Manufacturing of Composites
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Lecture – 12
Compression Moulding Process

Let us move to lecture number 12; lecture number 12 is focused towards compression moulding process. Compression moulding process can be used for both thermosets, polymer, it can also used for thermoplastic polymers thermoplastic polymer matrix composite. That is why I thought like I will put this as the one of the last processes before starting into thermoplastic composites a overlap. In this lecture we will try to have a small introduction followed by it will be raw materials, different types of polymers then moulding process, what are all the process and then the process parameters.

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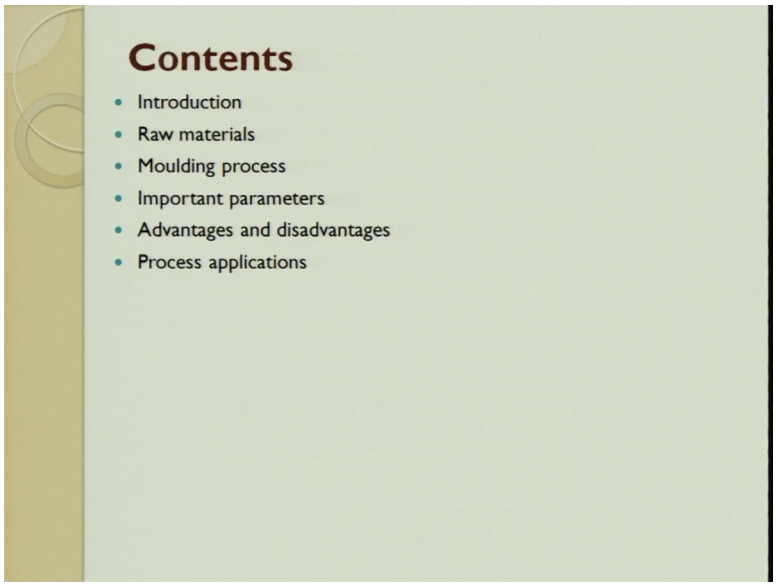

Which are very important and advantages, disadvantages and process applications?

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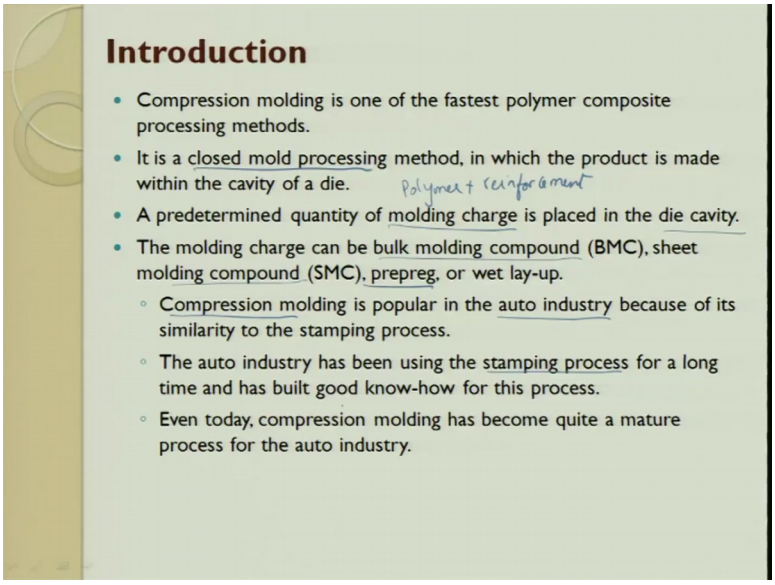

I would like to repeat my statement which I told in the beginning of this course itself manufacturing has 3 important parameters one is pressure, time and temperature. All the 3 parameters have to be optimumlly used to produce a required good quality output. Here in compression moulding this is a process which is a perfect example for what I have told. In compression moulding process we use pressure, time and temperature all the 3 at the require weightages, that you get a sound quality output and, here compression mould moment I said a mould you can have a both surface front surface and the back surface or both the surfaces we would like to have a very good surface finish.

When you use a mould we always get this a compression mould is one of the fastest polymer composite processing methods it is a closed mould process.

