Advanced Manufacturing Processes

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Module - 2
Advanced Metal Casting Processes
Lecture - 3
Continuous, Permanent mold, Centrifugal and Pressure Die Casting

Welcome to this session on advanced casting processes under the course advanced manufacturing processes. In this session we will study few advanced casting techniques mainly on the following processes.

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Continuous casting process, permanent mould casting process, centrifugal casting process and pressure die casting process. In the previous lecture we have discussed a process mainly evaporative pattern casting process.

In evaporative pattern casting process also called a binder less casting process, no binders are used. Now, let us move on to this few casting processes which are being used in the recent past.

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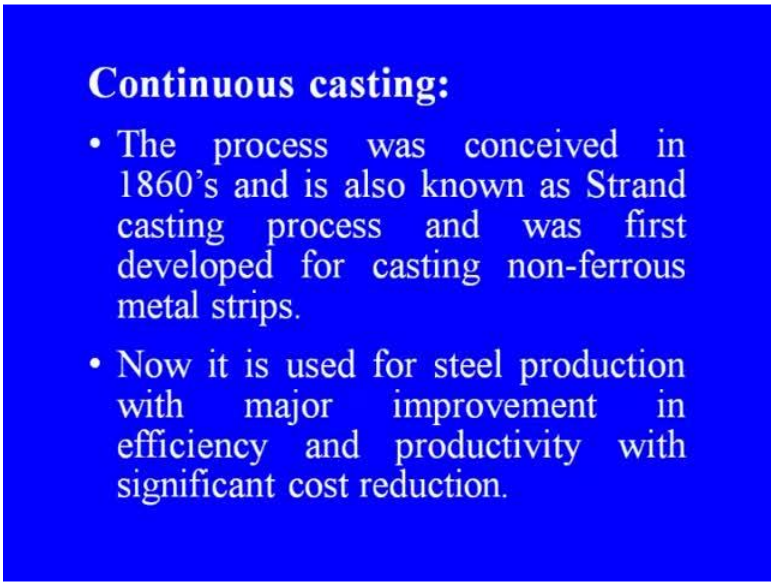

First of all let us discuss the continuous casting process. This process was conceived in 1860 and is also known as strand casting process. It was first developed for casting of non ferrous metal strips.

Now, it is used for steel production with major improvement in efficiency and productivity with significant cost reduction. It is a process used to produce billets, blooms or slabs much longer in lengths than obtained by any other process. In this process the molten metal gets gradually solidified as it is poured. The sections obtained are then subsequently rolled in a rolling mills.

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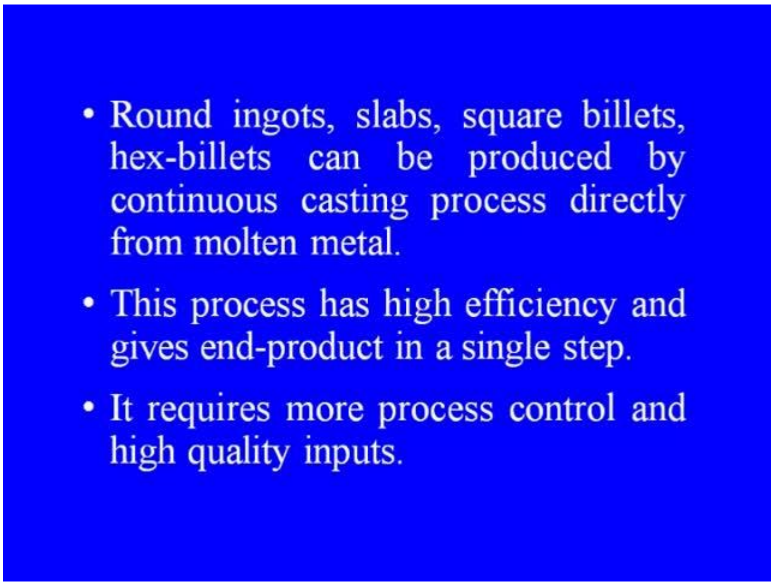

Round ingots, slabs, square billets, hex billets can be produced by continuous casting process directly from molten metal. This process has high efficiency and gives end product in a single step. It requires more process control and high quality inputs. In this process molten metal is transferred from a holding furnace into a special label called tundish. Molten metal from the tundish is poured into the top of the bottomless graphite mould of desired shape.

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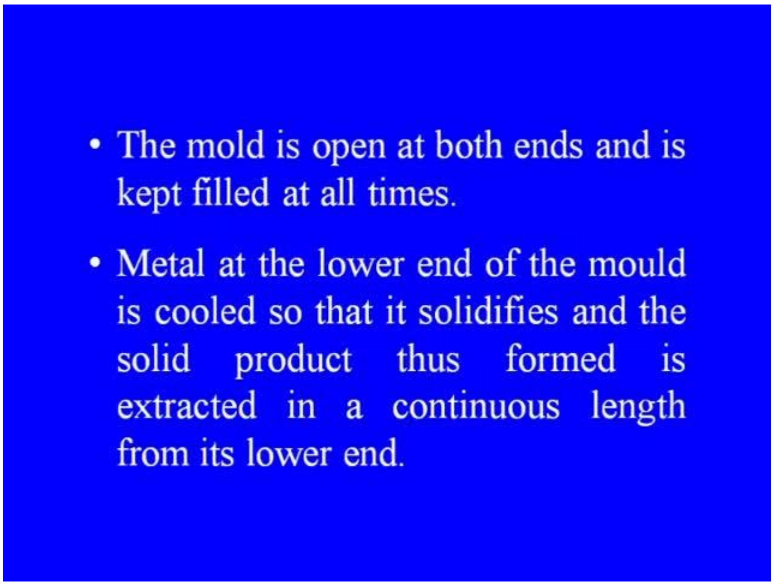

The mould is open at both ends and is kept filled at all times. Metal at the lower end of the mould is cooled so that it solidifies and the solid product thus formed is extracted in a continuous length from its lower end.

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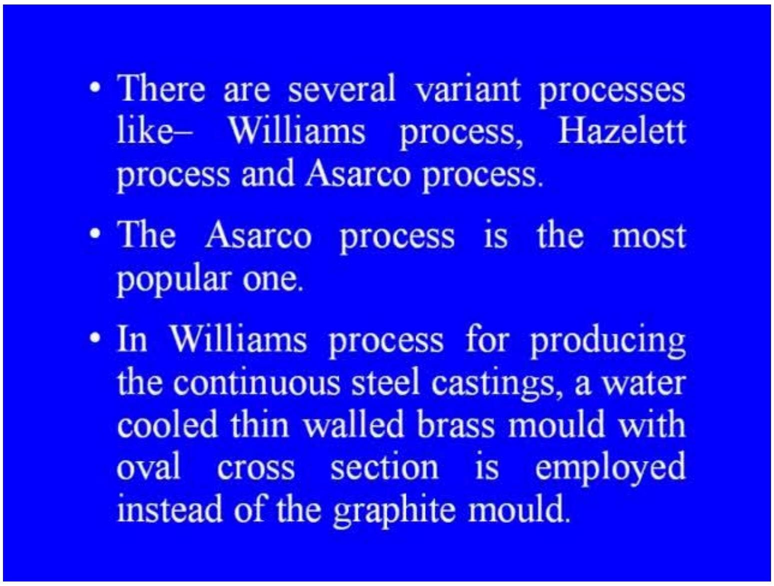

There are several variant processes like Williams process, Hazelett process and Asarco process. The Asarco process is the most popular one. In Williams process for producing the continuous steel castings a water cooled thin walled brass mould with oval cross section is employed instead of the graphite mould.

The more popular variants are the vertical type and the horizontal type wherein the obtained casting is bent by the rollers. This is also shown in figure one. The horizontal process on the other hand provides greater flexibility and larger lengths.

