Centrifugal Casting

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Centrifugal castings are produced by pouring molten metal into a rotating or spinning mould. The centrifugal force of the rotating mould forces the molten metal against the interior cavity (or cavities) of the mould under constant pressure until the molten metal has solidified. Cylindrical castings are generally preferred for the centrifugal casting process. Tubular castings produced in permanent moulds by centrifugal casting usually have higher yields and higher mechanical properties than castings produced by the static casting process. Centrifugal casting is the most economical method of producing a superior-quality tubular or cylindrical casting with regard to casting yield, cleaning room cost, and mould cost.

All metals that can be cast by static casting can be cast by the centrifugal casting process, including carbon and alloy steels, high-alloy corrosion and heat resistant steels, gray iron, ductile and nodular iron, high-alloy irons, stainless steels, nickel steels, aluminium alloys, copper alloys, magnesium alloys, nickel and cobalt base alloys, and titanium alloys. Nonmetals can also be cast by centrifugal casting, including ceramics, glasses, plastics, and virtually any material that can be made liquid or pourable. Sand moulds, semi-permanent moulds, and permanent moulds can be used for the centrifugal casting process. Selection of the type of mould is determined by the shape of the casting, the degree of quality needed, and the production (number of castings) required.

Centrifugal Casting Processes

There are three types of centrifugal casting:

- True centrifugal casting
- Semicentrifugal casting
- Centrifuge centrifugal casting (Centrifugal assisted)

True centrifugal casting is used to produce cylindrical or tubular castings by spinning the mould about its own axis. The process can be either vertical or horizontal, and the need for a center core is completely eliminated. Castings produced by this method will always have a true cylindrical bore or inside diameter regardless of shape or configuration. The bore of the casting will be straight or tapered, depending on the horizontal or the vertical spinning axis used. Castings produced in metal moulds by this method have true directional cooling or solidification from the outside of the casting toward the axis of rotation. This directional solidification results in the production of high-quality defect-free castings without shrinkage, which is the largest single cause of defective sand castings.

Semicentrifugal casting is used to produce castings with configurations determined entirely by the shape of the mould on all sides, inside and out, by spinning the casting and mould about its own axis. A vertical spinning axis is normally used for this method. Cores may be necessary if the casting is to have hollow sections. Directional solidification is obtained by proper gating, as in static casting. Castings that are difficult to produce statically can often be economically produced by this method, because centrifugal force feeds the molten metal under pressure many times higher than that in static casting. This improves casting yield significantly (85 to 95%), completely fills mould cavities, and results in a high-quality casting free of voids and porosity. Thinner casting sections can be produced with this method than with static casting. Typical castings of this type include gear blanks, pulley sheaves, wheels, impellers, and electric motor rotors.

Centrifuge centrifugal casting has the widest field of application. In this method, the casting cavities are arranged about the center axis of rotation like the spokes of a wheel, thus permitting the production of multiple castings. Centrifugal force provides the necessary pressure on the molten metal in the same manner as in semicentrifugal casting. This casting method is typically used to produce valve bodies and bonnets, plugs, yokes, brackets, and a wide variety of various industrial castings.

Main advantages of centrifugal casting

- Low density non-metallic inclusions and gas bubbles are moved to inner surface of the casting and can be removed with an easy machining process.

- Technique provides quite high casting pressure so feeding ability and soundness of the cast product increase.

- Because of high speed feeding of liquid metal into the mould, casting temperature can be kept low. Thus gas absorption and grain size decrease.

