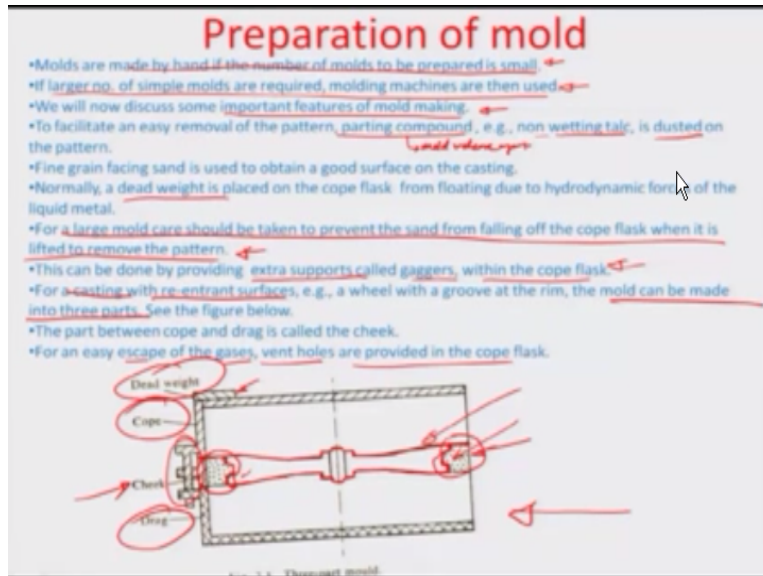Hello and welcome to this manufacturing process technology part 1 module 15 We would discussing about how to prepare different molds.

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Preparation of mold

- Molds are made by hand if the number of molds to be prepared is small.
- If larger no. of simple molds are required, molding machines are then used.
- We will now discuss some important features of mold making.
- To facilitate an easy removal of the pattern, parting compound, e.g., non wetting talc, is dusted on the pattern.
- Fine grain facing sand is used to obtain a good surface on the casting.
- Normally, a dead weight is placed on the cope flask from floating due to hydrodynamic force of the liquid metal.
- For a large mold care should be taken to prevent the sand from falling off the cope flask when it is lifted to remove the pattern.
- This can be done by providing extra supports called gaggers, within the cope flask.
- For a casting with re-entrant surfaces, e.g., a wheel with a groove at the rim, the mold can be made into three parts. See the figure below.
- The part between cope and drag is called the cheek.
- For an easy escape of the gases, vent holes are provided in the cope flask.

And typically the molds are made by hand that is very small in number obviously if you want to build one component or may be about closed probably ten components still economical that you make the molds mostly by ramming or squeezing sand by preparing a cope half and drag half separately and trying to now you know match them together.

So this whole thing can be a hand operation by the molder but the larger number of simple molds are needed than obviously for the yield purposes molding machines have to be used for example if you are talking about casting industry which produces that let say at the rate of probably 50000 casting of day or small parts.

So there every time making this kind of indicate molds is not possibility as you know you know it has to be a rigorous process of aligning a pattern to the core type of casting and for each and every part if such a process is executed and manually it is going to take a large amount of time so obviously you have to automate process and have to see how in a better manner this sand can be thrown or sling or slammed or whatever.

You know and the process has to be fast so that it can produce the patterning of the sand at a higher rate so we want to discuss some of the important features of the mold making process which are normally used for making or the system handle better or handle easily the metals in the liquid state. So one of them is you know using of this parting compound which is also known as the mold release agent the idea is that you should be able to distinguish after removal of the frozen metal piece.

You should be able to distinguish the mold half of the mold surface properly with respect to the piece which you are removing so for doing that you need a parting compound which is normally some kind of a talc powder you know it is like non wetting talc powder which is dried dust and which it is sprayed with than intention that whatever absorption whatever moisture was there within the mold part of absorbed.

And it formulates the layer you know parting layer on the surface where it immediately gets dried up and gets loose so that it releases the surface and the metal does not have to formulates some kind of bondage with material on the surface so the mold breakage will not be there then you can actually able to remove the frozen material properly.

So it is normally dusted this talc is dusted on a pattern before actually doing the molding so it will also ensure a sort of a finer grain facing by going into the voids etc of the surface because it is loose dust and so it can go into the voids easily smaller in size and the voids between the sands.

And so you can have a smoother surface rather than rough surface because of the you know distributed voids within the top of the sand cast there is also the requirement of a dead weight, it sometimes placed on the cope flask as you can see here in this particular illustrations three part mold assembly this is the dead weight on the top so these are normally provided to you know void the floating because of buoyancy forces or hydrodynamic forces the metals enters the molds.

