

**Metal Casting**  
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**Module - 01**  
**Introduction and Overview**  
**Lecture - 01**  
**Introduction**

Good morning dear friends, I welcome you all to this course on Metal Casting I am Dr D Benny Karunakar and I am from the Mechanical and Industrial Engineering Department of IIT Roorkee. My email address is given below it is bennymf at the rate of iitr dot ernet dot in I will be covering various topics of metal casting in the subsequent lectures.

Today first I would like to give you the introduction on the metal casting. Metal casting is the oldest manufacturing process today there are. So, many manufacturing process are there like machining or modern manufacturing process, welding, forming, compared to all this manufacturing process metal casting is the oldest manufacturing process it was in practice around 5000 B C in the ancient Mesopotamia and ancient Egypt.

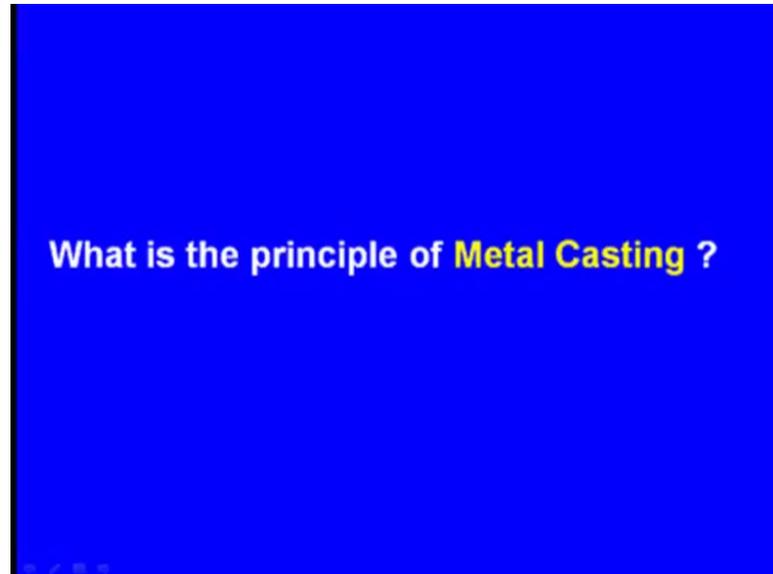
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Today its application include all areas of human requirements. We have applications of the metal casting in the automobile industry the automobile engines are manufactured by metal casting. The aircraft engines are manufactured by metal casting, the turbine blades,

the turbine housings, and the machine tool structures and many more are manufactured by metal casting.

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So, first of all what is the principles of the metal casting. I would like to draw your attention to this spears used in the wars during the ancient days here you can see the spears.

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So, these are all the spears you can see there is a pointed head will be there which is made up of metal and there will be a wooden handle will be there. So, these are this

spears these were used in the wars during the ancient days, here we can see a photograph or a picture of a ancient war taking place and here you can see a soldier is carrying a spear and here most of the soldiers are carrying the spears.

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These spears were widely used in the ancient wars. Now, the question is these spear heads were manufactured by metal casting.

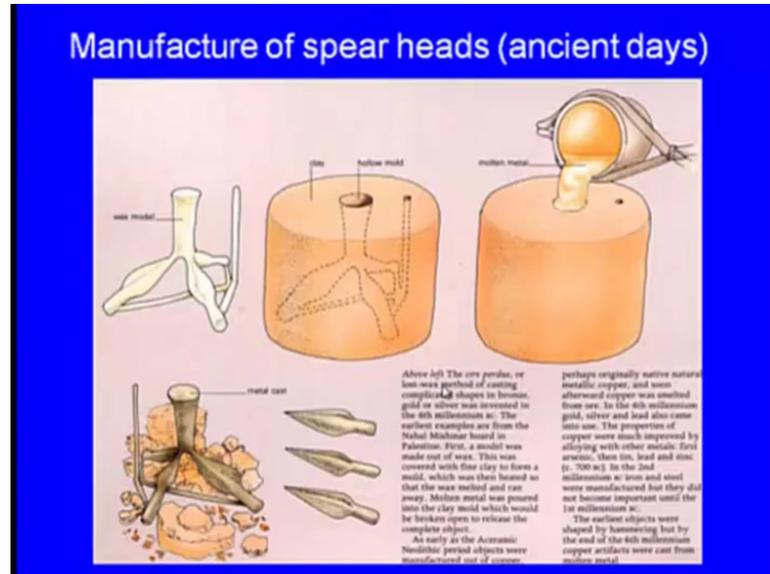
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You can see these spear heads so these were manufactured by metal casting means; even during the ancient days this metal casting process was in practice.

Now let us see how the ancient people have manufactured the these spear heads here you can see first of all they wanted to manufacture 3 spear heads.

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What they have done is they have made a wax model here you can see this is the one spear head and this is another spear head and this is the third spear head. This a what say actually these are the wax models initially they have made the wax models of the 3 spear heads and they have joined them and in between at the centre there is a what say tree; tree and they have joined again and there here we can see a projection. So, this is a wax model.

After making the wax model they have compacted the sand around this wax model, you can see they have compacted. After compacting the sand they have heated this system before that they have made a hole at the bottom then what happens after making the hole at the bottom after heating the system the whole wax will be melting and it might have drained outside, and they around that there is the compacted sand is there which is mixed with clay which has got some binding action. After this what say wax has drained out there is a cavity inside, now what is the shape of that cavity the shape of that cavity is the similar to the wax model which they have made in the beginning.

Now, they have melted the metal maybe iron or the bronze and they have poured through this hole the molten metal all has gone inside the cavity it has occupied all over the cavity it might have filled this first what say spear space, this another space another

space and after filling all this space it has raised like this. Once the metal has raised to this level they have stopped pouring the metal after some time the molten metal has solidified then after it has solidified they have broken this sand. Now you can see there is an assembly of 3 spear heads, now they have cut here they have cut and here they have cut and here they have cut and finally, they got the 3 spear heads. This is how the ancient man has manufactured the spear heads using the metal casting process

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### PRINCIPLE OF METAL CASTING PROCESS:

A sand mould with required cavity is created.

Metal is heated above its melting point.

Liquid metal is poured into sand mould.

Metal solidifies inside the cavity of the mould.

Sand mould is broken.

Solidified part is removed from the mould.

Now let us what say see the principle of the metal casting process. Now what we can say about the principle a sand mould with required cavity is created first using the maybe a wax model. Sometimes this wax model is also replaced or substituted by a wooden model, now after may creating this cavity the metal is heated above it is melting point liquid metal is poured into sand mould the metal solidifies inside the cavity of the mould and after some time the metal solidifies then the sand mould is broken. After breaking the sand mould the solidified part is removed from the mould. So, this is the simple principle of the metal casting.

Now, the ancient man initially he has made a wax model around that wax model he has compacted the sand and afterwards he has melted the this wax model.

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**Later, the wax used to make the cavity was substituted by wood, metal, etc.**

**Similarly, the sand used to make the mould was substituted by metal, ceramic shell, etc.**

Later this wax that is was used to make the cavity was substituted by wood metal etcetera the means initially one has to make a model to create that cavity this model is known as the pattern technically it is called as the pattern. So, ancient man has used the wax for the pattern later it was substituted by the wood and metal similarly the ancient man has used or compacted sand around the wax pattern. Today yes sand we use, but this sand is substituted by metal ceramic shell and so on. So, this is the simple principle of metal casting.

Now, before going to the further topics let us see the time line of the history of the metal casting.

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**TIMELINE OF METAL CASTING**

Metal casting process, according to biblical records, reaches back almost 5,000 years B.C.

Casting process was used during the stone age to make the rudimentary tools.

The metal casting process according to the biblical records which is back almost 5000 years B.C. it was 5000 years before Christ casting process was used during the Stone Age to make the rudimentary tools.

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**DEPICTION OF THE STONE AGE**



**STONE AGE CAST TOOLS:**  
Arrow heads, Axe heads, Spear heads, etc.

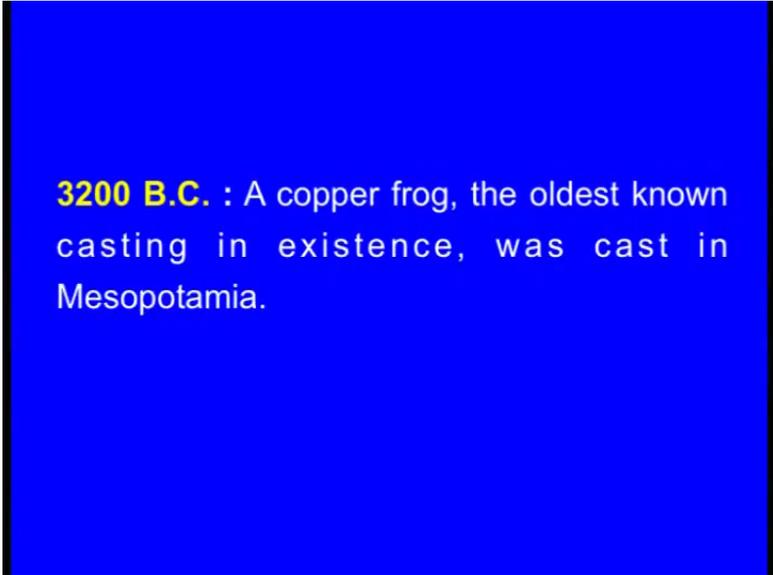
Let us have a look at the this one stone age here we can see the depiction of the stone age here we can see all the people who lived during the stone age. Those days they use to make some rudimentary tools like arrow heads or the spears or the axe the with those

they use to kill the enemies or with those they use to kill the animals for their food. Now let us see how this what say stone age man has used this metal casting technique.