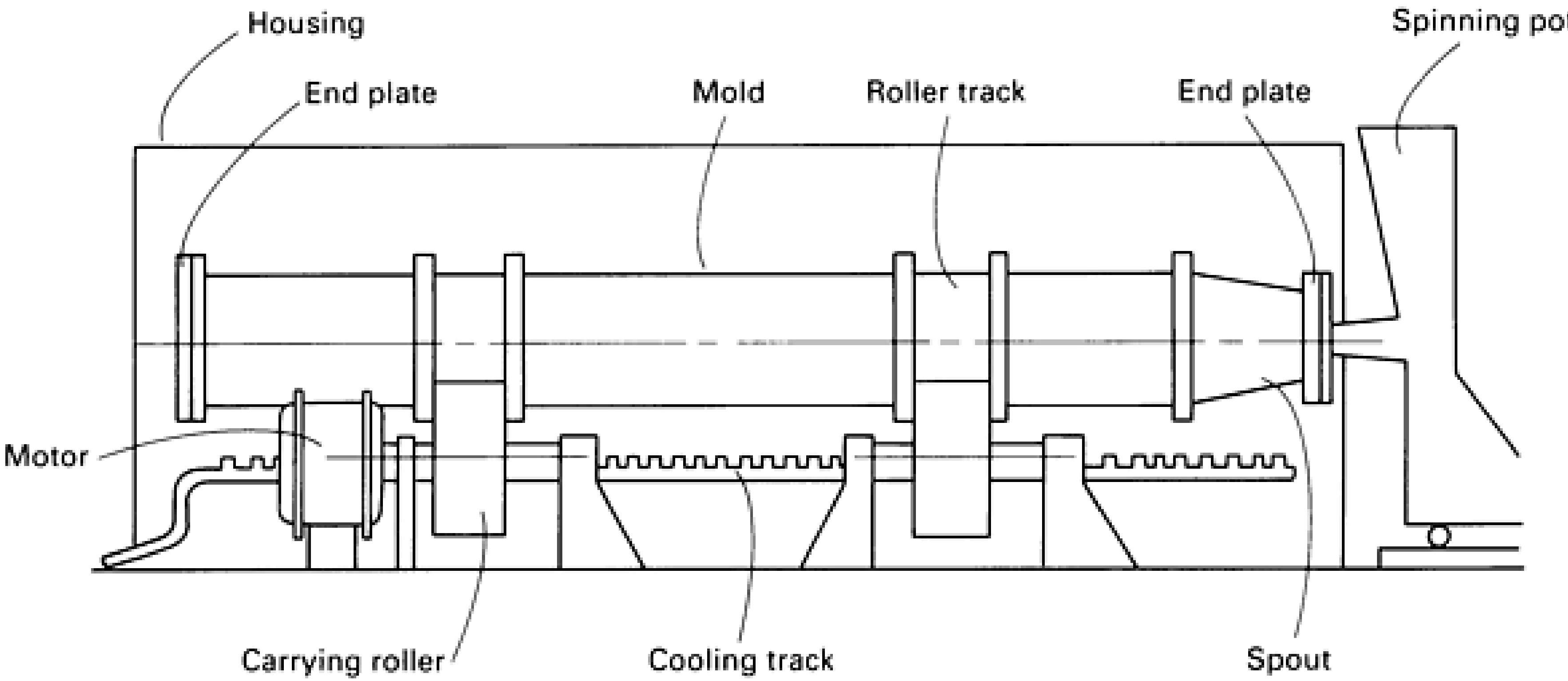
Horizontal Centrifugal Casting

The first patent on a centrifugal casting process was obtained in England in 1809. The first industrial use of the process was in 1848 in Baltimore, when centrifugal casting was used to produce cast iron pipes. In the 1890s, the principles already known and proved for liquids in rotation about an axis were extended to liquid metals, and the mathematical theory of centrifugal casting was developed in the early 1920s.