Obviously if even if the cope half is the smaller in comparison to the drag half as I discuss before there is tendency that the floating the liquid metal getting into a high pressure may able to float up the cope with respect to the drag because of the hydrodynamic forces okay so in order to stop that it is better that you always put a dead weight on the top of the cope half.

So that it remains intact and it manages to stay back in position instance of all these hydrodynamic forces are available so dead weight is normally placed .for a larger mold care should be taken to prevent the sand from falling of the cope flask when it is lifted and that is mostly to remove the pattern it should happen that you have the pattern implaces and the sand is nicely holding the moment.

You try parting the upper half the sand starts falling back so therefore the pattern gets damaged or lost so you have to have enough pressure and you have to have enough percentage of the water or sand and the clay as high illustrated just earlier module so that you can hold and constitute an integrated surface the exactly negative of the pattern in place.

So it can be provided you know extra supports and these are sometimes known as gaggers and which is normally provided within the cope flask to ensure that there is no fall of the sand loose sand thus damaging the overall pattern surface need cope half the other purpose of the gaggers is basically because if the casting size is too large than may be the sand is unable to hold such a weight of the sand over the whole cope half.

And therefore additional support etc which may be of the same metals has you are casting as to be made so the idea is an metal comes and fills up obviously this metals is gone to melt away into the parent metal makes which is otherwise, which are otherwise holding the sand cavity in place but there if it mixes then again hydrodynamic forces come because the liquid state.

And so like to still be compressing the mold on all sides and that hydrodynamic forces said would keep it stabilize after the liquid metal is poured so the purpose of the gaggers is only from the point of time that the patterning has been done to the point of time that the liquid metal reaches the mold cavity so you can also have re-entrance surfaces for casting and that is why casting is normally carried out in three parts as you can see here this big wheel casting so there is other half here which actually ease in the cope half.

You can see this particular half you know as been designed to hold the pattern you know the cope half and you can see this surface here which is really not there in the original pattern and it is the reentrance surface okay so this surface is basically preventing the metal from flowing out so that this cross section of the wheel can be obtained it is circular pattern that we are talking about in this particular things okay.

And so this shape is only obtained because you give additional sand reentrance sand only once the patterning has been done and it will prevent the metal from going into this place okay so such parts are also available and so he use now three parts of the mold and normally the name of the metal part is cheek. So you have the cope half that drag off and the cheek all three clammed together.

So you have to ensure this clamping arrangement also to prevent the cheek from moving up because of the hydrodynamic forces its al moving out because of the hydrodynamic forces etc you have to provide the escape out of the gases by vent holes and this are normally provided in the cope half cope flask so that some time to time you can withdraw the gases which are soluble otherwise the metal.

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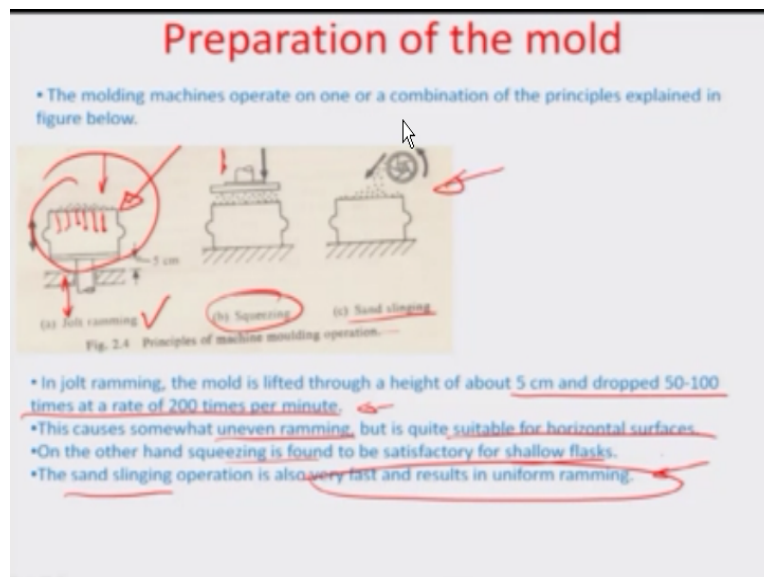
And let us now talk about a little bit high through put production process of the mold so typically there are different techniques like jolt ramming you can see this is the you know cope half drag half assemble together with sand and you have poured sand over it and basically trying to pick up the mold and jolt it by giving a linear motion to and fro linear motion here.