Here you can see this man this man is using the arrow head this arrow head was manufactured by metal casting. Here you can see this man this man is holding a spear you can see this spear head was manufactured by metal casting by the Stone Age man this man is also holding an axe here you can see this axe head was manufactured by metal casting.

So, during the Stone Age the ancient man has used this metal casting process for manufacturing the arrow heads axe heads spear heads and so on.

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**3200 B.C.** : A copper frog, the oldest known casting in existence, was cast in Mesopotamia.

Now, during what say 3200 B.C; A copper frog was manufactured in the ancient Mesopotamia this became very popular those days and because of this copper frog people even started calling those days as the copper frog age let us see this copper frog.

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So, this is the copper frog which was manufactured during 3200 B.C, this was manufactured by metal casting.

During thousand 500 B.C wrought iron was developed.

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**1500 B.C. : Wrought iron was developed.**

Wrought iron means 'Worked iron' .

It contains very low carbon and also some slag.

It was extensively used before steel.

Wrought iron means “Worked iron” it contains very low carbon and also some slag it was extensively used before steel was developed.

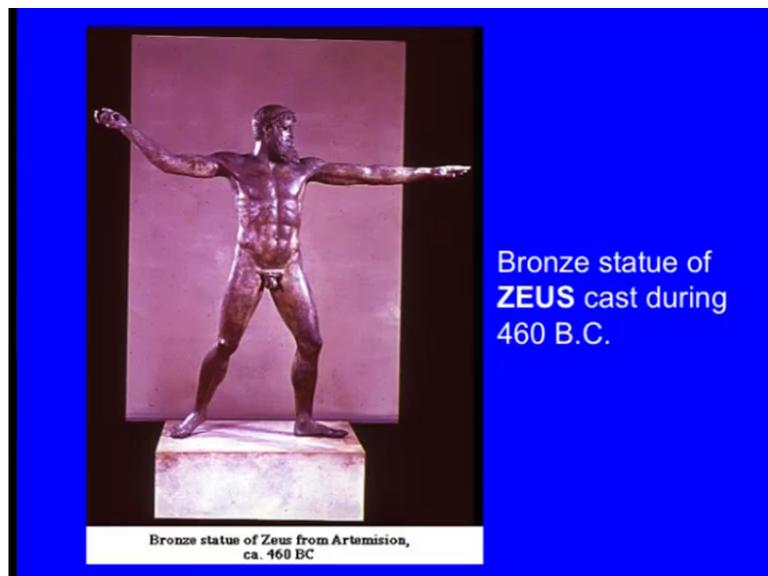
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**460 B.C.** : Bronze statue of **Zeus** was cast in Greece.

(**Zeus** was the god of the sky and the ruler of the Olympian gods).

Next during 400 and 630 B.C; Bronze statue of Zeus was cast in Greece who is this Zeus Zeus was the god of the sky and the ruler of the Olympian gods.

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Here we can see the bronze statue of Zeus which was cast during 460 B.C he was considered as the god of sky.

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Now, this Zeus Bronze statue is kept in a museum we can see this born Bronze statue in a museum and this was a this Zeus bronze statute was made by a casting.

Next during 233 B.C cast iron plowshares were produced in China.

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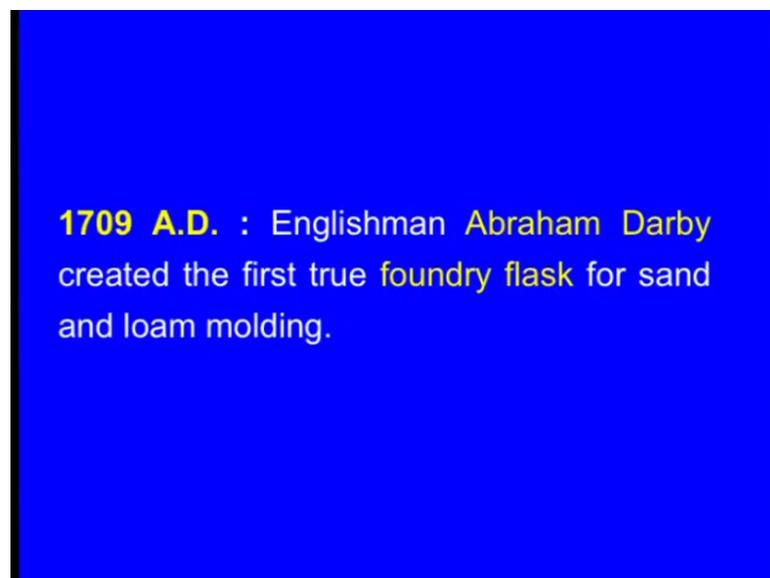
We know the ploughing of the land these plowshares were manufactured by casting here you can a plough which is used to plough the land this is the plough shield and this first manufactured by casting. During 1455 A.D yes cast iron pipes were manufactured for transporting the water.

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Here you can see big cast iron pipes which are used to what say transport water these pipes are manufactured by casting.

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Next one foundry flask for a loam molding was developed in the year 1709 A.D by an English men by name Abraham Darby.

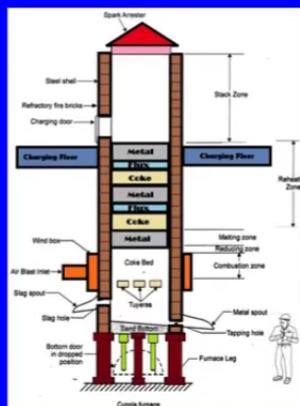
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**1750 A.D.** : Benjamin Huntsman reinvented the process of cast crucible steel in England.

During 1750 A.D Benjamin Huntsman reinvented the process of cast crucible steel in England.

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**1794 A.D.** : Cupola was invented by John Wilkinson of England.



And during 1794 A D Cupola was developed by John Wilkinson from England.

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**1809 A.D.** : Centrifugal casting was developed by **A.G. Eckhardt** of Soho, England.

During 1809 A.D Centrifugal casting was developed in England. In this centrifugal casting there will be cylindrical mould and this cylindrical mould will be rotating and into this rotating cylindrical mould the molten metal will be poured and as a result we get cylindrical castings with hollow space inside. So, this is the principle of the centrifugal casting. So, this was developed during the year 1809 A.D

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**1897 A.D.** : **Investment casting** was rediscovered by **B.F. Philbrook** of Iowa.

Investment Casting is the casting process in which the pattern material used is **wax**.

He used it to cast **dental inlays**.

During 1897 A.D investment casting was Rediscovered by Philbrook of Iowa Investment Casting means it is the casting process in which the pattern material is the wax. Some

time back we have seen that a ancient man has used wax as the pattern material means to make the hollow cavity inside the compacted sand medium he has used the wax, later this wax was substituted by wood and also by metal, but the process in which only wax is used as the pattern material is known as the investment casting that was rediscovered during the year 1897 A.D

Next one he used this to cast the dental inlays.

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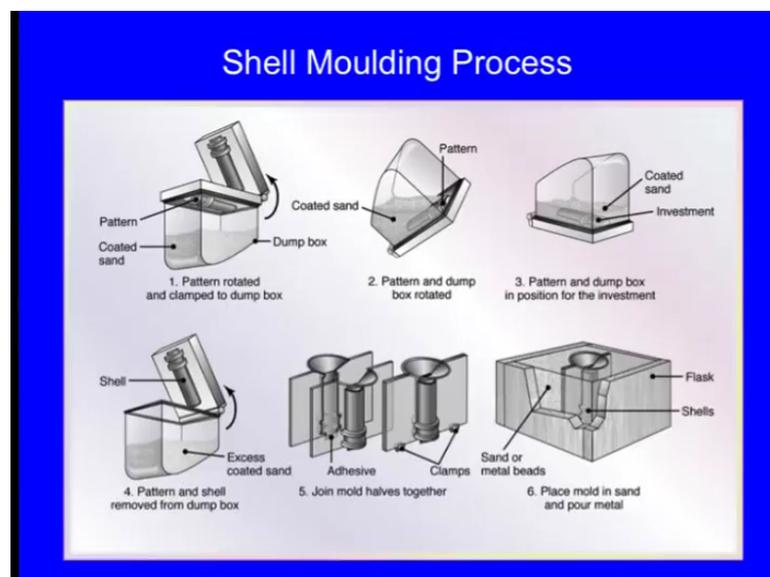
Let us see this dental inlays you can see these are the what say teeth and this tooth is damaged. So, here has made a gold inlay on this tooth. So, for this purpose he used the investment casting.

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**1947 A.D. : The Shell Moulding Process,**  
was invented by **J. Croning** of Germany  
during the Second World War.