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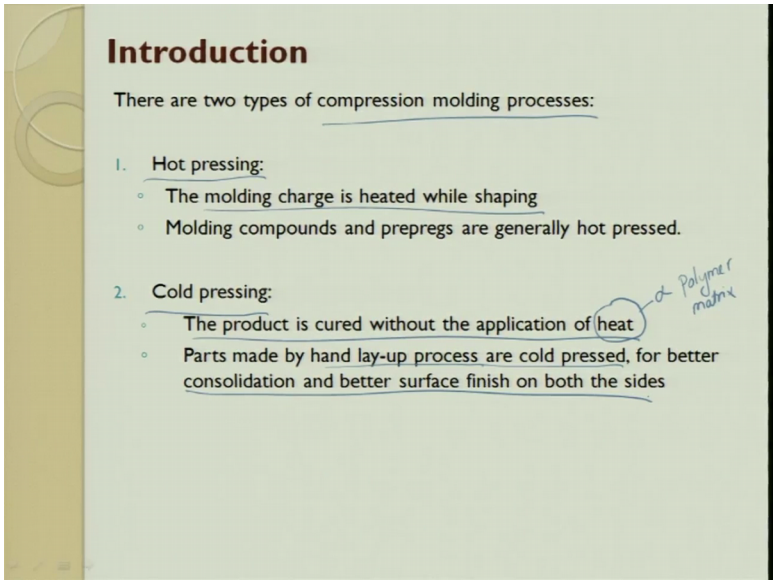

So, you are pretty sure about the quality of the output; that means, to say the surface quality both front and back you will get a good quality output, this makes the product which is to be confined within a cavity. So, you then it leads to another thinking that yes this process needs a die yes it needs a die. Then a predetermined quantity of a mould charge is placed in a die cavity, like in injection moulding process you have to inject some raw material such that this raw material flows inside the barrel and when it goes inside a die you try to get the output.

Here what happens they try to make the charge, here what moulding charge I said, this moulding charge is nothing, but a polymer plus a reinforcing agent. This reinforcement agent can be chopped strand mat and the polymer can be thermoplastic or thermoset, it is kept inside a die. The mould charge can be bulk mould component or a sheet mould component; that means, to say it talks about the surface to volume ratio of the components.

Bulk mould compound or a sheet mould compound, sheet mould has a large surface suppose if this one polymer and reinforcement you can mix it and prepare make a charge or what we do is we try to have a prepreg which is already there a prepreg is a resin infused reinforcement you have it in terms of a sheet, it is something like your banded which I told earlier also, you have it so, moment you remove the covering sheet top and bottom, immediately and if there is the required ambience around immediately it starts curing.

You can also buy a prepreg and keep it inside the mould cavity to make a required output, the compression moulding process is exhaustively used by automotive industry. So, automotive industry where they have a large surface area products they wanted to make covers on a bonnet they wanted to make or on a machine cover they wanted to move back it is basically a secondary structure it does not take, but load it gives you a covering they always use this compression mould process. The auto industries has been using it in a as a using the stamping process for metal forming, for them it was so easy to make a charge and with lesser loads they were able to make good outputs.

They could because of the existing knowledge they no on stamping they could quickly have a good know- how about the compression moulding process. So, today compression moulding process is very matured, people have understood all the process parameters their effect of parameters the flow patterns and now the auto industry is producing components to their requirements.

When I was talking about the compression moulding there are 2 type of press one is a hot press another one is a cold press. In a hot press what happens between the 2 plates you start applying heat, why because they wanted to have a small thermal gradient they would like to have a gradient so, that this gradient will try to give you a sound product. The mould charge is heated while it is getting shaped and then what happens the plates keep continuing to apply that heat for some more time until the die is all locked and moment the time is reached the die is removed and then the component is released.

The mould the charge whatever is kept there is heated and kept there, so that you can have a better flow ability property. In a cold pressing the product is cured without applying heat interesting heats, heat has a direct influence over the polymer matrix, more the heats for an for a thermoset charring will happen, more the heat for a thermos plast the viscosity will change the flow pattern changes. This heat has to be very carefully handled; the product is cured without applying heat that you get a sound product, basically if you do not apply so, much of heat, natural you have to compensate it. The load which is applied on the on the component is high, the parts are made up by hand layup process or are cold pressed for better consolidation and for better surface finish.

So, here when we talk about die you can have a solid die or you can have a flexible die.