To this surface so that the sands settles down so by you know changing the momentum of the sand from time to time ensure that sand compresses with respect to each other and there can be other methods high throughput methods of doing and molding or example you put the sand and squeeze you know so this can be automated system which can do squeezing action over several mold.

That single part of time even this can be an automated system were the whole cast is basically put with all the sand and jolt rammed so that sand con settle down there are slingers which are even able to increase this through put further were basically sand is thrown at higher pressure so that it can go and sit on the top of the you know cope and drag.

And squeeze on the top of the pattern so in jolt ramming the mold is lifted through height of about 5cms on dropped 50 to 100 times of the weight of 200 times per minute some uneven ramming is here but it is quite suitable for horizontal surfaces, for shallow flask kind of squeezing is found to be a alternative.

And sand slinging operation is mostly you know when there is a uniform ramming requirement which is there of the whole sand .so apart from that obviously the process of separating the cope and the drag half and releasing the pattern as to be automatic so in large foundries this is how things are normally made.

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So let us know look into another aspect which is melting. so obviously we have now prepared the sand mold we have also prepare different kind of patterns we are integrated the patterns on to salve mold formulated the cavity given a riser and a runner and also the gate and pouring basin so now the next question is that you have to melt in the material.

So that it can come to the liquid state and flow into the mold cavity so proper care needs to be done during melting it is essential for good and defect free casting the factors that are to be considered for melting include gases in metals this is very, very important constituent hydrogen for example makes iron go very brittle so as low solubility as possible would be advisable when you are talking about making perfect of you know high strength castings.

Then the selection and the control of these scrap is very, very important obviously flux the furnaces and the temperature which can release lot of gases because of presence oil etc. that is as over important in this case and so typically what do gases do so the gases in metals normally led to as I told you faulty castings however the presence of a controlled amount of a specified gases can be beneficial particularly imparting certain desirable qualities of the casting.

How do the metals or how do gases get trapped into the metals again if you had no proper venting arrangements for the gases the first trapping that may come is mechanical trapping because obviously there are gone to be some hydrocarbons or oils within the furnaces which is going to generate this gas and the liquid has a certain solubility and there are classification of the materials based on.

Whether there are endothermic or exothermic where the solubility may vary with that the temperature in a non-identical manner and for example you know the as regards the group which is called endothermic metals they may include metals such as aluminum magnesium copper iron and nickel and exothermic metals may include other like titanium and zirconium okay.

So the difference here is obviously in terms of what happens to the solubility of the gases into this materials at higher temperature or may be during cooling situations. so mechanical tramping is one aspect so because of the bubbling of the hydrogen and not letting it vent out very easily there can be also case where let us say two different metals have been casted as an alloy and there is a variation in the solubility of gas phase and one of the metal systems and it actually suddenly out gases because of the vent temperature that gas does not have any other way to go.

But to get trapped in the material and then obviously there can be chemical reactions between the gases and some phases of the material which may lead to again embrittlement of the material .so these are the some of the ways that mechanical you know gases are kind of introduced within the casting.

And most common problems which are there in the casting of iron and steel are the two gases hydrogen and nitrogen and as far the metals are divided as I told you for the solubility of hydrogen you can divide them into and endothermic and exothermic category the only difference here is that if you look at the solubility equation.

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The solubility equation here as is related to some constant C times of an exponential minus Es/Kθ, θ is the absolute temperature and you know K is a constant so related to the materials so this is the absolute temperature K is a constant related to the material and C is also an other constant okay again related to the material.

And this Es here is really the heat of the solution for one mold of hydrogen so Es is positive for the endothermic materials so therefore you supposing θ over to increase I am saying

$$S = C exp\left(\frac{-E_s}{K\theta}\right).$$ so if θ were to increase and Es is positive in this particular case.

So obviously the solubility is going to go down as you are going temperature and the solubility would be more as the temperature goes down okay because now $C/\exp\left(\dfrac{E_s}{K_\theta}\right)$ this would this term here as a θ goes down would increase and the solubility goes down as the θ goes down also so there is no problem that in such cases the gases are going to get out gas.

Obviously because from the freezing temperature of the casting you are going to room temperature and if the process are doing that you are taking the temperature down so as the temperature is going down the solubility of the gases are also going to reduce as you can see here from this plot of however is this Es is negative which is the case of the exothermic materials.