During 1947 A.D Shell Moulding Process was developed by J Croning from Germany. So, here a chemical sand shell will be made into that shell the molten metal will be poured.

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This is known as the shell Moulding and this was manufactured during the Second World War.

During 1953 A.D hot box system of making and curing cores was developed.

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**1953 A.D.** : The **hotbox system** of making and curing cores was developed.

This eliminated the need for dielectric drying of ovens.

This eliminated the need for dielectric drying of ovens.

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**1958 A.D.** : **H.F. Shroyer** was granted a patent for the **full mould process**.

He became the forerunner of the expendable pattern (lost foam) casting process.

During 1958 A.D Shroyer was granted a patent for full mould process he became the forerunner of the expendable casting process.

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**1968 A.D.** : The **Coldbox process** was introduced by **L. Toriello and J. Robins** for high production core making.

During 1968 A.D the Cold box process was introduced for high production core making.

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**1971 A.D.** : **Rheocasting** was developed at Massachusetts Institute of Technology.

During 1971 A.D; Rheocasting was developed at USA.

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**1971 A.D. :** The Japanese developed **V-Process** molding.

This method uses unbonded sand and vacuum to make the mould.

And during 1971 A.D Japanese developed the V-Process molding.

So, this became very popular in this V-Process molding there loose and fine and clear sand is used. If this sand is used this sand will be used to hold the what say mould cavity by means of the vacuum, because of the vacuum the loose sand will be held together tightly around the pattern. While the vacuum is still holding the loose sand tightly the pattern will be withdrawn and the molten metal will be poured into the mould cavity. So, this creates a clean environment. So, this was developed by Japanese during the year 1971.

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**1996 A.D.** : Cast **metal matrix composites** were first used in automobiles, in the brake rotors.

And during 1996 A.D Cast metal matrix composites were first used in the automobiles. Metal casting history in India; now let us see what was the history of metal casting in India.

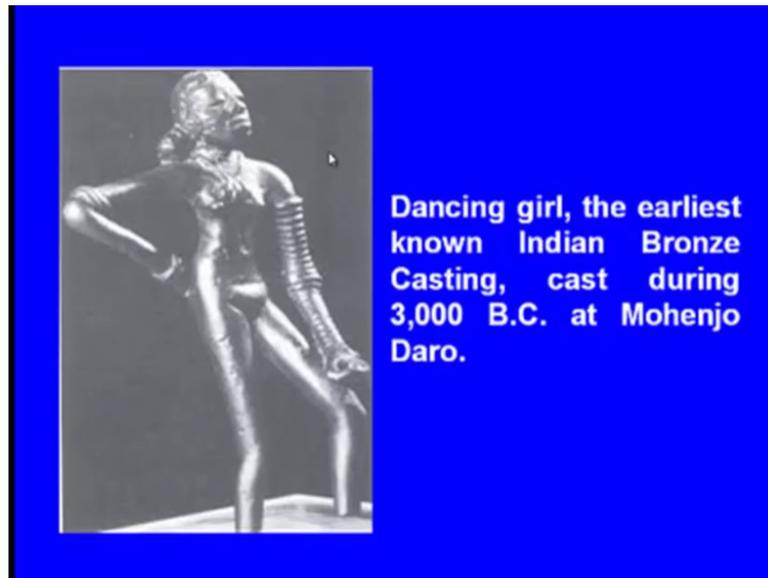
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**METAL CASTING HISTORY (INDIA):**

**3000 B.C.** : Earliest castings include the 11 cm high bronze **dancing girl** found at **Mohen-jo-daro**.

During 3000 B.C a dancing girl made up of bronze was manufactured at Mohen Jo Daro. Now it is Pakistan. So, this dancing girl became very popular those days now let us see this dancing girl. So, this is the dancing girl which was cast in Mohen Jo Daro during 3000 B.C.

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Now you can see all the important features all the minute features were excellently cast in this dancing girl, now it is still there in a museum in Mohen Jo Daro Pakistan this was manufactured originally in India. So, India was also popular for the casting process.

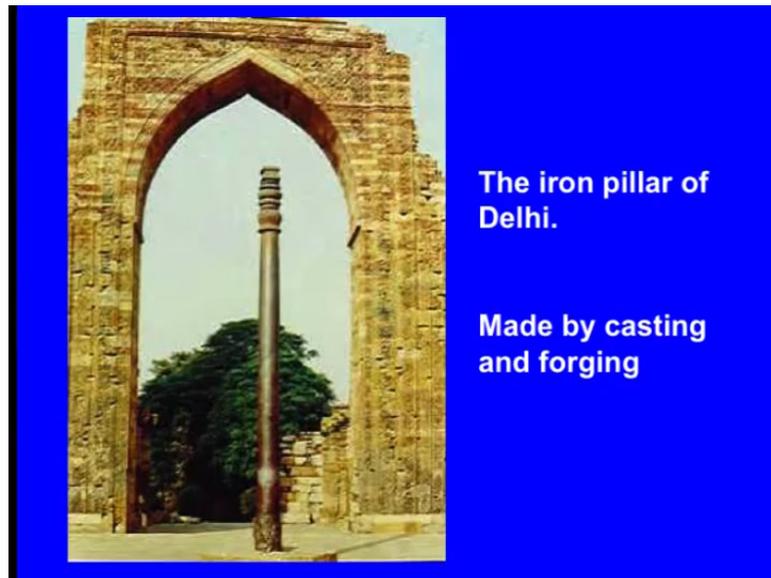
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### **Metal Casting History (India):**

**375 - 414 A.D. :** Iron pillars, arrows, hooks, nails, bowls, etc. have been found in Delhi, Nashik and other places.

Now, during 375 to 414 A.D, Iron pillars, arrows, hooks, nails, bowls, etcetera have been found in Delhi, Nashik and other places, now this is the iron pillar of Delhi So, this was manufactured by casting and for forging together.

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This iron pillar as we can see near Qutub Minar in Delhi.

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So, this is the iron pillar of the Delhi.

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**450 A.D.** : Large scale state-owned **mints** and **jewelry units** were in operation.

The processes of **metal extraction** and **alloying** have been reported.

During 450 a d large scale state owned mints and Jewellery units were in operation the process of metal extraction and alloying have been reported in India.

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**500 A.D.** : Cast crucible steel was first produced in India.

But the process was lost until 1750 A.D., when Benjamin Huntsman reinvented it in England.

During 500 A.D cast crucible steel was first produced in India, but the process was lost until 1750 A.D when Benjamin Huntsman reinvented it in England.

These are the important applications of the casting the ancient man used this metal casting technique to manufacture the rudimentary tools like spear heads arrow heads or the axe heads today these are the applications.

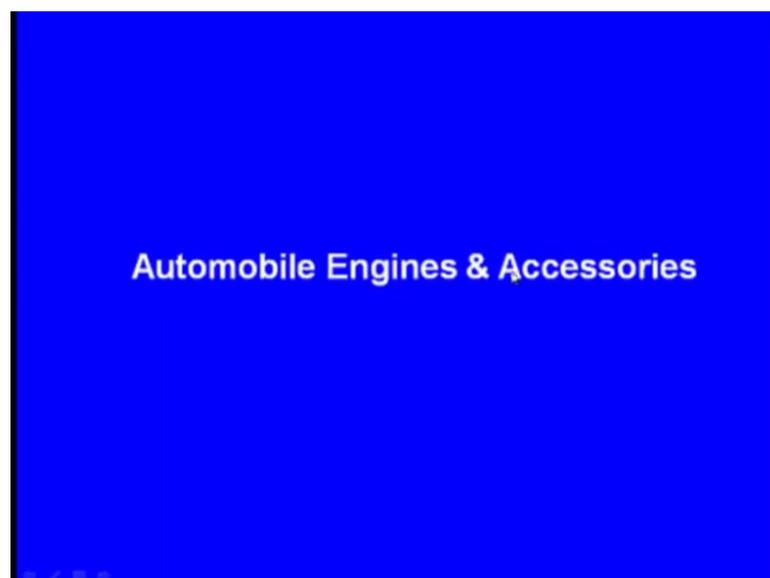
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These are used in the automobile industries, aircraft engines, Machine tools structures, Electrical motors, Compressors, locomotives and parts, pumps and accessories, turbines and blades, art castings, Jewellery castings and miscellaneous components. Let us see examples from each of these applications.

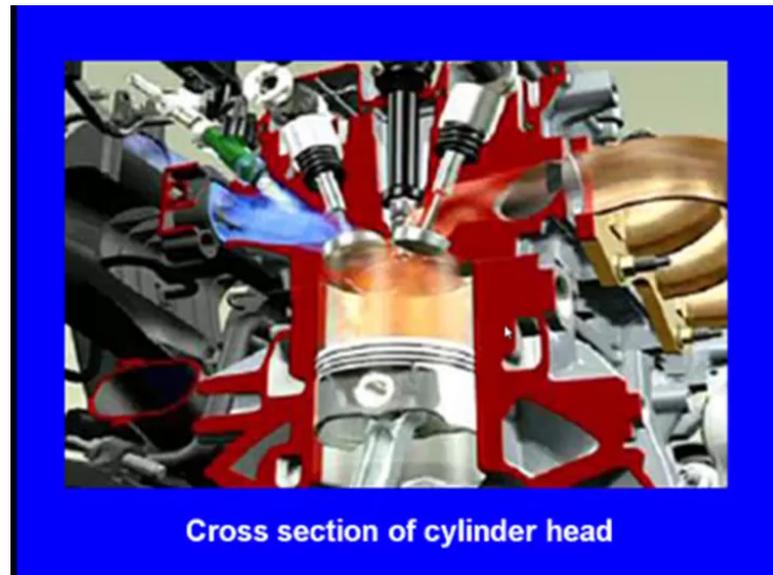
First let us see in the automobile engines and accessories What are the components manufactured by metal casting.