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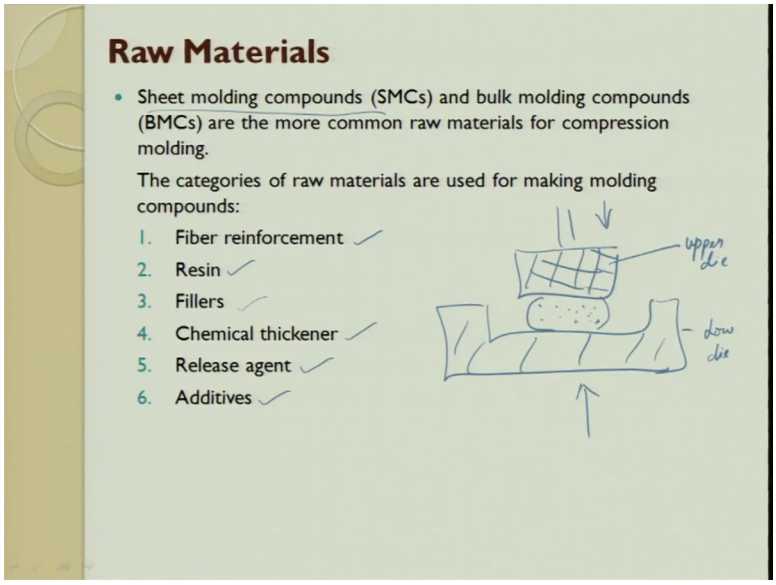

Flexible die means you this is a top die this is a bottom die, this is a die which is top and this is a die which is bottom the load is applied here if you want to apply you can apply load on both positions. This is the lower die, this is the upper die, you can have die these dies are made out of metal the load is applied from the top. So, you have the charge which is put here this is the polymer charge, it is put here, you apply load it can be one side it can be on both sides to get the required output.

So, here making these die is expensive, people have come out with novel ideas making the die itself flexible, the advantage is this die is flexible. It exerts uniform pressure and it is spread through so, that you get a good product. Raw materials Sheet metal moulding that is called as SMC and then bulk moulding component the only difference is surface area to volume ratio. So, the category of raw materials for making mould is reinforcement fiber reinforcements or short fiber you can also have particulate you want you can also have viscor you want, then you try to have a resin you we try to add fillers because fillers are used to fill up fillers are basically used to are not added to give strength, but to reduce the weight.

Fillers are use then chemical thickeners are used releasing agents are used because this polymer when it is the charge when it is in contact with both the dies there is a possibility that if the die surface is not smooth, it might get sticked to that, or they might say pinching marks are seen. So, you can see that pinching marks in order to avoid it and have a smooth surface finish we apply releasing agent and of course, additives for color we do. These are some of the raw materials which are added together to make a charge.

So, again the mould can be sheet metal or bulk depending upon the surface to volume ratio of the component, fiber reinforcement.

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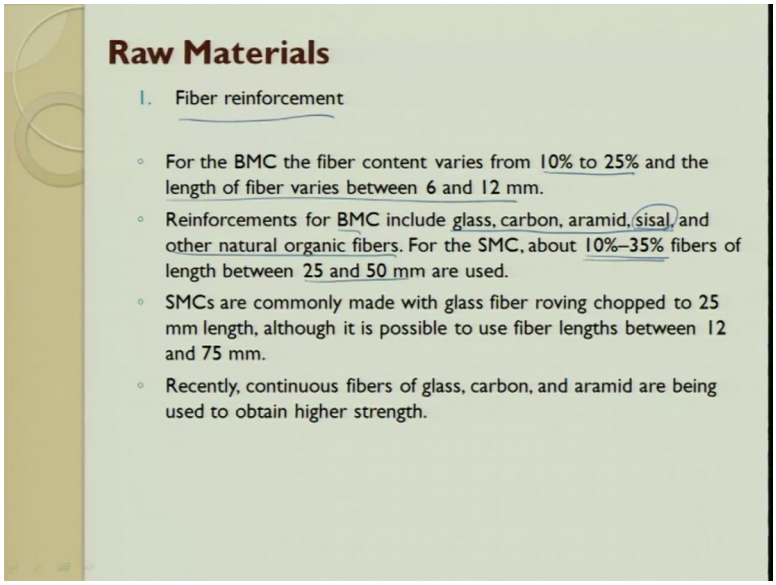

It can vary from 10 percent to 25 percent anything more than 25 percent the problem is it tries to restrict the polymer flow. So, the viscosity goes high and if the viscosity goes high then and the flow does not happen properly then within the stipulated time the polymer flow will not happen and reach at all points of the die.