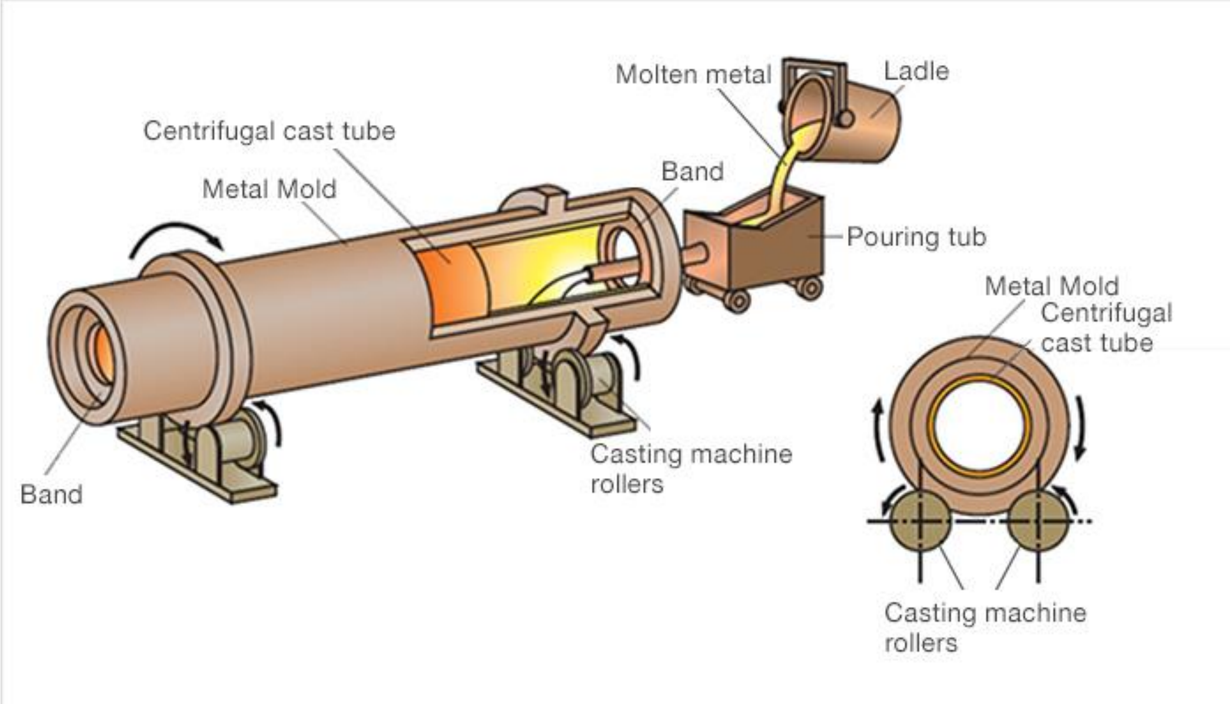
Horizontal centrifugal casting was first used mainly to manufacture thin-wall gray iron, ductile iron, and brass tubes. Improvements in equipment and casting alloys made possible the development of a flexible and reliable process that is both economical and capable of meeting stringent metallurgical and dimensional requirements. Cylindrical pieces produced by horizontal centrifugal casting are now used in many industries. Of particular importance are large-diameter thick-wall bimetallic and specialty steel tubes used in the chemical processing, pulp and paper, steel, and offshore petroleum production industries

A horizontal centrifugal casting machine must be able to perform four operations accurately and with repeatability:

- The mould must rotate at a predetermined speed.
- There must be a means to pour the molten metal into the rotating mould.
- Once the metal is poured, the proper solidification rate must be established in the mould.
- There must be a means of extracting the solidified casting from the mould.