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You can see this is the cross section of a cylinder head.

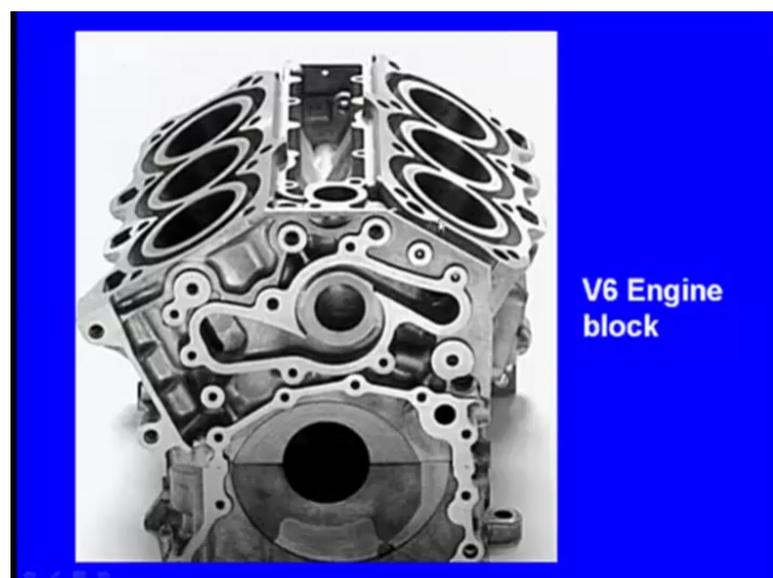
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I C engine head you can see here this is the cylinder and this is the piston this piston will be reciprocating up and down and here the fuel will be burned and hot gases are produced and these hot gases will be pushing the piston downwards in turn the piston connecting rod will be rotating the fly wheel.

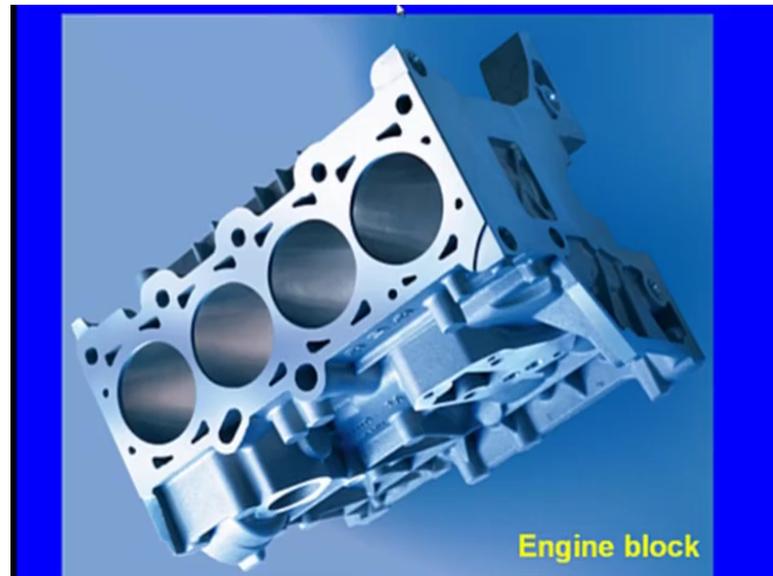
So, this is the simple principle of the I c engine or an automobile engine this engine head is manufactured by metal casting.

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So, you can again we can here this is a cylinder engine cylinder with 6 cylinders, this side we can see 3 cylinders and this side we can see 3 cylinders and this is manufactured by metal casting.

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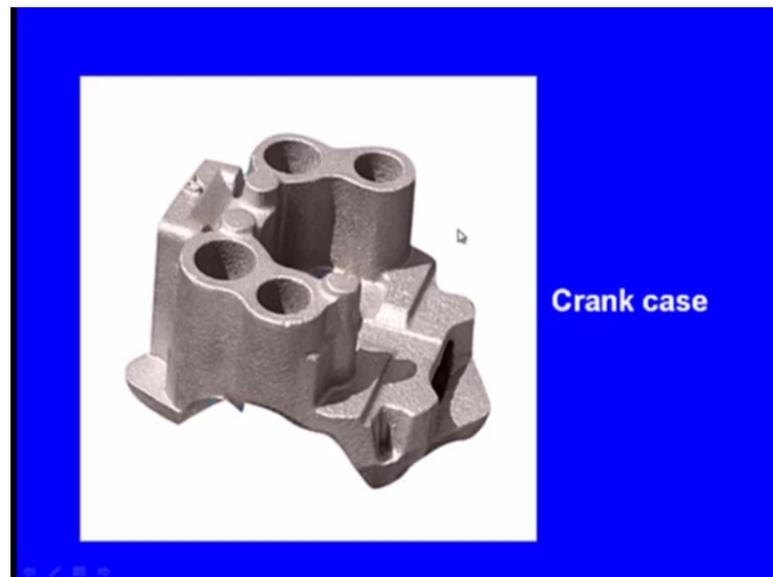
And this is another engine cylinder 4 cylinders here you can see 4 cylinders are there means maybe this engine is used for heavy truck or even for a heavy car and this engine is manufactured by metal casting.

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This is the again engine head, this is manufactured by metal casting.

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Now this is the crank case this is also manufactured by metal casting.

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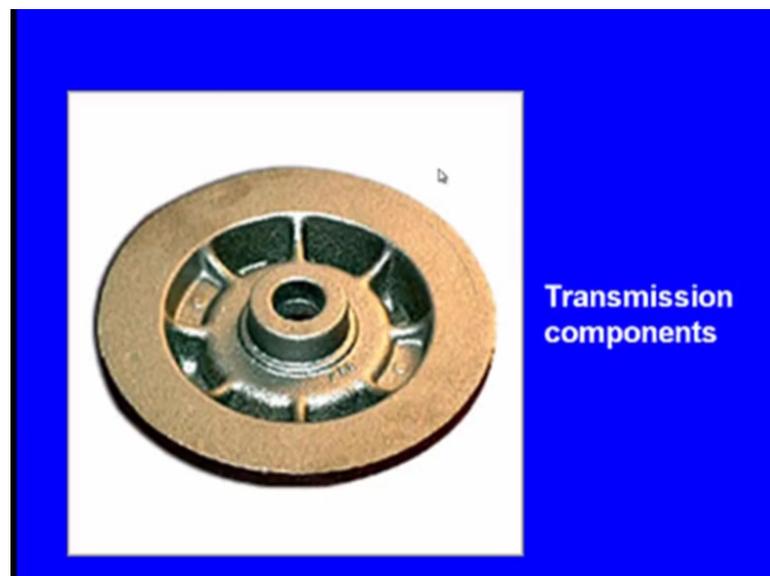
This is the cylinder head manufactured by metal casting.

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This is the car rim this is manufactured by metal casting.

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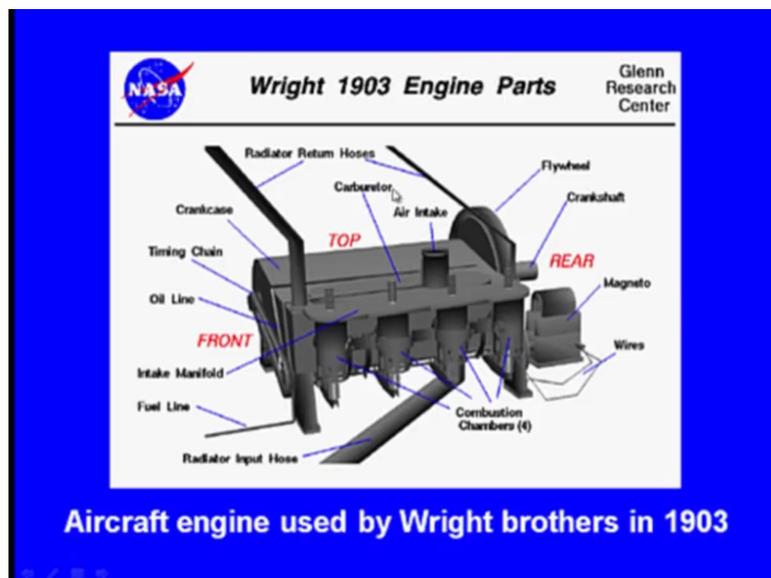
These are the transmission components and these are also manufactured by metal casting.

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Now, let us see the applications of the aircraft engines and the rocket parts.

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This is the a aircraft engine, which was used by the wright brother during the year 1903 this engine was manufactured by metal casting.