So, you might get a poor quality output and the length of the fiber can vary from 6 millimeter to 12 millimeter, when you go for prepregs you can also use continuous fiber or a woven roving mat or a carbon mat can be used to get the required output. The reinforcement in BMC bulk are basically glass, carbon, aramid, sisal are natural fibers sisal and other organic natural fibers are also used today to get the required output. For example, if you are looking at the dive boards or the swimming pool, they are made out of compression moulding in the amusement park dive boards where you can just before falling into the pool you can see that.

That is made of this there people have started using glass fibers which are economical and people have also gone one step ahead then in using sisal which is a natural fiber. So, for sheet metal it can go slightly higher, 10 to 35 percent and the length can go from 25 to 50 millimeter are used. The sheet metals are commonly used for glass fiber roving of a

chop strand mat of this length, recently continuous fibers are also used for this particular application.

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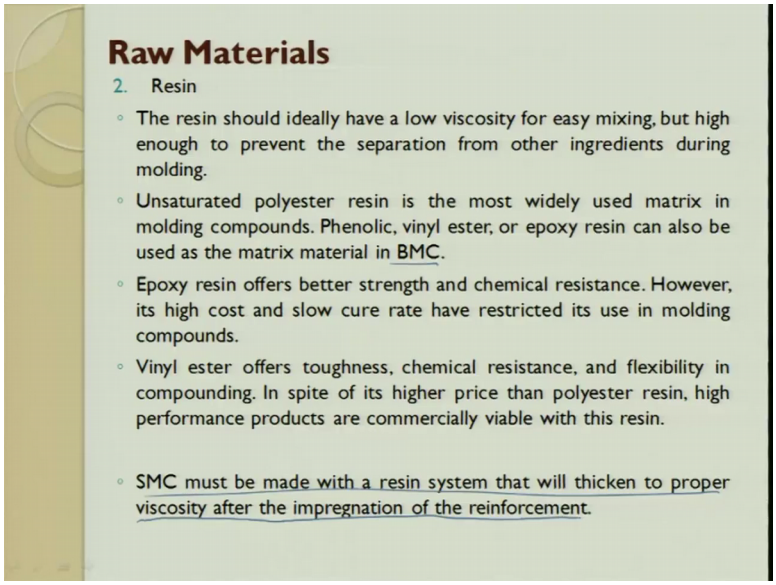

When you talk about Resin you have thermoset resin and you have a thermos plastic resin, thermoset resins we have already dealt in lot, I do not wanted to repeat. So, one example is polyester otherwise it is epoxy can be used this is for bulk and when you wanted to do for sheet yes you can also try reducing the content adding more the volume fraction you can tried for sheet.

The sheet metal must be made with resin system that will thicken to proper viscosity after impregnation of the reinforcement this point is very very important. So, we also add a curing agent for making this composite.

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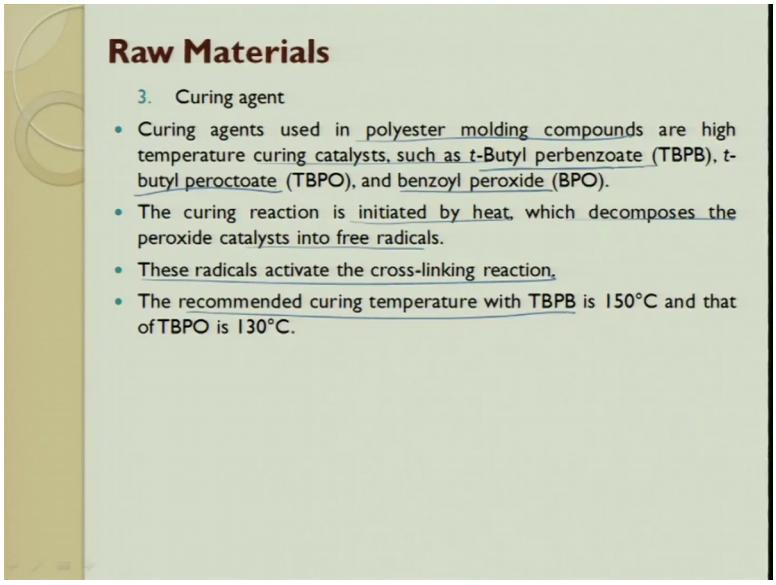

The curing agents are basically accelerators which are added, that it can try to reduce the cycle time. The curing agent used in polyester mould compounds, I have taken only one example polyester are high temperature curing catalyst such as t- Butyl TBPB which is t butyl perbenzoate, t-butyl peroctoate and benzoyl peroxide BPO all these things are used as catalyst for reducing the cycle time.