Schematic of a common design for a horizontal centrifugal casting machine


Molten metal
Ladle
Centrifugal cast tube
Band
Metal Mold
Pouring tub
Metal Mold
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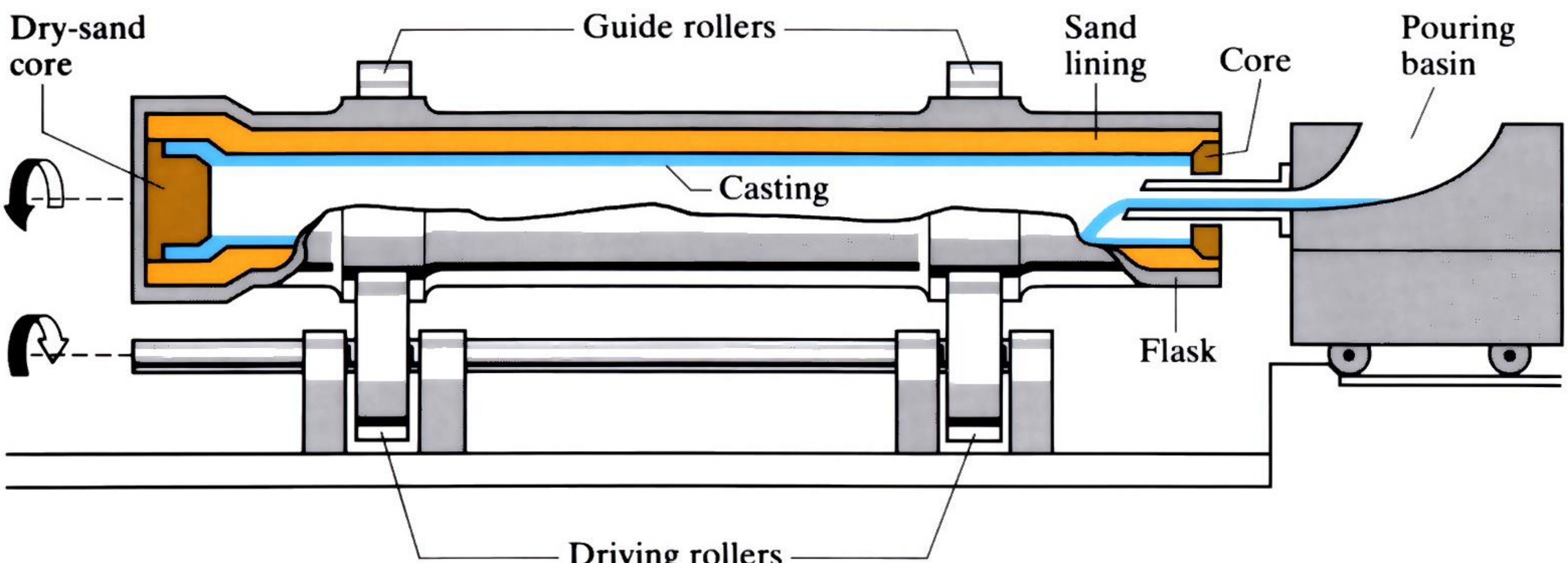

Dry-sand
core
Guide rollers
Sand
lining
Core
Pouring
basin
Casting
Flask
Driving rollers

Moulds consist of four parts: the shell, the casting spout, roller tracks, and end heads. The mould assembly is placed on interchangeable carrying rollers that enable the use of different mould diameters and fine adjustments. Moulds are cooled by a water spray, which can be divided into several streams for selective cooling. Different types of moulds are generally used according to the geometry and quantity of castings needed and the characteristics of the metal or alloy being cast. Moulds can be either expendable (a relatively thin case lined with sand) or permanent.

Expendable moulds lined with sand are widely used in centrifugal casting, especially for producing relatively few castings. A single mould case can be used with different thicknesses of sand linings to produce tubes of various diameters within a limited range.

Permanent moulds. The most common materials for permanent moulds are steel, copper, and graphite.

Pouring. Molten metal can be introduced into the mould at one end, at both ends, or through a channel of variable length. Pouring rates vary widely according to the size of the casting being produced and the metal being poured. For example, a pouring rate of 1.1 to 2.2 tons/min has been used to cast low-alloy steel tubes 5 m long and 500 mm in outside diameter with 50 mm thick walls. Pouring rates that are too slow can result in the formation of laps and gas porosity, while excessively high rates slow solidification and are one of the main causes of longitudinal cracking.

Casting Temperatures. The degree of superheat required to produce a casting is a function of the metal or alloy being poured, mould size, and physical properties of the mould material. The following empirical formula has been suggested as a general guideline to determine the degree of superheat needed:

$$L = 2.4\Delta T + 110$$

where L is the length of spiral fluidity (in mm) and ΔT is the degree of superheat (in degrees centigrade). The use of this equation for ferrous alloys results in casting temperatures that are 50 to 100 °C above the liquidus temperature. In practice, casting temperatures are kept as low as possible without the formation of defects resulting from too low a temperature.

A high casting temperature requires higher speeds of rotation to avoid sliding; low casting temperatures can cause laps and gas porosity. Casting temperature also influences solidification rates and therefore affects the amount of segregation that takes place.