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This is a 12 cylinder aircraft engine 12 cylinders are there engine block again this is manufactured by metal casting.

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This is an aircraft engine you can see here and here you can see this is the engine this is the engine this engine is manufactured by metal casting.

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Now, you can see this is the modern aircraft engine you can see all this turbine what say blades are there. So, many blades are there all this blades are manufactured by metal casting the in outside covering the cover of the housing is manufactured by metal casting.

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This is the again aircraft engine all this parts are manufactured by metal casting.

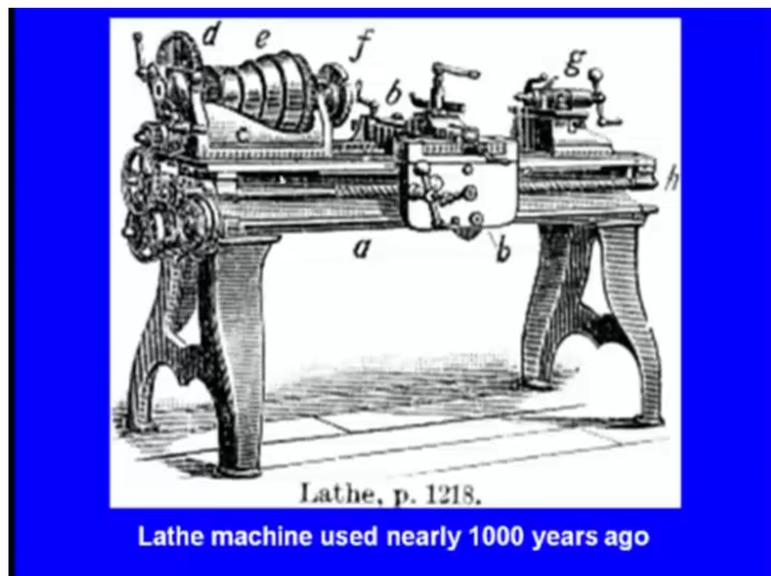
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This is the a rocket engine you can see this rocket engine is also manufactured by metal casting.

Now, let us see the applications of metal casting in the machine tools and the structures.

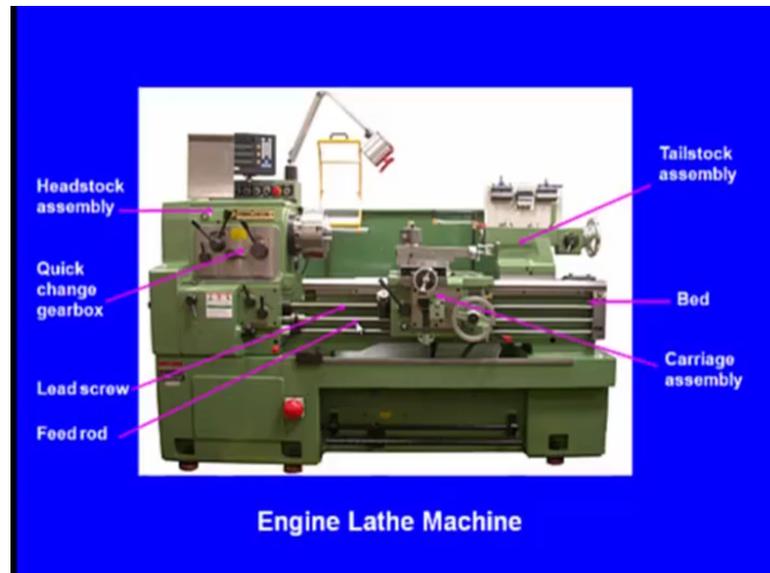
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This was the lathe machine used by ancient man nearly 1000 years ago, you can see a what say heavy metallic structure and you can see these are the legs of the lathe machine and this is the bed of the lathe machine. So, this is the tailstock of the lathe machine all

this parts are manufactured by metal casting, Now you can see this is the what say today's year engine lathe machine.

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And all this components the what say bed the legs, the tailstock and many components of the lathe machine are manufactured by metal casting.

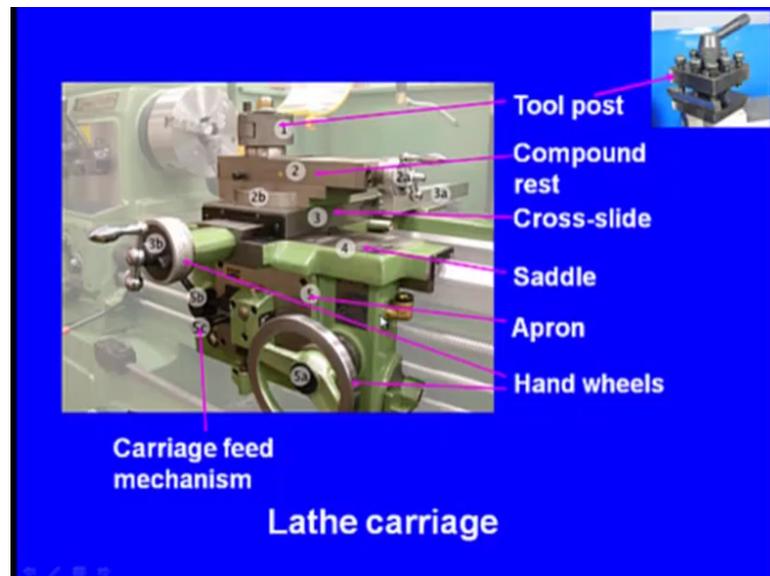
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This is the lathe bed. So, this lathe bed looks like this and this is manufactured by metal casting.

Now, you can see this is the lathe carriage.

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Lathe carriage has go so, many sub components like apron, saddle, cross slide, compound rest and tool post all this are manufactured by metal casting.

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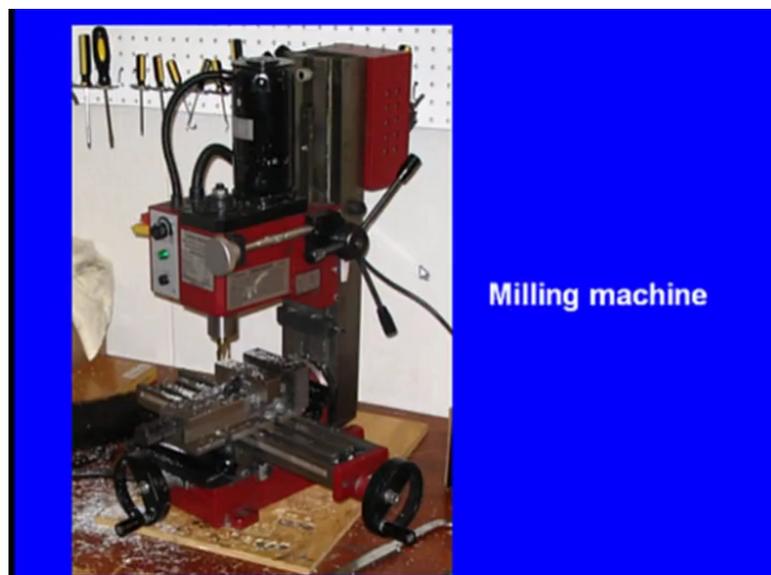
Now, this is the tailstock assembly this tailstock of lathe is also manufactured by metal casting.

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Now you can see this is a drilling machine this drilling machine you can see this is the base and this is the column and this is the table all this components base column and the table are manufactured by metal casting.

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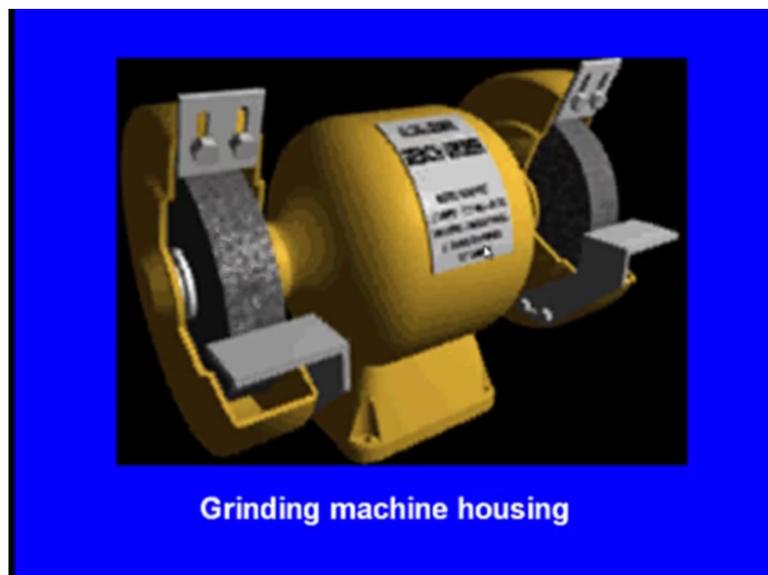
You can again we can see this is the milling machine; the milling machine base the column the structure is manufactured by metal casting.