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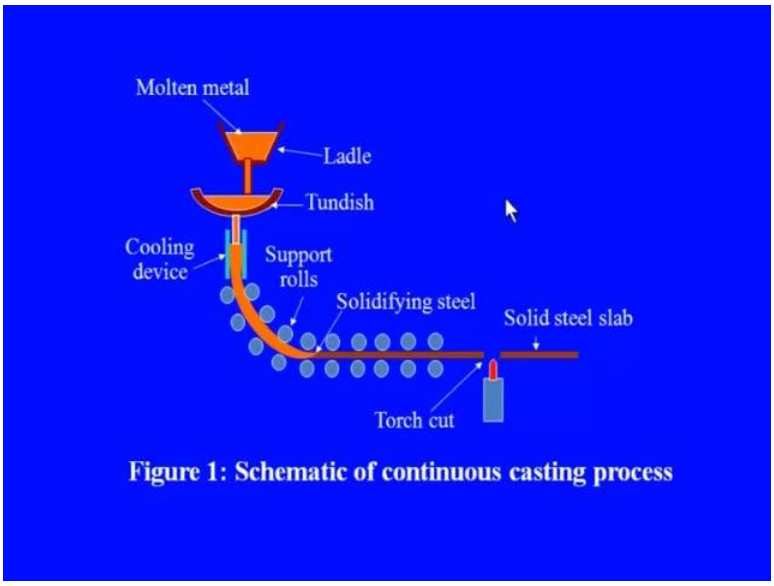

Figure 1: Schematic of continuous casting process

This is a common schematic of representing the continuous casting process. This is the tundish which receives molten metal through the ladle where molten metal is poured. The molten metal is then carried through this where a series of roll, rollers support the molten metal coming out through this which will be simultaneously getting solidified upon some special cooling arrangement. The metal in the meanwhile will get solidified and there will be an arrangement for separating the pieces in a required length.

This device for separating the cast material will be appropriately placed as per the design requirements of the pieces. There is length restriction for a vertical process as controlling the continuously incoming metal is difficult and consequently deep underground arrangements are needed. Let us see the process requirements for continuous casting process.

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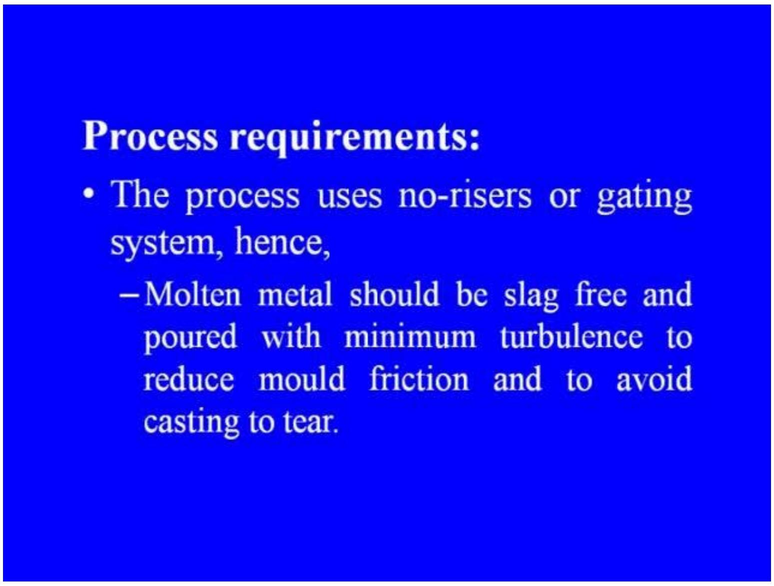

The process uses no risers or gating systems. Hence, molten metal should be slag free and poured with minimum turbulence to avoid, reduce mould friction and to avoid casting to tear. The process is started by placing a dummy bar in the mould upon which the first liquid metal falls. The liquid metal gets cooled and is pulled by the pins rolls along with the dummy bar.

The schematic of the bent horizontal process is shown in the figure one. This is the bar upon which the molten material are being allowed to get solidified, and then finally guided towards the cutting zone. Shrinkage effect provides a very small gap between the metal. And the mould thereby reducing friction between the two and permitting cast safe to move continuously through the mould. Pings and guide rolls regulate the rate of settling cast safe and proper alignment.

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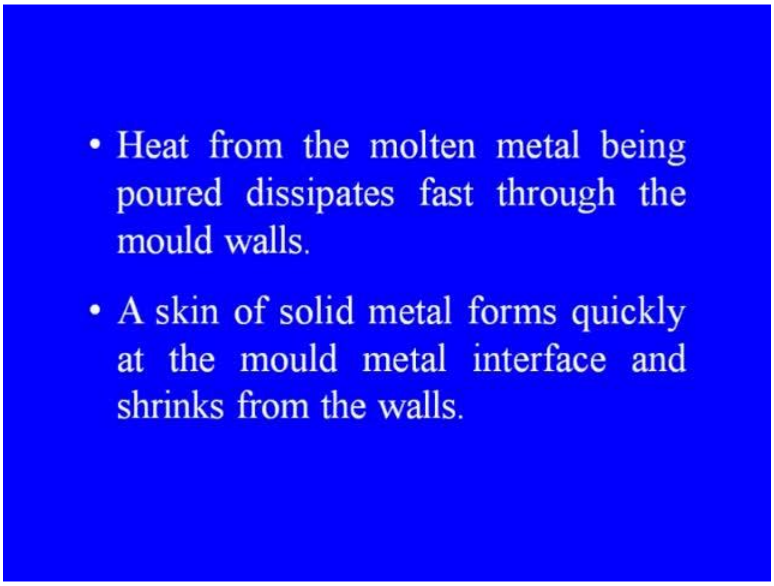

Heat from the molten metal being poured dissipates fast through the mould walls. A skin of solid metal forms quickly at the mould metal interface and shrinks from the walls.

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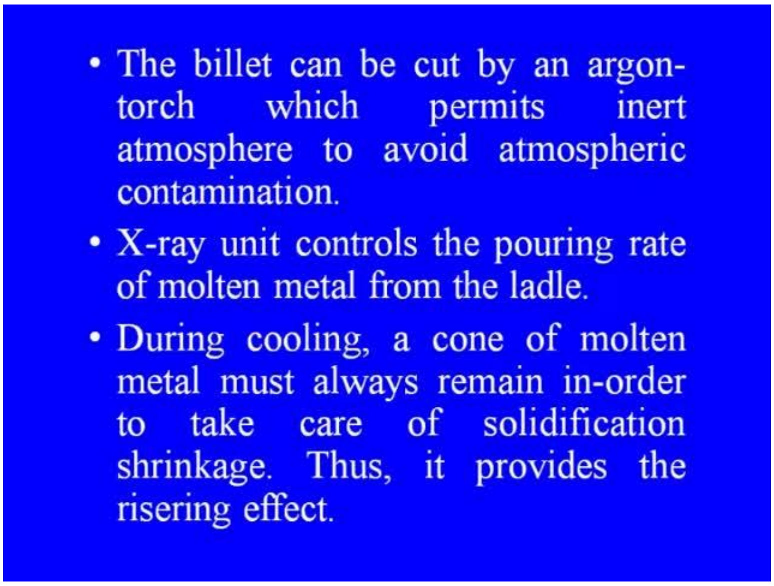

The billet can be cut by an argon torch which permits inert atmosphere to avoid atmospheric contamination. The X ray unit controls the pouring rate of molten metal from the ladle. During cooling a cone of molten metal must always remain in order to take care of solidification shrinkage. Thus, it provides the risering effect. Heat extraction is done through water feeding mechanisms so that directional solidification is promoted.

The rate at which the heat from the molten metal is removed must be synchronised. Now, let us see the advantages of the continuous casting process.