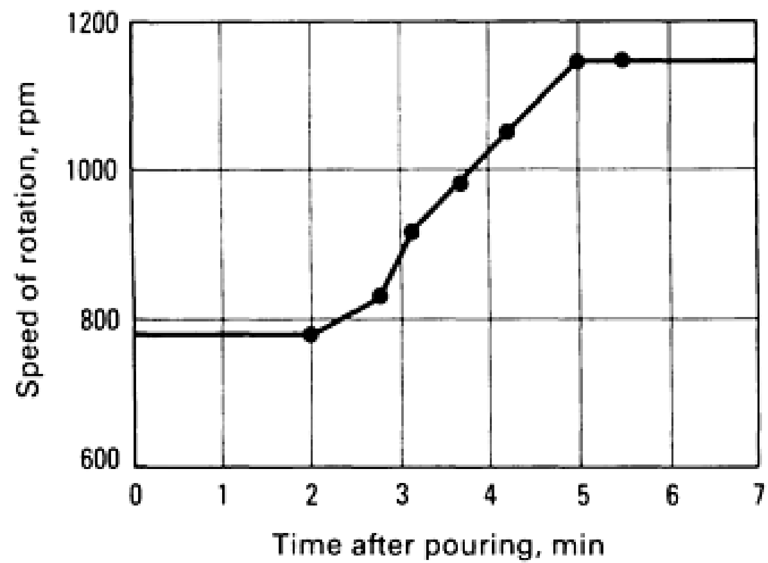
Mould Temperature. Numerous investigators have studied the relationship between initial mould temperature and the structure of the resultant casting. Initial mould temperatures vary over a wide range according to the metal being cast, the mould thickness, and the wall thickness of the tube being cast. Initial mould temperature does not affect the structure of the resultant casting as greatly as the process parameters discussed above do.

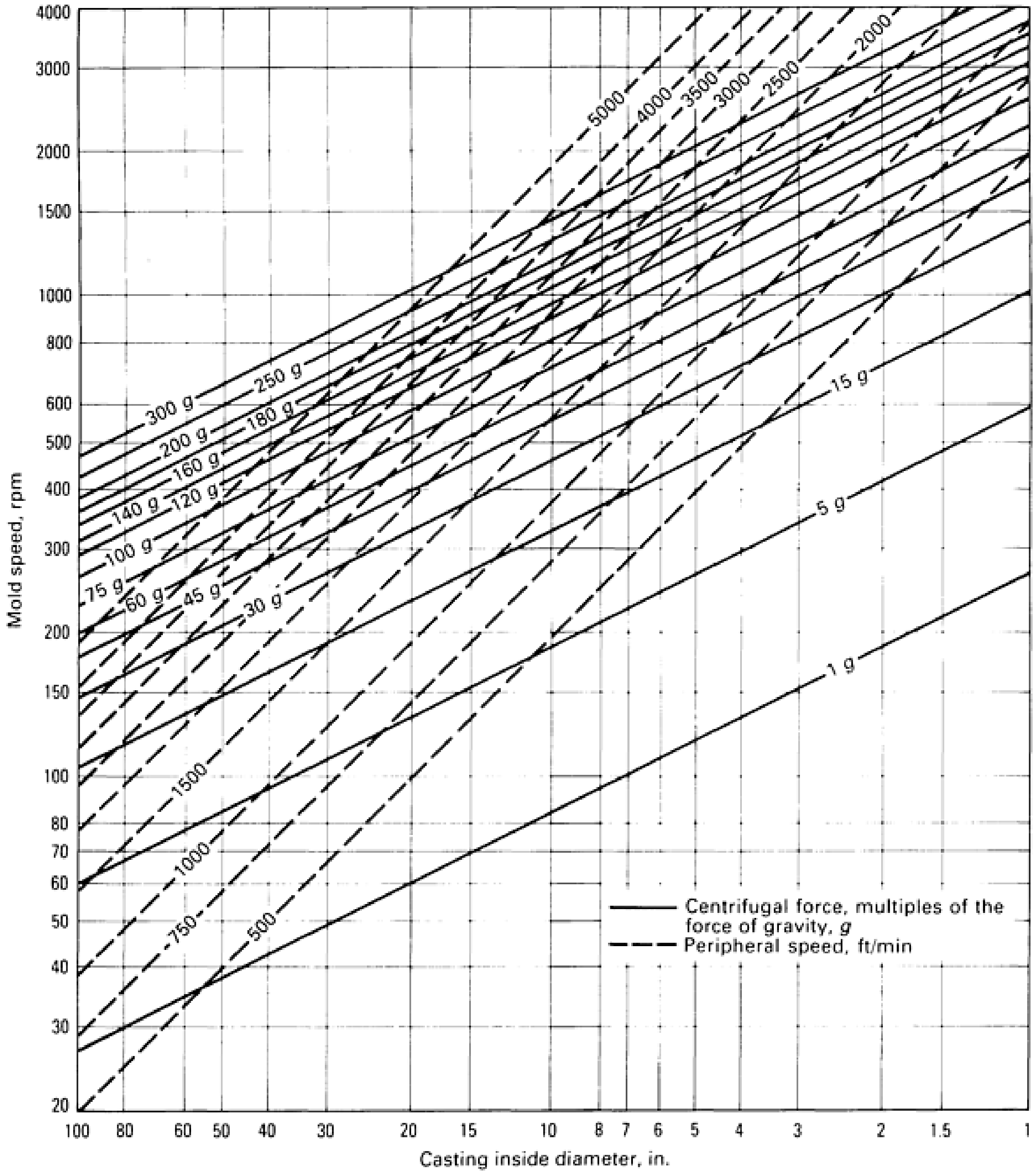
Speed of Rotation. Generally, the mould is rotated at a speed that creates a centrifugal force ranging from 75 to 120 G (75 to 120 times the force of gravity). Speed of rotation is varied during the casting process.