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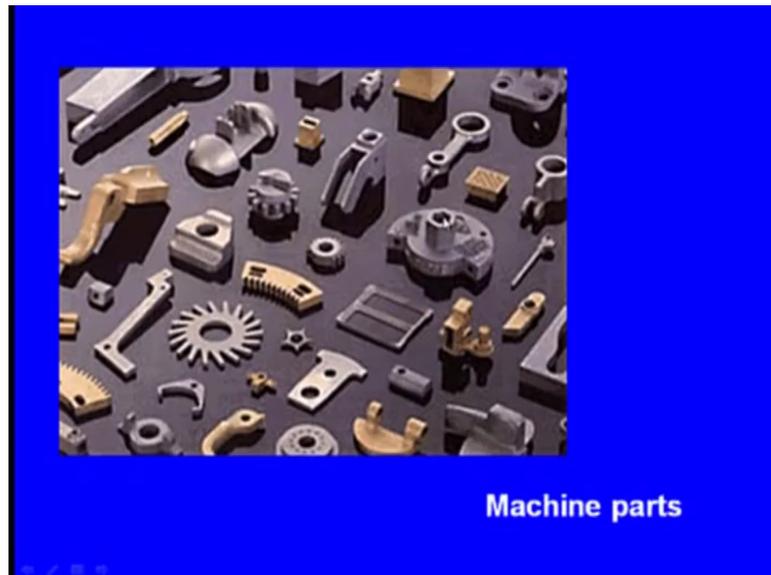
This is again a machine tool structure you can see outside there is a thick casing is there thick housing and inside there will be. So, many components moving parts and levers will be there the outside structure is manufactured by metal casting.

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Now, this is the grinding machine and you can see grinding wheel and here one wheel is there other side another wheel is there this is the grinding machine housing a thick shell this is manufactured by metal casting.

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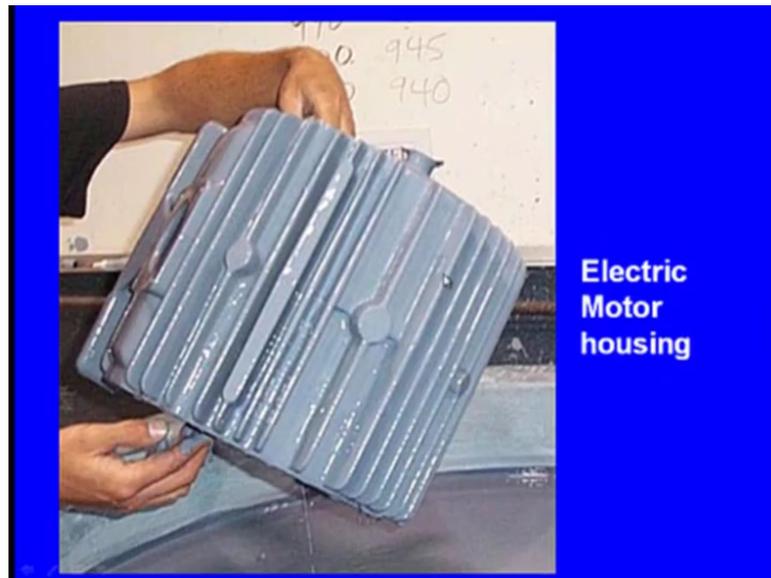
Now you can see these are the small machine parts tiny component these are also manufactured by metal casting you can see the small components with very excellent sharp details these are manufactured by metal casting.

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Now, let us see the applications of the metal casting. In electrical systems yes this is the electrical motor housing.

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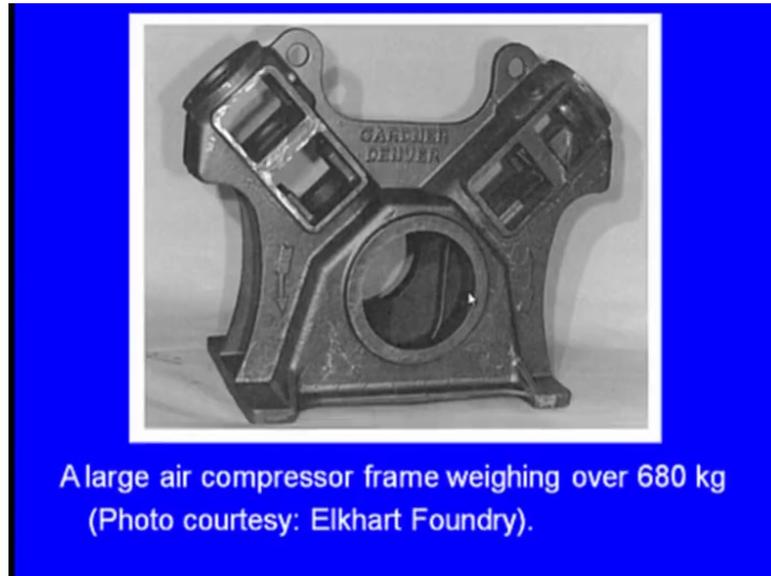
This is manufactured by metal casting.

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Now, let us see the compressors.

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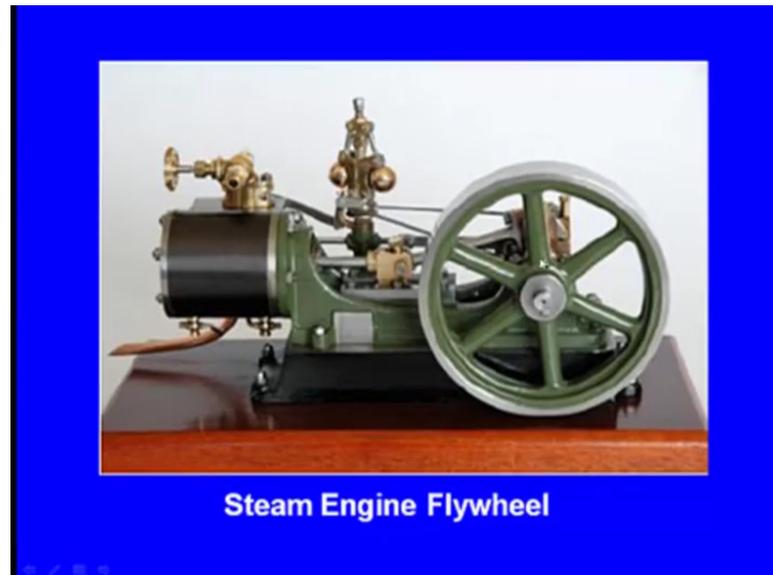
So, this is the compressor frame this is manufactured by metal casting, this is a heavy casting you see it weighs over 600 and 80 kilo grams manufactured by metal casting.

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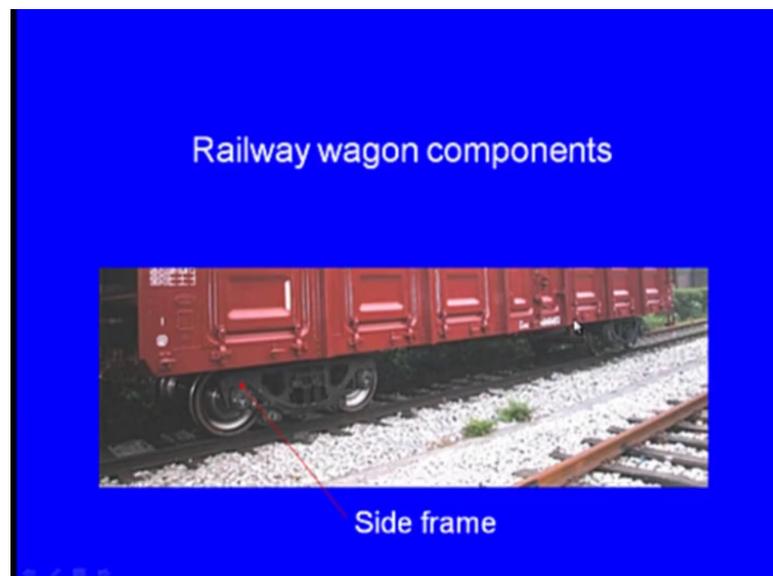
Now, let us see the locomotive parts. Now this is a locomotive there will be fly wheel like this.

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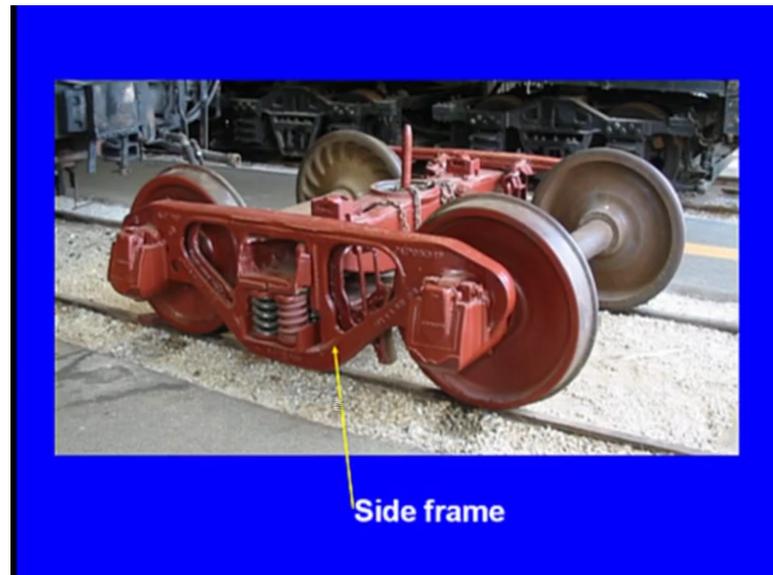
This fly wheel is manufactured by metal casting.