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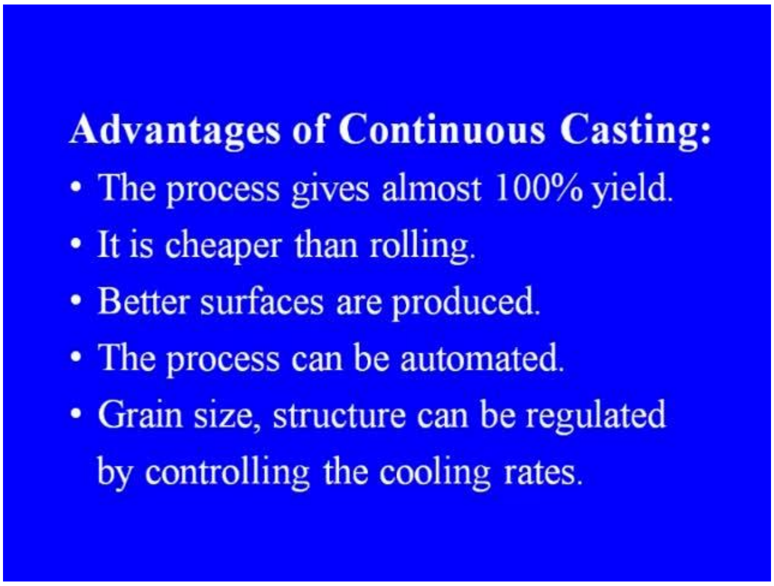

First of all the continuous casting process gives almost 100 percent yield. The process is cheaper than rolling, better surfaces can be produced in these process. The process can also be automated. The grain size, the grain structure can be regulated by controlling the cooling rates. Let us see the applications of the process.

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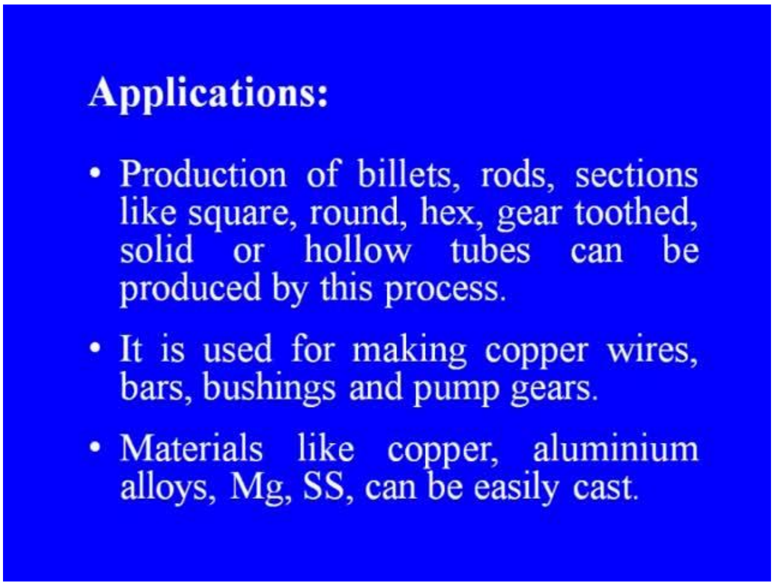

The continuous casting process can be used for production of billets, rods, sections like square, round, hex, gear toothed, solid or hollow tubes etcetera. The process can also be used for making copper wires, bars, bushings and pump gears. Materials like copper, aluminium alloys, magnesium, stainless steel can also be easily cast using this continuous casting process. Some of the products made by continuous casting process are like this.

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These are further cut into required shapes or size by gas cutters or power saws or band saws. Continuous casting in brief, in short the continuous casting process gives a continued casting output as long as we keep feeding the defect free pure metal at the inlet. The yield of the process is very high. Let us now move on to another process called permanent mould casting.

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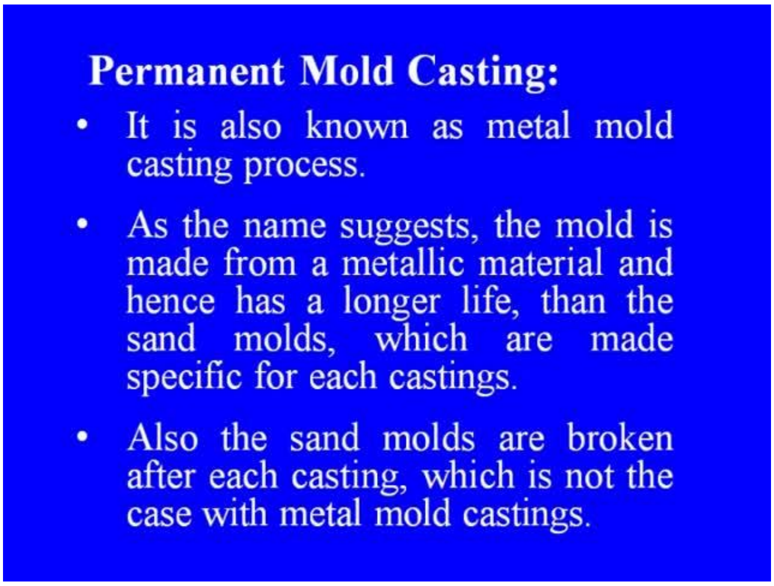

The permanent mould casting is also known as metal mould casting process. As the name suggest the mould is made from a metallic material and hence has a longer life than the sand moulds which are made specific for its castings. Also, the sand moulds are broken after each casting which is not the case with metal mould castings. More number of castings can be taken out successively from the same moulds therefore, increasing the productivity. Unlike sand moulds the finish here is much better and fine.

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The metallic moulds may be one piece or made of split pattern depending on the requirement. Typically cast iron or meehanite is used as the mould material and the cores are made from metal or sand. The cavity surfaces are coated with a thin layer of heat resistant material such as clay or sodium silicate.

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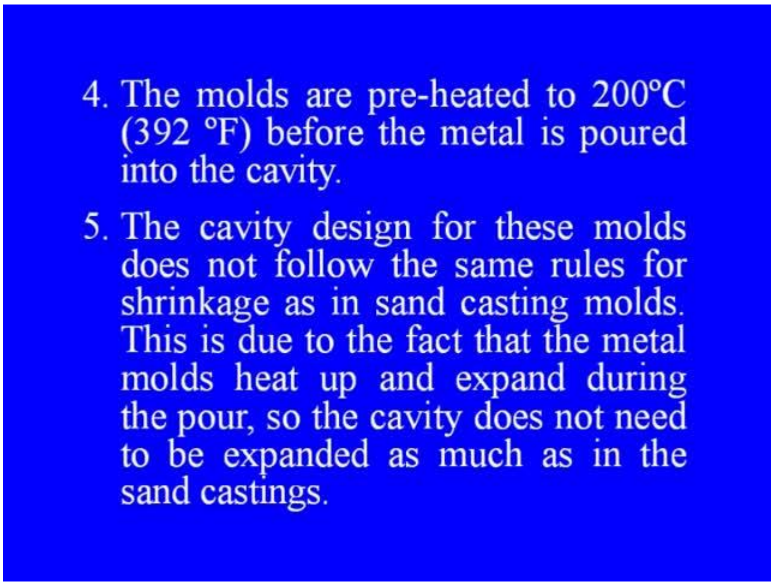

The moulds are usually pre heated to around 200 degree Celsius before the metal is poured into the cavity. The cavity design for these moulds does not follow the same rules for shrinkage as in sand casting moulds. This is due to the fact that the metal moulds heat up and expand during the pour. So, the cavity does not need to be expanded as much as in the sand castings.

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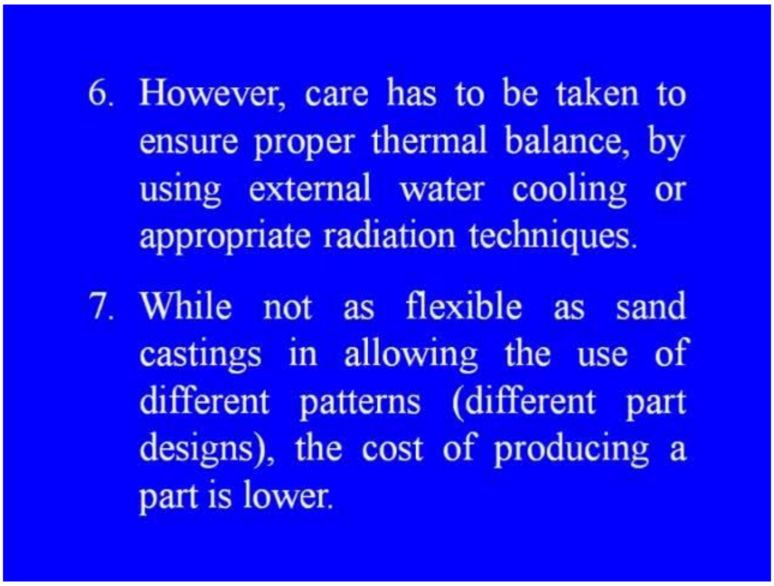

However, care has to be taken to ensure proper thermal balance by using external water cooling or appropriate radiation techniques. While not as flexible as sand casting in allowing the use of different patterns, the cost of producing a part using this process is much lower.