The curing reaction is initiated by heat which decomposes the peroxide catalyst into free radicals that is what is a mechanism which happens these radicals activate cross linking. So, once cross linking happens thermoset cures and it forms a solid, the recommended curing temperature for TBPB which is nothing, but t butyl per benzoate is around about 150 degree c and for TBPO butyl peroctoate is around about 130 degrees. So, you can decide what temperature you want to operative by choosing a proper curing agent without a curing agent the time cycle time goes larger.

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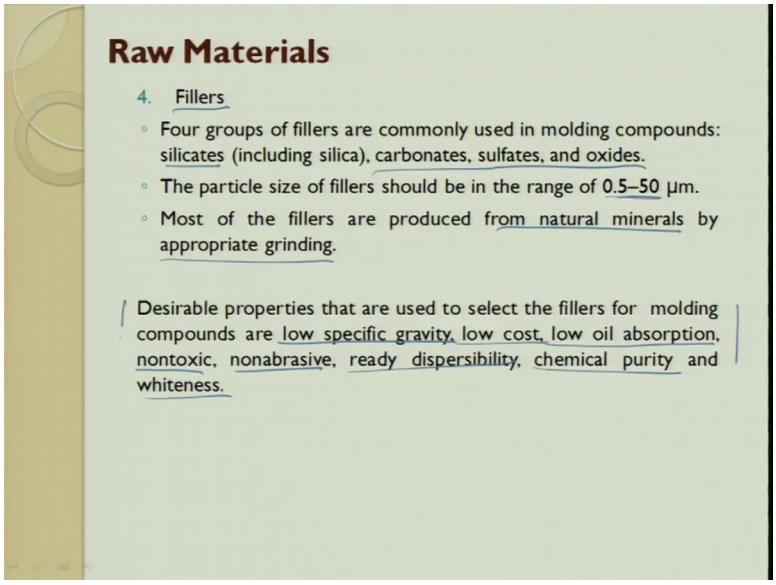

Then filler is there are 4 groups of filler which are commonly used in mould making one is silicate which is in expensive then carbonate sulfonate and oxide the filler size particles can be between point 5 to 50 microns most of the fillers are produced from natural minerals by appropriate grinding. So, basically what they do is they do a crushing process to get the required output. The desirable properties that are used to select a filler for the mould is one it has to be low specific gravity low cost, low oil, absorption, nontoxic, nonabrasive, ready to disperse, chemical purity and the whiteness all these things play a very very important role for fillers.

This is very important this will try to tell you how do you choose filler, what are the important properties which by which a filler can be chosen.

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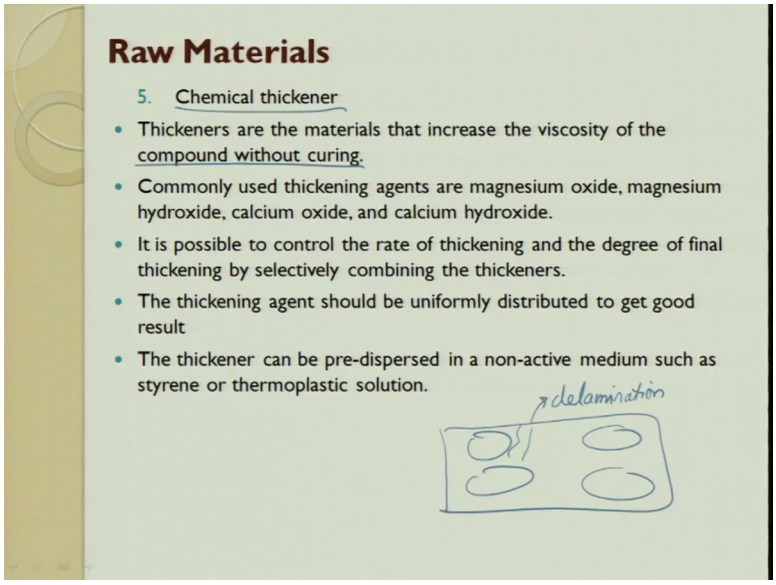

What are chemical thickeners, chemical thickeners are materials that basically increases the viscosity of the component without curing so; that means, to say what it tries to give you more self or more time for curing suppose what happens if you have a very large surface area component and moment the heat is applied and the catalyst is added it is quickly going to cure and moment it cures what happens is it cures as eye lens. If it cures as eye lens, between the eye lens and the non cure portion there is always a possibility of a delamination.