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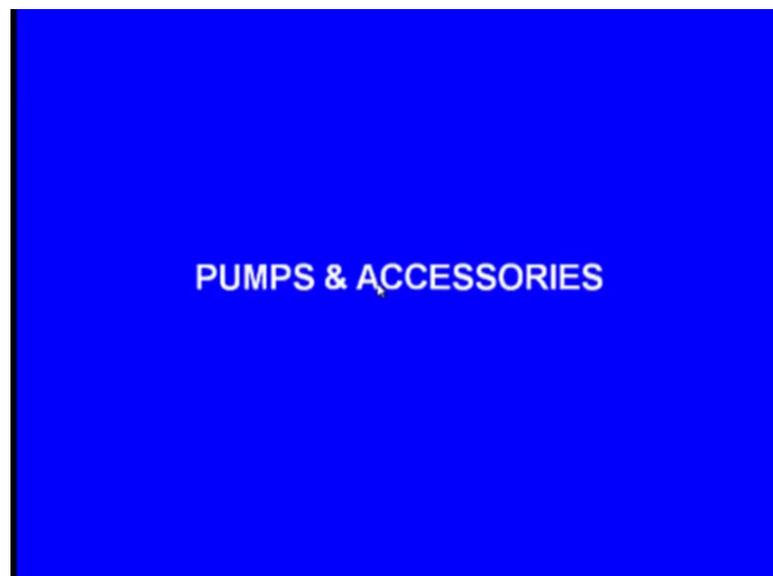
Now, you can see this is a goods wagon this is a goods wagon and you can see here is one wheel and here is one wheel and there will be frame which is supported on this 2 wheels this is known as the side frame this side frame is manufactured by metal casting.

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You can see this is the side frame this side frame is manufactured by metal casting.

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Let us see the pumps and the accessories.

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This is the pump housing this is manufactured by metal casting again this is a big pump housing.

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And inside the turbine grade will be there and it will be rotating and this pump housing is manufactured by metal casting, not only this pump housing the inside blades are also manufactured by metal casting.

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This is again a pump casting manufactured by metal casting.

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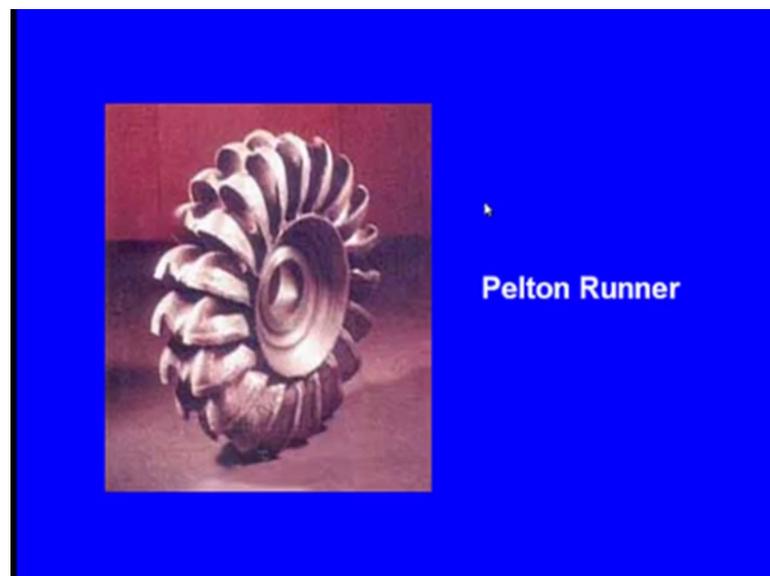
Now, these are the turbine and blades let us see the applications in the turbines and the blades.

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This is the Francis runner very important this is manufactured by metal casting.

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This is the Pelton Runner which is very important again this is manufactured by metal casting.

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Now you can see the steam turbine, which is used in the thermal power plants the steam turbine inside the rotor will be looking like this. So, many blades are there you can see. So, many blades all this blades are manufactured by metal casting of the steam turbine.

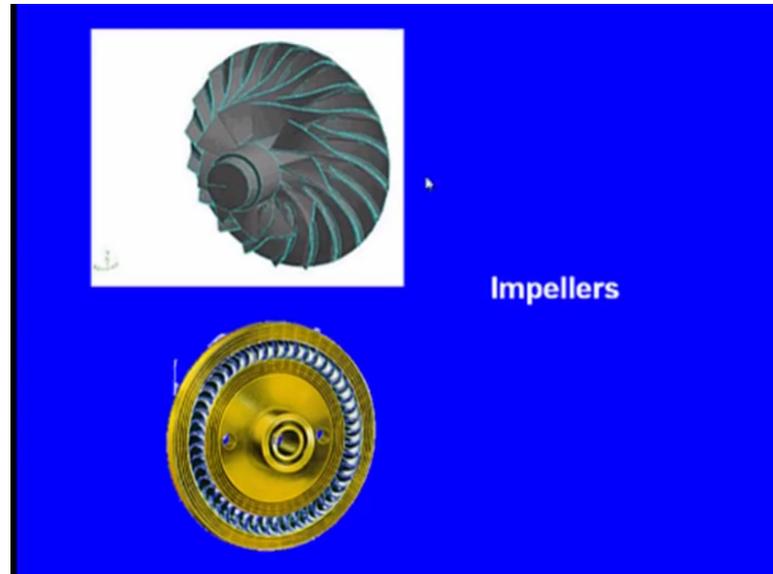
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Now, this is the steam turbine housing some just now we have seen the this steam turbine blades all this blades will be mounted in this housing. You can see this is a this is a huge casting and it is weight is nearly 10 tons this housing is manufactured by metal casting.

The turbine blades are manufactured by metal casting the turbine housing is manufactured by metal casting.

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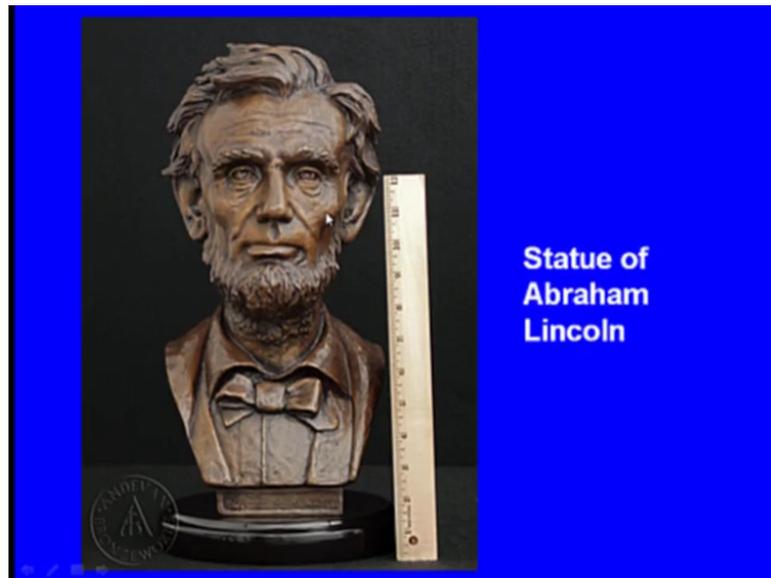
Now, these are the impellers these are also manufactured by metal casting.

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Now, let us see the art castings.

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Now you can see this is the statue of Abraham Lincoln most of the times we use the we use to see the bronze statues of the celebrates. How this statues are made initially they make a wax model of that person and around that they make the compacted medium sand medium or a ceramic medium later the way will be melted and it will be drained out then they will pour the molten bronze into that cavity that is how the art castings are manufactured and here we can see the art castings are art casting of Abraham Lincoln which is manufactured by the metal casting.

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And this is a again another art casting, which is there in a museum in USA this is also manufactured by metal casting.

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These are all the art castings manufactured by metal casting.

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So, these are all the art castings.

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Next metal casting is also used in the Jewellery industry.

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Now, you can see these are all the jewellery items these are manufactured by metal casting.

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Now, you can see again these are all the jewellery items of course, these are all assembled later they will be what say separating the different parts initially they make a what say assembled casting. So, this is manufactured by metal casting.

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This are all the again jewellery items these are manufactured by metal casting.

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Miscellaneous components.

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Now, you can see this is the nozzle may in a petrol bunk we can see this kind of nozzle this is manufactured by metal casting.

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You can see this dumbbell this dumbbell is used for the exercise purpose most of the times we use this, but we never think of how this is manufactured this is manufactured by metal casting.

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These are industrial castings manufactured by metal casting.

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These are the pulley castings.

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These are the submersible pump components. So, this are all manufactured by metal casting.

Now, let us see the advantages of the metal casting process.

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### ADVANTAGES OF METAL CASTING

1. Intricate shapes can be made.
2. Flexibility of size and weight.
3. Simple and inexpensive tools.
4. High production rate
5. Any material can be cast (Ferrous or non-ferrous).
6. Wastage of raw materials is less.