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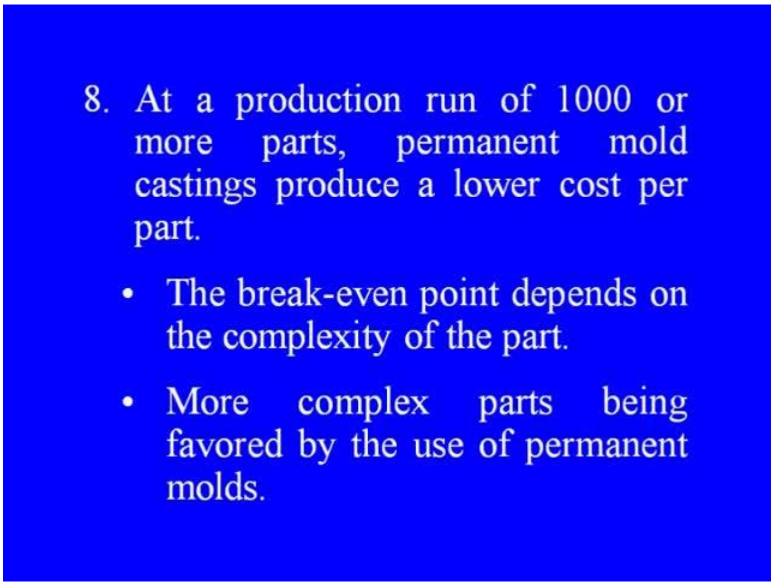

At a production run of 1000 or more parts permanent mould castings produce a lower cost per part. The breakeven point depends on the complexity of the part. The more complex parts being favoured by the use of permanent moulds.

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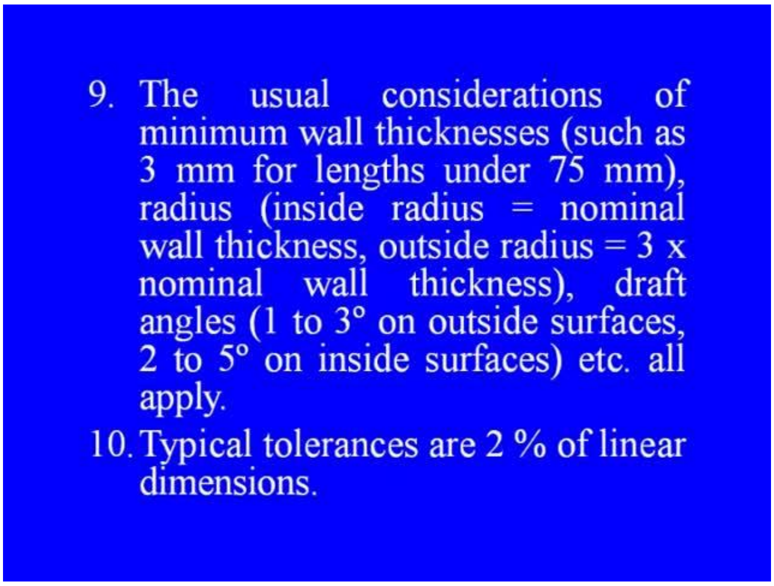

The usual considerations of minimum wall thickness such as 3 millimetre for lengths under 75 millimetre, radius, wall thickness, outside radius which is three times the wall thickness, draft angles which is 1 to 3 degrees on outside surfaces and the 2 to 5 degrees on inside surfaces etcetera. All apply. The tolerances are 2 percent of linear dimensions.

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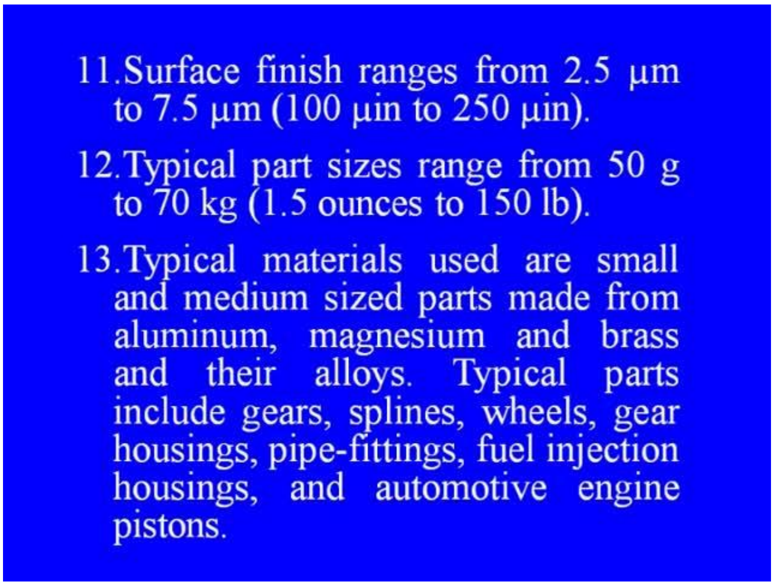

Surface finish ranges from 2.5 micro meters to 7.5 micro meters. Typical part sizes range from 50 gram to 70 kilogram. Typical materials used are small and medium sized parts made from aluminium, magnesium and brass and their alloys. Typical parts include gears, splines, wheels, gear housings, pipe fittings, fuel injection housings and automotive engine pistons. Now, let us see what are the requirements of metal mould process?

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The metal or alloy to be cast by this casting process should possess the following properties. Number one low pouring temperature, number two adequate hot strength to avoid hot tearing problems, number three good fluidity for filling cavities, number four commonly used alloys are aluminium, magnesium, zinc, lead, copper and cast iron. Now, let us see what are the advantages of this particular process? First of all closer dimensional tolerances and accuracy, then smooth surfaces can be obtained, next metal cores can be used to produce holes and the process is good for mass production.

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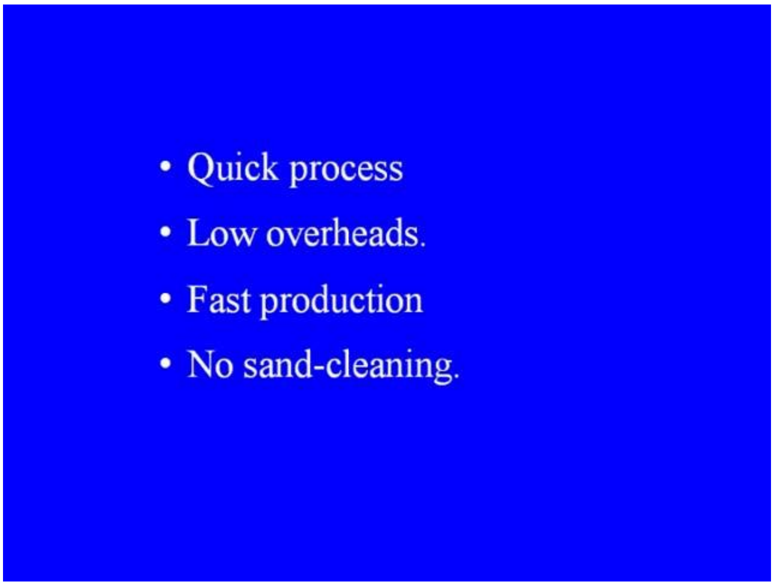

Also the process is known as a quick process which has low overheads and yields fast production with no sand cleaning. Now, let us see the other sides of this process too that is the disadvantages of the process.

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The first and for most consideration is the process has high initial cost. The pattern design needs to be final in all respects and does not have the possibility for changes as can be done with sand moulds. In sand moulds manual mould cutting and minor changes are still possible. Unconventional, for smaller production runs. Chilling effect exists which may lead to non uniform cooling and defects.

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In this figure some of the product examples of permanent mould casting process are shown. Permanent mould casting is similar to sand casting except the sand mould is replaced by an accurate metallic mould. Casting finish and accuracy is generally higher. Process has higher productivity than sand casting. Now, let us move on to another casting process also known as centrifugal casting.