Cycle of rotation. The cycle can be divided into three parts:

- At the time of pouring, the mould is rotating at a speed sufficient to throw the molten metal against the mould wall.
- As the metal reaches the opposite end of the mould, the speed of rotation is increased.
- Speed of rotation is held constant for a time after pouring; the time at constant speed varies with mould type, metal being cast, and required wall thickness.

The ideal speed of rotation causes rapid adhesion of the molten metal to the mould wall with minimal vibration. Such conditions tend to result in a casting with a uniform structure. Too low a speed of rotation can cause sliding and result in poor surface finish. Too high a speed of rotation can generate vibrations, which can result in circumferential segregation. Very high speeds of rotation may give rise to circumferential stresses high enough to cause radial cleavage or circular cracks when the metal shrinks during solidification.





Nomograph for determining mould speed based on the inside diameter of the casting and the required centrifugal force. See text for example of use.

Mould Speed Curves. Mould speeds are determined by the inside diameter of the castings to be made. The mould speed curve shown in nomograph is based on the inside diameter of the casting. The length of the casting is not considered in determining mould speed.

For example, the mould speed for producing a casting 100 mm (4 in.) in outside diameter by 75 mm (3 in.) in inside diameter at a centrifugal force of 60g is calculated as follows. Find the 3 in. diameter at the bottom of the curve. Move vertically from this point until the 3 in. line intersects the diagonal line marked 60g. From this intersection, move directly to the right-hand edge of the curve; the speed of rotation of the mould in this case should be 1150 rpm.