Delamination is defects where in which it will try to produce a poor quality output, in order to avoid and in order to have a uniform spreading we always add chemical thickeners. The chemical thickeners are basically to increase the viscosity of the compound without curing, the agents are magnesium oxide, magnesium hydroxide, calcium oxide and calcium hydroxide, it is possible to control the rate of thickening and the degree of the final thickening by selectively combining the thickeners. If you can play with your choice then you can try to have a very good thickening agent, the thickening agent should be uniformly dispersed to get good results the thickening can also be pre dispersed in a non active media. So, that it can later start curing when you apply heat and pressure.

The releasing agents which is the same which we used for a hand layup process.

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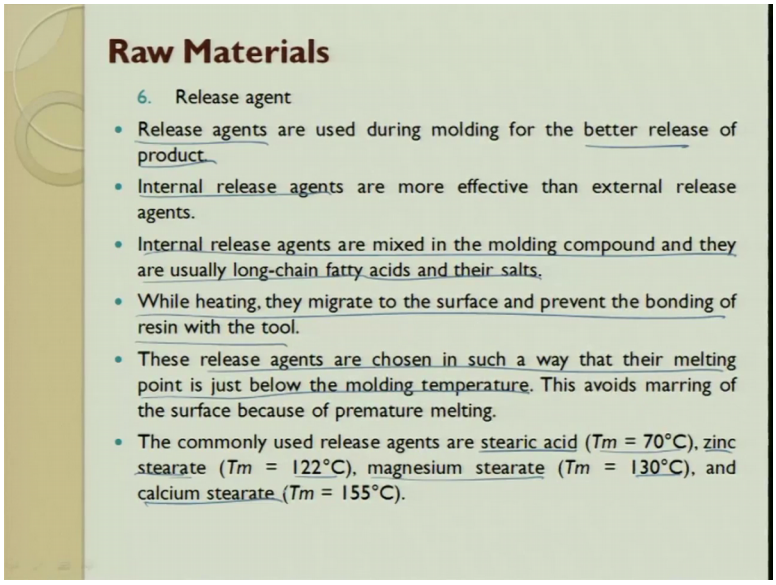

Releasing agent to give a better surface on both sides and generally what happens before releasing or during the time of releasing there is always a possibility that it creates a damage on the surface of the composites and in composites even a small damage on the surface will try to deteriorate the quality of the product to a large extent or exponentially.

Releasing agents are used for better release of the product without damage internal releasing agents are more effectively used for external releasing agents. Internal is internally within the die I am talking about, internal releasing agents are mixed with mould compounds and they are usually long chain fatty acid and their salts. So, basically this is first it is rubber it is coated with a releasing agent and then we place a die, while heating they migrate the surface and prevents the bond to the resin, now it does not react with the resin and forms some new compound.

While heating they migrate to the surface and prevent the bonding of the resin with the tool. So, that is what it does a true function the releasing agents are chosen in such way such that the melting point is just below the molding temperature, you should know that see for example, when you are we always use while making cake a butter paper, what is the function of the butter paper is nothing, but a releasing agent when we prepare good food stuff we always try to give initially and onion and oil coating. This oil coating is basically nothing, but a releasing agent oil coating or a butter coating or a ghee coating it is all basically acts as a releasing agent.

What is how do you choose a releasing agent, the releasing agent is chosen in such a way such that the melting point is just below the moulding temperature. So, that when it goes the moulding temperature if at all if it is a solid it becomes liquid and it quickly flows around. It is spreads on the die the commonly used releasing agents are citric acid which is having a melting point of 700 degree Celsius. Then we have zinc stearate which has a melting point of 122 degree Celsius, magnesium stearate which has 130 degree say and calcium stearate which is at 155 degree Celsius, these are some of the thing some of the releasing agents which are used.

What are the Additives which are used the Additives basically are used to give smoothness of to the surface; it gives color to the surface.