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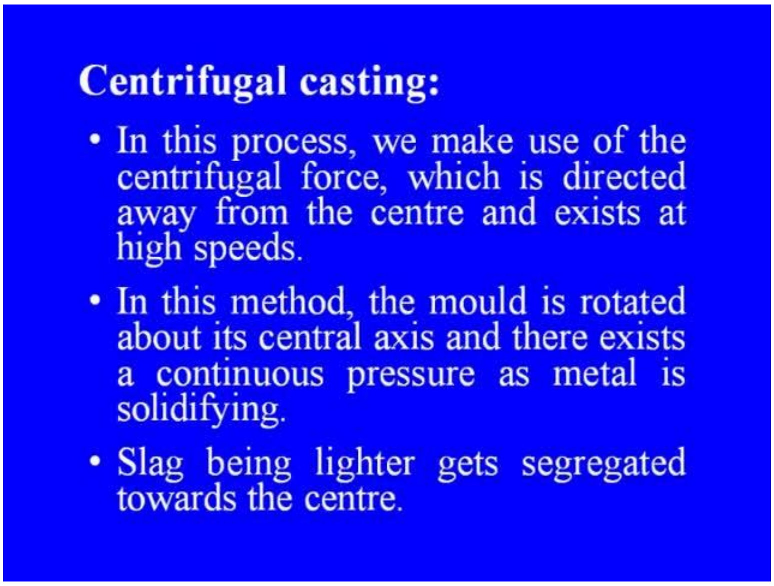

Centrifugal casting is a popular process. In this process we make use of the centrifugal force which is directed away from the centre and exists at high speeds. In this method the mould is rotated about its central axis and there exists a continuous pressure as metal is solidifying, slag being lighter gets segregated towards the centre.

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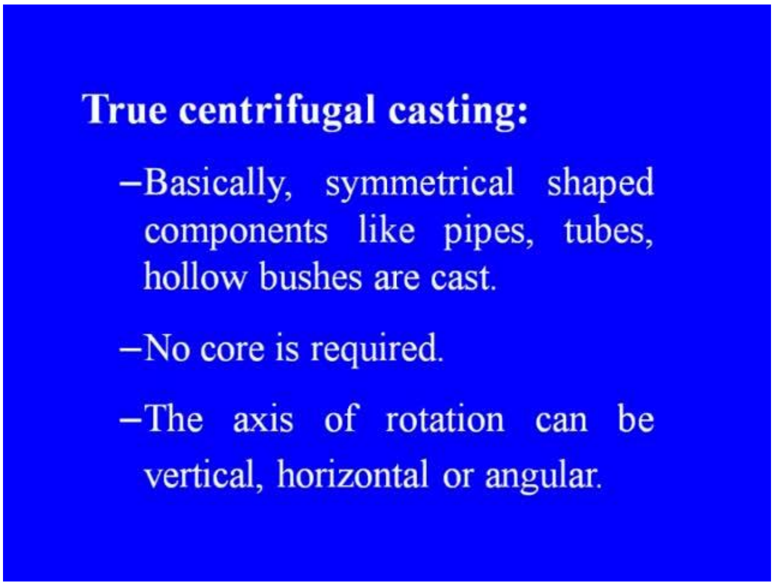

True commercial casting, basically, symmetrical shaped components like pipes, tubes hollow bushes are cast. In these products no core is required. The axis of rotation can be vertical, horizontal or angular. The mould flask is rammed with as is outer contour. To get shapes at ends sand cores such as (( )) shapes are placed. Flask is dynamically balanced to reduce vibrations.

This is mounted on rollers and rotated slowly. As the molten metal is fed from a movable pouring machine, the amount of metal determines casting thickness. Water jacket can also be provided for cooling. Casting is rotated till the pipe is fully solidified. Now, let us see the distinct advantages of this process.

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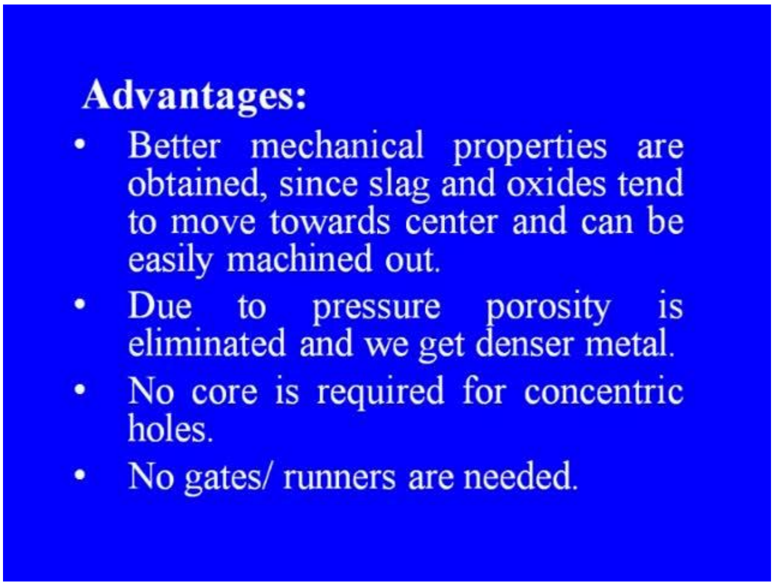

The process is better mechanical properties are obtained since slag and oxides tend to move outwards and can be easily machined out. Due to pressure porosity is eliminated and a denser material can be produced. No core is required for concentric holes, no gates or runners are needed.

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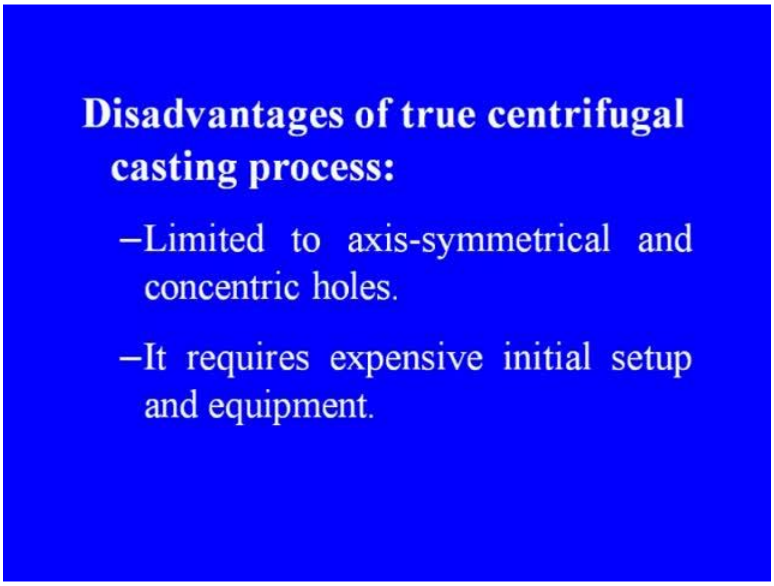

What are the disadvantages then of the true centrifugal casting process? The process is limited to axis symmetrical and concentric holes. It requires expensive initial setup and equipment. Semi centrifugal casting, in this process a core is provided which makes a hole at the centre. Thereby we have higher rotating speeds and casting can be produced one over the other which is also called stacked. This increases the production rate. It is in contrast to the true centrifugal casting process where no core exists.