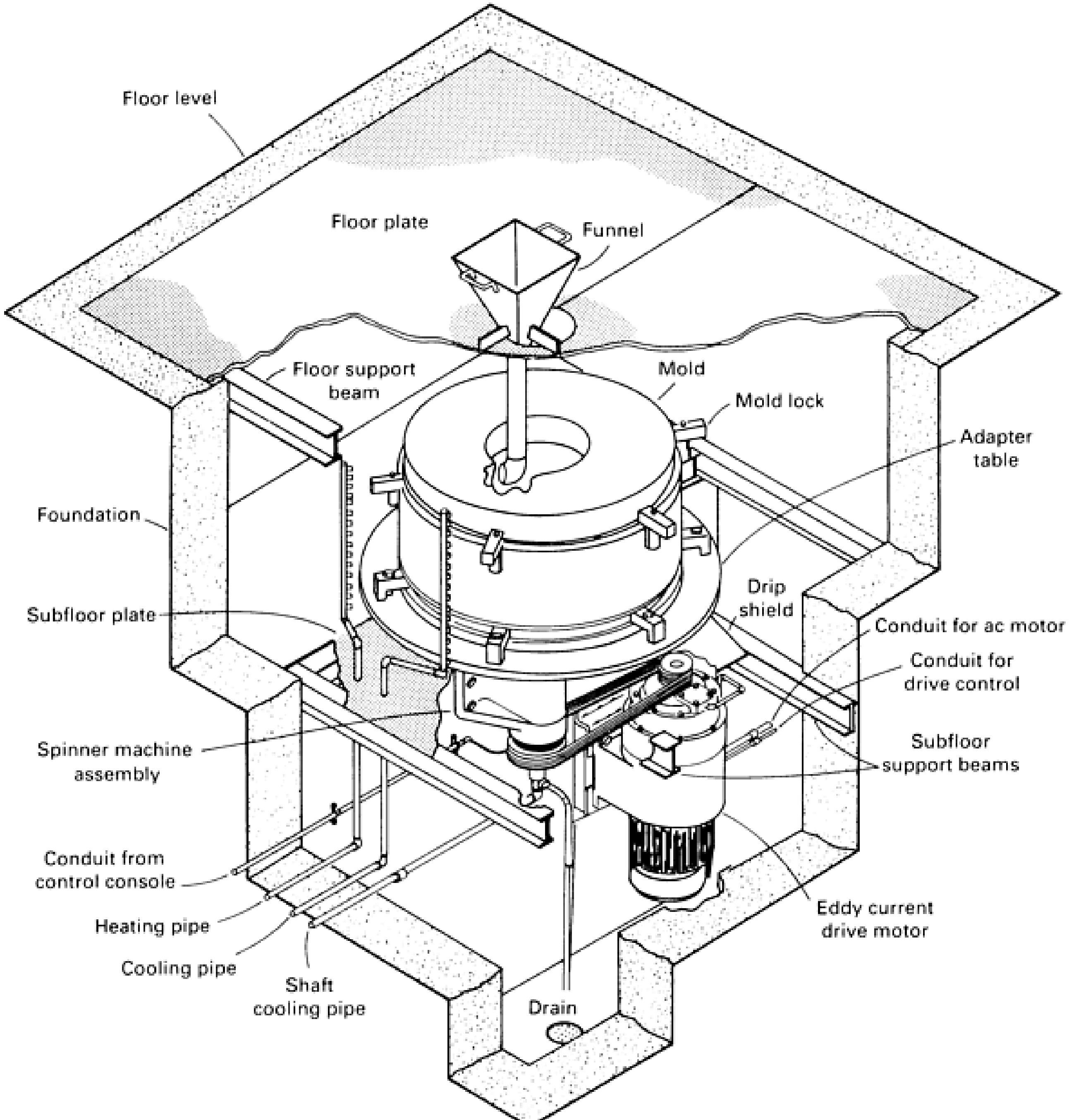
Bimetallic tubes with metallurgical (rather than mechanical) bonds can be readily produced by horizontal centrifugal casting. They are most commonly produced by successively casting one alloy inside the other. Bimetallic tubes are used for two primary reasons: to reduce cost by using an exotic material bonded to a less expensive backing material, and to obtain combinations of properties that could not be achieved by other methods. There are no general rules regarding what materials can be combined in centrifugally cast bimetallic tubes, although it may be beneficial to cast the inner layer of such tubes from a material that is more fusible than the outer material. In addition, relatively thin inner layers should be manufactured from alloys with coefficients of thermal expansion smaller than that of the outer alloy. In this way, the thin inner layer is put into compression, making it more resistant to cracking.

