-IF-04-004

http://isddc.dot.gov/OLPFiles/FHWA/011435.pdf

3. Office of Industrial Technologies. Energy Efficiency and Renewable Energy. U.S. Department of Energy. Metal Casting Industry of the Future. Annual Report 2000. Published in May 2001

http://eelndom1.ee.doe.gov/OIT/oitpdf.nsf/Files/annual2000.pdf/$file/annual2000.pdf

4. OSHA. Solutions for Prevention of Musculoskeletal Injuries in Foundries. OSHA 3465-08 2012

http://www.osha.gov/Publications/osha3465.pdf

5. NIOSH Recommendations for Control of Occupational Safety and Health Hazards. Foundries. US Department of Health and Human Services. September 1985.

http://www.cdc.gov/niosh/docs/85-116/85-116.pdf

6. Success Story: Harrison Steel. US Department of Energy. Energy Efficiency & Renewavle Ennergy/ Industrial Technologies Program

http://www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/harrison_steel_success_story.pdf