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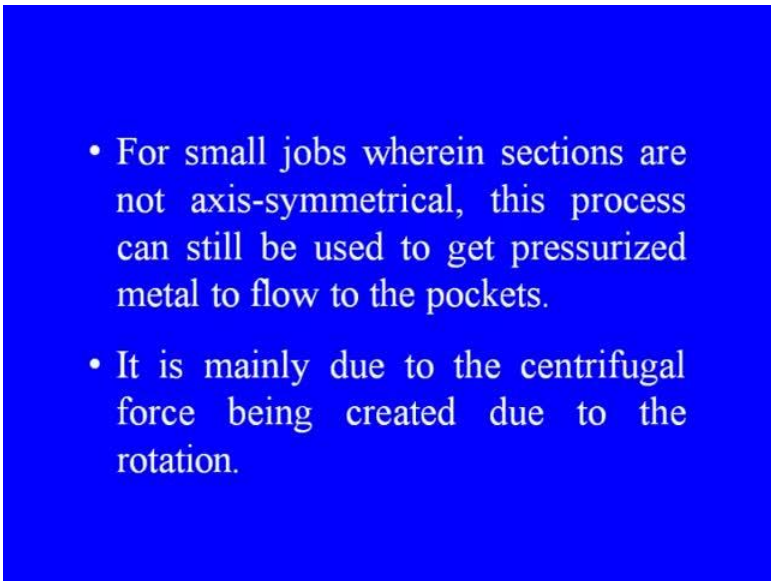

For small jobs wherein sections are non axis symmetrical, this process can still be added to get pressurized metal to follow to the pockets. It is mainly due to the centrifugal force being created due to the rotation. If the masses are properly balanced then we can have uniform layers stacked one over the other.

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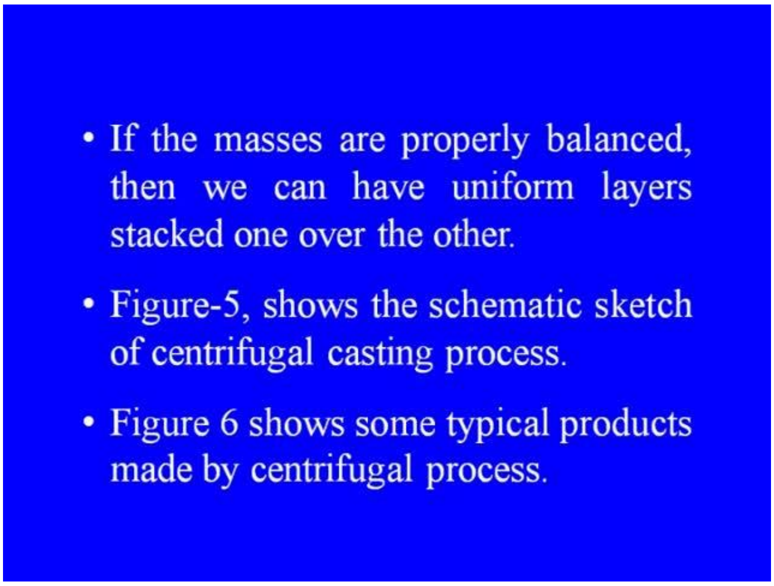

Figure five below shows the schematic sketch of a centrifugal casting process, whereas figure six shows some typical products made by centrifugal process.

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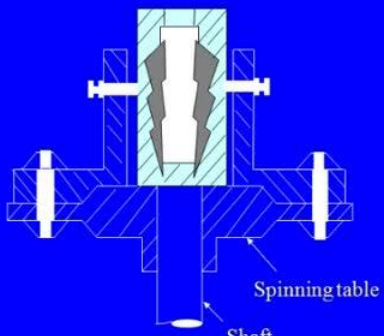

Fig.5 Schematic of centrifugal casting process

This shows the schematic of a centrifugal casting process.

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Some product examples made by centrifugal casting process

Fig.6: Few centrifugal casting products

And this figure shows few more centrifugal casting products. Now, in summary what we have learnt?

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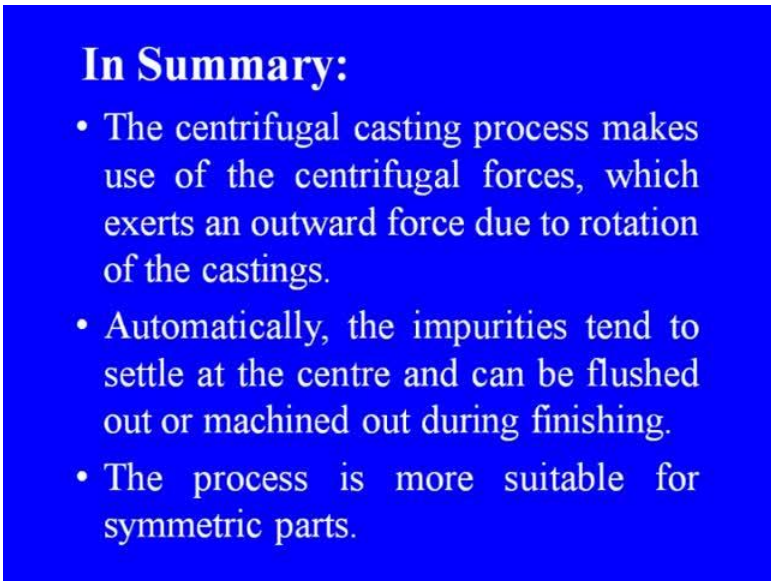

The centrifugal casting process makes use of the centrifugal forces which exerts an outward force due to rotation of castings. Automatically, the impurities tend to settle at the centre and can be flushed out or machined out during finishing. The process is more suitable for symmetric parts. The next process in this is pressure die casting.

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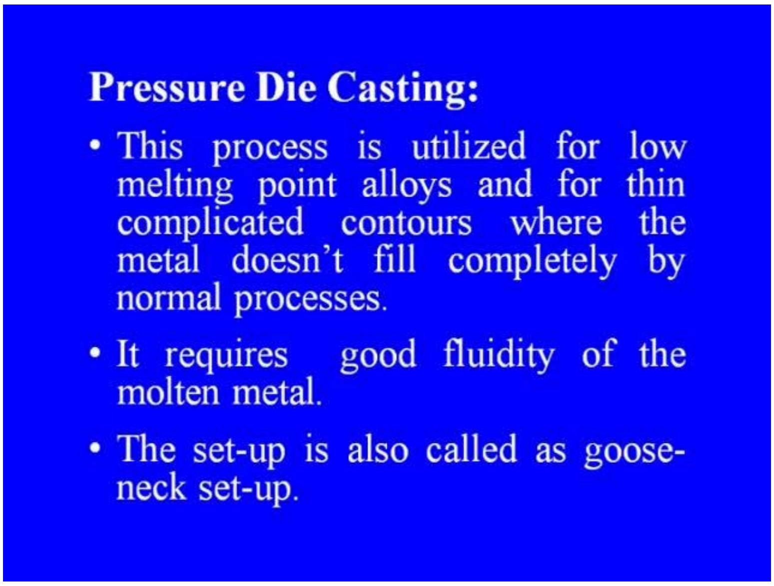

This process is utilised for low melting point alloys and for thin complicated contours where the metal does not fill completely by normal process. It requires good fluidity of the molten material, the set up is also called as goose neck set up. In this set up we make use of a pressuring device such as a hydraulic actuator which forces the metal to flow in to the cavity. The mould is made of metallic material and also termed as die. It is made in split form, so that the casting can be easily moved out by ejector pins as shown in figure seven.

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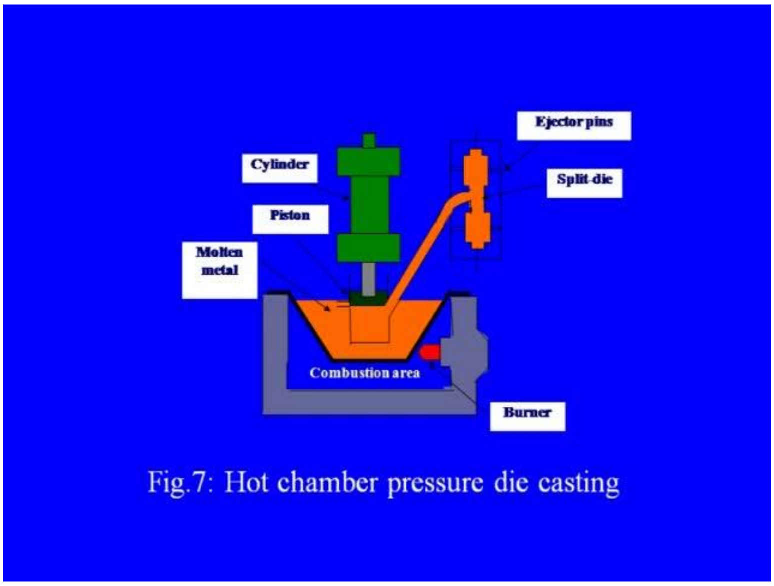

Fig.7: Hot chamber pressure die casting

The arrangement has a goose neck shape through which molten metal is sucked from a reservoir and fed to the cavity by hydraulic force. The arrangement may be hot chambered where it is continuous, heated by a special heating arrangement to maintain the temperature and the fluidity.