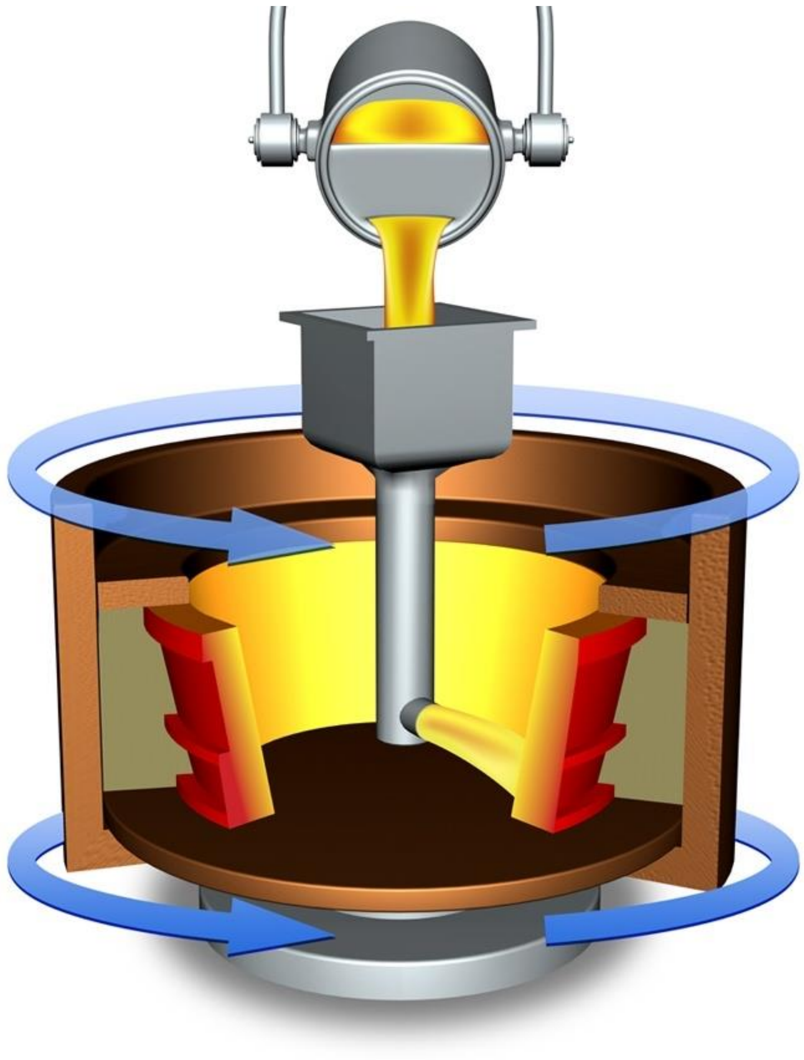
Common material combinations used in bimetallic centrifugally cast tubes

Outer material	Inner material	Typical applications
Chilled iron	Gray iron	Bearing rollers
27% Cr cast iron	Ni-Resist cast iron	Mill rollers
Low-alloy steel	Manganese-molybdenum steel	Continuous casting rollers
Low-alloy steel	Ni-Hard cast iron, martensitic or 27% Cr white iron	Wear-resistant applications
Chromium-nickel white iron	Gray ductile iron	Mill rollers
Chromium white iron	Gray iron	Mill rollers
Stainless steel	Gray iron	Rollers for pulp and paper industry
Low-alloy steel	Pearlitic gray iron, stainless steel, or superalloy	Liners, pipelines for corrosives

Vertical Centrifugal Casting

The range of application of vertical centrifugal casting machines is considerably wider. Castings that are not cylindrical, or even symmetrical, can be made using vertical centrifugal casting. The centrifugal casting process uses rotating moulds to feed molten metal uniformly into the mould cavity. Directional solidification provides for clean, dense castings with physical properties that are often superior to those of the static casting processes.


Floor level
Floor plate
Funnel
Floor support beam
Mold
Mold lock
Adapter table
Foundation
Drip shield
Subfloor plate
Conduit for ac motor
Conduit for drive control
Spinner machine assembly
Subfloor support beams
Conduit from control console
Heating pipe
Cooling pipe
Shaft cooling pipe
Drain
Eddy current drive motor



Vertical centrifugal casting machines are used for producing bushings and castings that are relatively large in diameter and short in length. The usual maximum length of the casting is two times the outside diameter of the casting. Vertical axis machines are also used for producing castings of odd or asymmetrical configurations.

Video links

- https://www.youtube.com/watch?v=NIPM2pnL9bQ
- https://www.youtube.com/watch?v=o4vkUHb91H0
- https://www.youtube.com/watch?v=ZxVA-htTunU
- https://www.youtube.com/watch?v=s4jdBOKiF_w
- https://www.youtube.com/watch?v=iUjOhtXCoro
- https://www.youtube.com/watch?v=OSNft6xyurc
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- https://www.youtube.com/watch?v=idKWzhL494M