Intricate shapes can be made what is this intricate shapes maybe it has got. So, many complex features using the what say other machining process or the forming process it may be very difficult to manufacture such a complicate shapes, but using the metal casting process these intricate shapes can be successfully cast that is the advantage of the metal casting.

Next one the second advantage is the flexibility of size and weight, what is this flexibility of size and weight various small components can be manufactured just now we have seen that the metal casting has application in the jewellery industry, what is a weight of your jewellery component few grams so a small casting as small as few grams can be made by metal casting.

Now we have also seen the turbine blades, the turbine housings, whose weight is more than tons that is also manufactured by metal casting means there is a great flexibility of size and weight in the metal casting process.

Next one simple and inexpensive tools there are no high tech what say equipments are required for the metal casting only thing is you have to create a hollow cavity in a compacted sand medium, for that initially one has to use a model which this model is known as the pattern. After creating a hollow a cavity inside the compacted sand medium we melt the metal and pour into the cavity. So, it is very simple and no costly tools are required that is the advantage of the metal casting.

Next one next advantage is high production rate the production rate is very high. Next one next advantage is any material can be cast both ferrous or non ferrous materials can be successfully cast the finally, the advantage sorry the wastage of raw material is very less in the metal casting. So, these are all the advantages and this are the important advantages and let us see the limitations or demerits of the metal casting.

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This is a labor intensive process what is the labor involved initially what is the principle of the metal casting if we want to manufacture a particular component of a particular shape, a similar hollow cavity of the same what say shape has to be created inside the sand medium for that one has to initially make the pattern that is that involves the labor and after that one has to carefully prepare this sand and that sand has to be compacted around the pattern very carefully. And afterwards the pattern has to be withdrawn from the compacted sand medium that requires labor on the other side one has to melt the a metal in a furnace that has to done very carefully, that should be handled very carefully, that should be brought to this molding medium very carefully, then it should be poured into the cavity this requires the labor that is how the metal casting is a labor intensive process.

Next one the demerit of the metal casting is the dimensional accuracy is not so good, because we use the sand medium right. So, there will be a small irregularities on the what say sand surface, that is why even the casting will develop these kind of small

irregularities on its surface that is why we use to overcome this limitation we keep the size of the pattern little larger. So, that later we can machine the casting that is how the dimensional accuracy of a cast part is not so good.

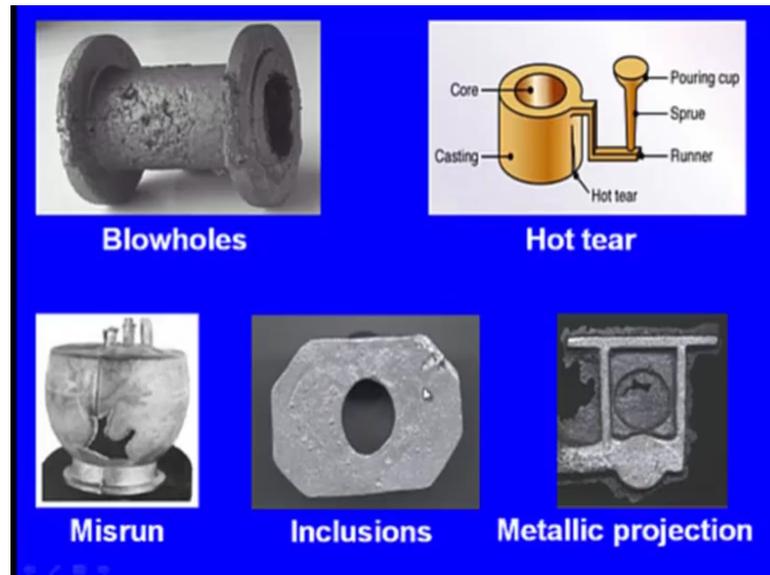
Next one the next demerit is the poor surface finish just now we have seen that the molten metal is poured into the compacted sand medium inside the compacted sand medium, there will be a hollow cavity and into that hollow cavity we pour the molten metal the hollow cavity will have the small irregularities accordingly even the casting will develop these irregularities that is how the surface finish is very poor in the case of the castings.

Next one requires the casting process requires close process control means the molding medium has to be prepared very carefully the molding sand contains the base sand and the clay and the moisture this clay and moisture should be controlled very carefully if the clay is less the binding of the medium will be very less and it may break and if the clay is very tight then what happens the ability of the hot gases to pass through the sand medium will be very less. So, these hot gases will be accumulated inside the mould cavity and they may lead to defects.

Similarly, the moisture of the water in the sand should be controlled very carefully if the sand is very dry if the water is very less what happens the binding action will be very less the molding medium may break on the other hand, if the moisture content is very high what will happen when we pour the molten metal this molten metal comes in contact with this moisture immediately this moisture will turn into vapor, if the moisture content is reasonable it will escape, if the moisture content is very high the whole steam may not escape outside and part of the steam will be staying inside the mould cavity and this will develop into defects.

Next one there are defects can develop in the castings like blowholes hot tearing misruns inclusions metallic projections, shrinkage porosity these are some of the defects of the metal castings. In fact, all these defects we will be studying later in detail. So, these are the important defects what are these defects let us see so this is you can see few defects here.

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So, this is a blowhole means what happens the moisture content was very high and the clay content was very high excessive of hot gas and steam was produced and the excessive steam was not able to escape through the sand medium, because the clay content was very high and the steam is occupying on the surface of the cavity that is how we can see large holes on the surface of the casting.

So, these kinds of holes are known as the blowholes this is a defect and this kind of defects can occur in the casting. Now you can see another defect is the hot tear; hot tear means a crack on the casting during the solidification process, there are several reasons of the hot tearing, but we will be just we are knowing that there is hot tear we will be learning the reasons for this and how to overcome this defects in our subsequent lectures.

And here we can see another defect called Misrun this Misrun means here it say kind of what say closed vessel and here you can see the metal has not occupied the thin what say portion because the casting has got a thin surface thin what say cross section the molten metal could not flow at particular location this is known as the Misrun this is of no use now why this Misrun is happening and we will be seeing in our next lectures.

Next we can see this are the inclusions; inclusions means foreign particles like slag or sand particles will come along with the molten metal and they occupy on the casting here you can see an inclusion. So, again this is a defect next one this is a metallic projection

and actual this is the actual casting, but here you can see some projection is there which is not required this is again a defect.

Next we can see another defect called Shrinkage porosity.

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Now, you can see this is the casting, but inside there is a hollow cavity a depression. So, this is a Shrinkage porosity. Again we can see this is the casting and inside there is a hollow cavity which is not required and which is detrimental this is the shrinkage porosity; likewise there are more defects these defects should be minimized otherwise if the sufficient care is not taken these defects will be persisting and it is a loss to the industry and all this defects we will be studying in detail in the next lectures.

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Now, finally, the classification of the casting process; the casting processes can be broadly classified into 4 types. One is the conventional molding process; second one the chemical sand molding process the third one permanent mould process.

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And the fourth one the special casting process, under the first one, under the conventional molding process we have green sand molding, we have the dry sand molding and we have the flask less molding. Green sand molding means where there is moisture in the molding sand are in the mould if there is moisture then we call it as the

green sand mould. In some cases for making the large castings what they do is after making the mould they take this mould and dry it. So, that the moisture will be dried out this is known as the dry sand molding and in all these cases we use the molding flask and what is this molding flask we will be seeing in the next lecture and there is another what say process under this conventional molding process that is the flask less molding. So, under the conventional molding process we have this 3 green sand molding dry sand molding and the flask less molding.

And the second broad classification is the chemical sand molding process and of this chemical sand molding process we have the shell molding, we have the sodium silicate molding, we have the no bake molding and in the third category that is the permanent molding process, we have the gravity die casting and also the pressure die casting.

Sometime back I have told you the sand what say mould medium was later substituted by the metal also here instead of using the sand medium we use the metallic medium, into a metallic mould we pour the molten metal. And in one case the into the what say metallic what say mould we pour the molten metal with all through the gravity and in another case we applying external pressure into the metallic moulds and that is known as the pressure die casting again this pressure die casting is sub classified as the cold chamber pressure die casting and hot chamber pressure die casting in the cold chamber pressure die casting the furnace will be away from the cold chamber pressure die casting machine whereas, in the hot chamber pressure die casting the furnace is an integral part of the die casting machine.

And in the fourth category the special casting process we have investment casting, continuous casting, vacuum sealed molding, this is also known as V- Process. And next we have the squeeze casting, process centrifugal casting, stir casting plaster molding, evaporative pattern casting ceramic shell molding slush casting. So, all this we are going to learn in the subsequent lectures.

And friends today we have seen the introduction to the metal casting, when it has originated, how it has originated, how the ancient man has used this technique to manufacture the rudimentary tools like the spear head, axe head, or the arrow head and how this process has developed and what is its role in today's world we have seen and we have seen the important applications of the casting process in the modern world and

if there is no casting process today we have to shut down the power generation industry we have to close down the automobile industries, we have to close down the all the machine tools, no space applications, no aero craft aircrafts nothing is there. So, the metal casting has become part and parcel of the human race.

We are going to learn more topics in the subsequent lectures.

Thank you very much.