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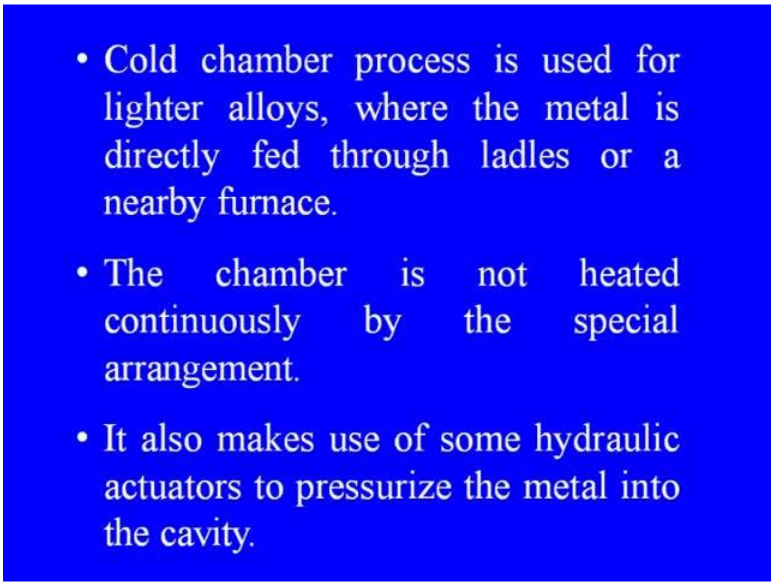

The cold chamber process is used for lighter alloys where the metal is directly fed through ladles or a nearby furnace. The chamber is not heated continuously by the special arrangement. It also makes use of some hydraulic actuators to pressurize the metal into the cavity.

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The pressure die casting process can be used in the making of automobile parts, carburettors, decorative and fancy articles.

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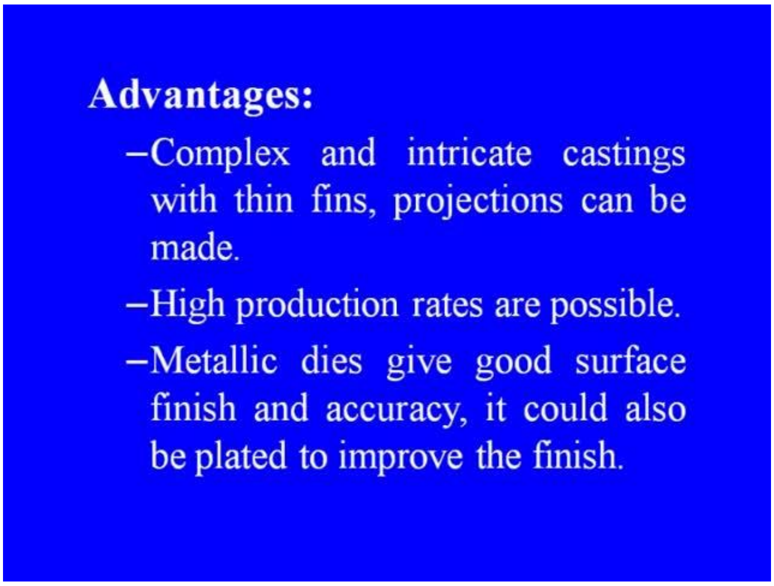

Advantages of these processes are complex and intricate castings with thin fins, projections can be made, high production rates are possible, metallic dies give good surface finish and accuracy. It could also be plated to improve the finish. Now, let us see the limitations of this process. It is not suitable for higher melting point metals since they require higher temperature withstanding die materials.

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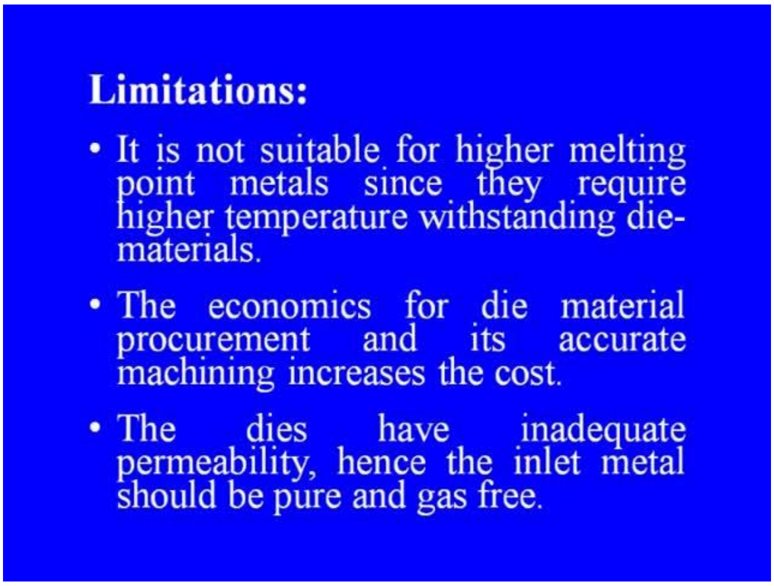

The economics for die material procurement and its accurate machining increases the cost. The dies have inadequate permeability; hence the inlet metal should be pure and gas free. The machinery used in pressure die casting is expensive and also require initial high set up costs. There is a size limitations and the process is suitable for maximum about 15 kilograms. In cold chamber process if there is a time lag it can lead to non filling of the cavities and molten metal may get solidified earlier than filling the moulds.

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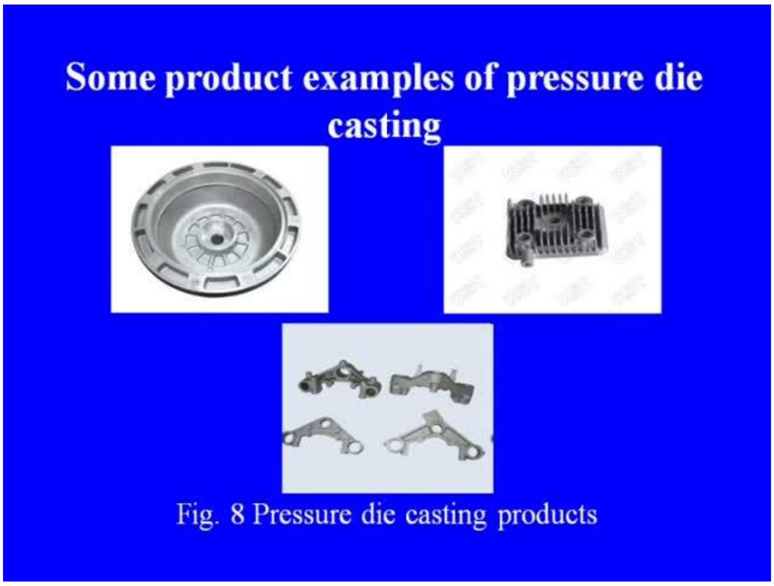

Some of the products manufactured through pressure die casting products are shown in this figure. In summary it can be said that due to the application of continuous pressure, pressure die casting process and source that the complete cavity is filled.