The problems starts happening okay because now of the negative Es value the decrease in the temperature may actually result in an increase in the solubility okay so obviously in such materials like exothermic materials as the Es value is negative the solubility here will be C $\exp\left(\dfrac{E_s}{K_\theta}\right)$ and if θ decreases in this particular case obviously this exponential factor is going to increase and the solubility also increases.

So if the temperature comes down in an exothermic material the solubility of the gas is going to increase so that is the problem because the gas cannot be precipitated   anymore so where does the gas go so it formulates small pockets small voids within the materials imperfections and such exothermic materials is very difficult to actually do the casting process.

And you have to somehow the able to play around with this solubility by making some additives or something so that the gases can start coming out .so hydrogen is wide is so detrimental to the you know particularly the exothermic materials is that actually dissolves interstitially within the exothermic material so it causes lot of mechanical energy lots of stress within the lattice by distorting the lattice by getting it into the interstitial sides.

You know so it is a sort of defect that you are introducing into the metals by adding a hydrogen species everywhere within that lattice site so the lattice gets prestressed because of it okay and that is why it is not very good idea to have hydrogen into play particularly with exothermic materials.

So the solubility is going up with the reduction in temperature so you can see this table here the solubility of hydrogen in various metals corresponding to one atmospheric pressure and you can see that for iron although liquid solubility is 270 cubic cm per kg the solid solubility is about 70.

Similarly in magnesium it is 260 and 180, in copper it is 55 and 20, aluminum it is 7 and 0.4 and this brings the problem that particularly in the liquid state if the solubility is high of the material an in the solid state the solubility is low so therefore where this is the gas is going to go if supposing the material is exothermic in nature.

So obviously it is going to be there has gas pockets because now it has not being it has been sell out of the material and it cannot go because the solid solidification rates is quite fast and there is going to be formulation of gas pockets so that is how solubility is very, very important from melting perspective when we talk about castings.

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And in a way the other important factor here which would like to see is that if you look at you know is there is an quantification of the percentage hydrogen present as a function of the partial pressure of the hydrogen which is around so this is actually given by Sievert's law which states that percentage hydrogen present is basically proportional to the partial pressure of the hydrogen to the power of half.

And this is actually the partial pressure of the hydrogen in the atmosphere over the melts so when you are melting this you know iron in the furnace and there is some hydrogen pressure which is there it actually determines what is the percentage solubility or what is the percentage dissolution within the species.

So the constant K is actually can be evaluated from table 2.2 where you can see these solubility S to be given in iron and so with that you can evaluate with different partial pressure is one atmosphere and the percentage present is some X cc per kg as a percentage so then the K obviously is going to be the value cc per kg as a percentage of hydrogen present.

So you can calculate the table or you can from the table you can calculate this K value of the various metals assuming one atmosphere partial pressure of hydrogen the primary sources of the hydrogen in the melt half furnaces dampness air and oil I think I have mentioned this already so you have lots of excess oil air and dampness or grease.

And this can actually hydrocarbons they can be generate hydrogen and carbon dioxide and these two and that get added into the melt there is no simple dehydrogenation to eliminate hydrogen in the form of slag that is an other big problem so you have to really when in case of hydrogen of avoid formulating at the first place because you cannot remove it has a floating slag layer you know. so at the partial pressure of the hydrogen can be reduce by bubbling some other dry insoluble gases.

And that is only way where you can actually reduce the partial pressure and for non ferrous metals things like chlorine, nitrogen, helium or argon is very frequently used so that the hydrogen partial pressure drops down and the solubility of the percentage of the hydrogen present also drops down so over all you can have a good situation with less as less as possible of hydrogen in the cast. for again ferrous and nickel materials kind of base alloys you cannot use nitrogen because of them formulating again nitrate which are not very conducive as strength aspect of the castings.

And it may generally affect the grain size also you know the grain size is an important mechanical property which brings out the strength aspect of the materials generally better procedure is to avoid the formulation of nitrates so that this strength can be reasonably control so

there is an increasing trend in the industry you have doing vacuum melting nowadays so it do not really bother about the various gases.

Because you out gases the furnace before you have started the melting process and so this is being increasing used though it is expensive and you know it has to really be a smaller furnace and it cannot be you know apply to very, very large scale melting process because vacuuming a certain region becomes very expensive but there is a use increased utility of vacuum based melting methods for producing you know melts.

So I would like to end on this module here but in the next module we will look at some of the furnaces and then start designing some real castings with you know among the dimensions of the cavity or the runner at the time of flow of the materials so and so forth thank you so much.

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