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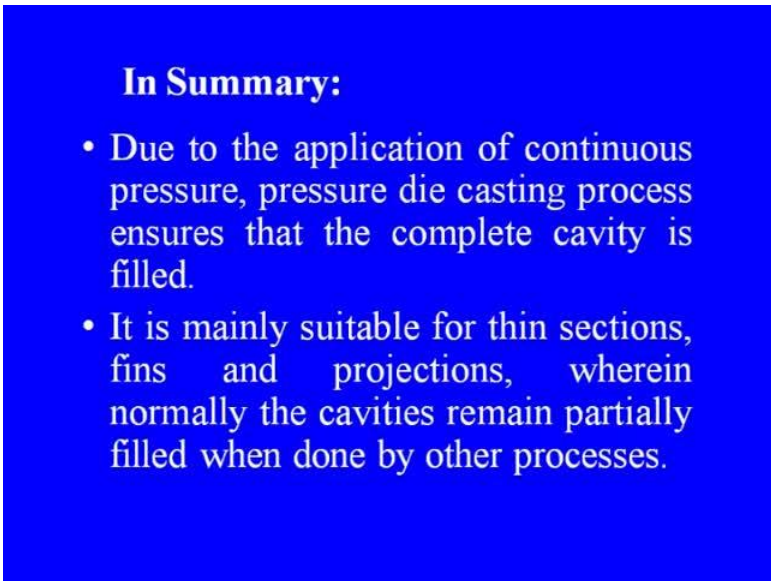

It is mainly suitable for thin sections, fins and projections, wherein normally the cavities remain partially filled when done by other processes. Now, let us have some comparisons between the different casting processes namely continuous casting process, permanent mould casting process, then pressure die casting process and centrifugal casting systems.

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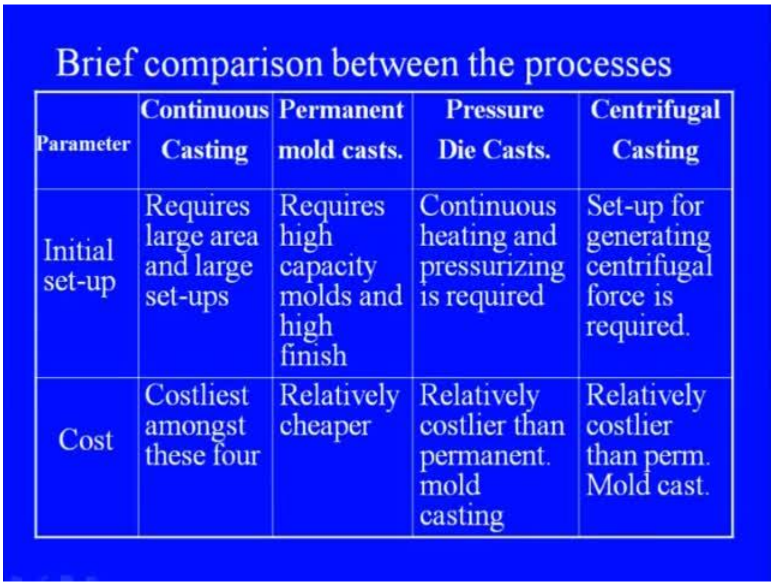

Brief comparison between the processes

Parameter	Continuous Casting	Permanent mold casts.	Pressure Die Casts.	Centrifugal Casting
Initial set-up	Requires large area and large set-ups	Requires high capacity molds and high finish	Continuous heating and pressurizing is required	Set-up for generating centrifugal force is required.
Cost	Costliest amongst these four	Relatively cheaper	Relatively costlier than permanent. mold casting	Relatively costlier than perm. Mold cast.

This is represented in the table as as can be seen in the screen. The first parameter we can take up as initial set up and these are the different processes as far as the continuous casting is, casting process is concerned it requires large area and large setups, whereas permanent mould casting requires high capacity moulds and high finish. This is, we are talking about as far as the initial set up is concerned, requirement is concerned. Then in case of pressure die casting continuous heating and pressurizing is required and in case of centrifugal casting set up for generating centrifugal force is required.

That means we can see in all four different processes, different conditions are required. In one case centrifugal action, centrifugal force generating system is required, in another case high pressure is required that is in case of pressure die casting whereas in another case high capacity and high finish is required in case of permanent mould casting.

If we see these processes cost wise probably continuous casting process is the costliest one among these four, then permanent mould casting is relatively cheaper, then pressure die casting is relatively costlier than permanent mould casting and centrifugal casting is relatively costlier than permanent mould casting. However, continuous casting process is the costliest among these four.

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Parameter	Continuous Casting	Permanent mold casts.	Pressure Die Casts.	Centrifugal Casting
Key benefits	Over a period the costs come down much lower	Mold life is very high, no swelling and moisture problems as in wooden patterns	Ensures complete mold filling and blow holes are much reduced.	Best suited for symmetrical shapes, ensures better flow and filling
Yield	Almost 100%	Comparatively lower	Comparatively lower	Comparatively lower

Now, as far as the key benefits are concerned continuous casting process can be used over a period and the cost come down much lower. Although we have seen this is the costliest one, but over, over the years it the cost comes down. In case of permanent mould casting the mould life is very high. No swelling and moisture problems as in wooden patterns because here most of the cases metallic materials are used, metals or alloys are used as the pattern whereas in wood, wooden patterns because of the moisture or the ageing effect they gets swelled or deformed or degraded you can say whereas in case of pressure die casting it ensures complete mould filling and blow holes are much reduced because it is cast under pressure.

Therefore, blow holes are almost eliminated whereas the centrifugal casting process it is best suited for symmetrical shapes which ensures better flow and better filling as well. Now, as far as yield is concerned in continuous casting process yield is almost 100 percent, but all the other processes permanent mould casting, pressure die casting and centrifugal casting they are comparatively lower, yield is comparatively lower.

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Parameter	**Continuous Casting**	**Permanent mold casts.**	**Pressure Die Casts.**	**Centrifugal Casting**
Suited material	Lamellar and nodular CI, Cu- alloys	Light alloys, Cu alloys, Zn, lamellar and Spheroidal Gray cast iron	Alloys of Al, Mg, Cu, Zn, Sn and P-b (phospho bronze)	lamellar and nodular CI, Cast steel, light alloys and Cu based alloys
Typical products	Round, hex, square and profiled bars.	Pistons	Oil pan, gera case	Tubes

As far as the martial suitability is concerned continuous casting process lamellar and nodular cast iron and copper alloys can be cast. In case of permanent mould casting light alloys, copper alloys, zinc, then lamellar and spheroidal gray cast iron these materials can be suitable, then pressure die casting alloys of aluminium, magnesium, copper, zinc, tin and phosphorous, phosphor bronze. Then centrifugal casting lamellar and nodular cast iron, cast steel, light alloys and copper alloys can be used.

Then the typical products are the continuous casting process round, hexagonal, square and profiled bars can be produced. Then by permanent mould casting pistons can be produced, pressure die casting oil pan, gera case can be produced and centrifugal casting as we have already indicated mostly symmetrical products should be produced and therefore, tubes are very common examples of these casting process, casting product.

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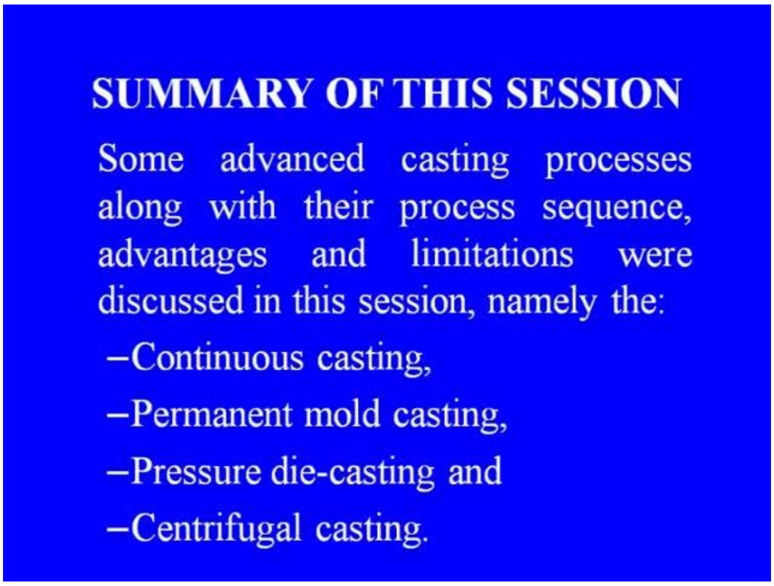

Now, let us summarise what we have discussed in this session. We have discussed some advanced casting processes along with their process sequence, advantages, limitations etcetera. Then the casting processes we have discussed are continuous casting process, permanent mould casting, pressure die casting and centrifugal casting process. We have tried to compare these processes based on various factors like cost, set up required, the materials that can be cast etcetera, etcetera. We hope this session was informative and useful.

Thank you.