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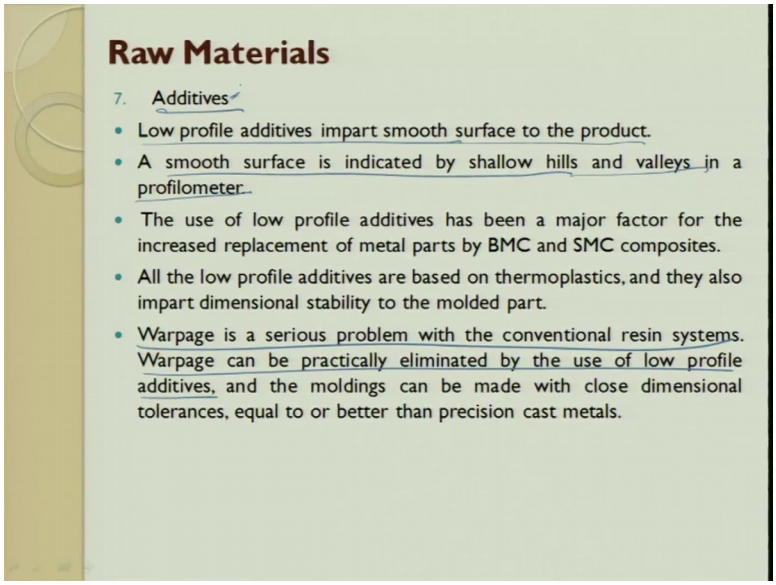

It sometimes also tries to avoid some of the dimensional inaccuracies, for example, warpages one.

The low profile additive imparts smooth surface on the surface the on the product and low the smooth surface indicated by shallow hills and valleys are which can be measured by a profilometer can be used to measure what amount of additive is used, so that it gets a smooth and the surface. Warpage is a serious problem while using the conventional resins; this warpage can be practically eliminated by adding some amount of additives, that you get a better quality output.

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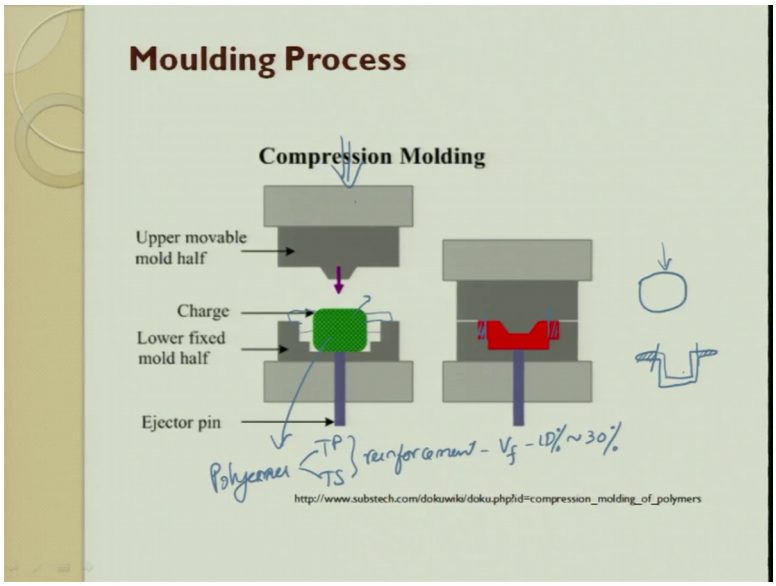

This is the process, here is a fixed die, here is a moving die, the load is applied from here this is a charge, it is a polymer, which is polymer which can be made out of TP or TS and then they are reinforced and the reinforcement can be of volume fraction may be from 0 may be from 10 percent to 30 percent maximum. This is what it is and then we try to apply pressure the material whatever is there the volume is known, it covers this the volume here and then tries to give you an output.

Generally what happen we always used to have excess volume here so, that this tries to form something like flash and these flash; that means, to say for example, if you have a box and then you try to apply load, when you have get a required shape a cup or something, you get something like this, so this is called the flash these flashes are removed, that you get the sound quality output and by the way these flashes are also intentionally made in the die. For example, if you consider this portion is to be trimmed they are intentionally given why because this puts a restriction to the flow of the polymer and because of this restriction there is a uniform distribution of material which happens inside the die.

These are intentionally flash has given, this gets trimmed and then you get a required output, this process is called as compression moulding process where in which you try to choose proper matrix, proper reinforcement, proper thickener, proper releasing agent and other fillers to get the require output.

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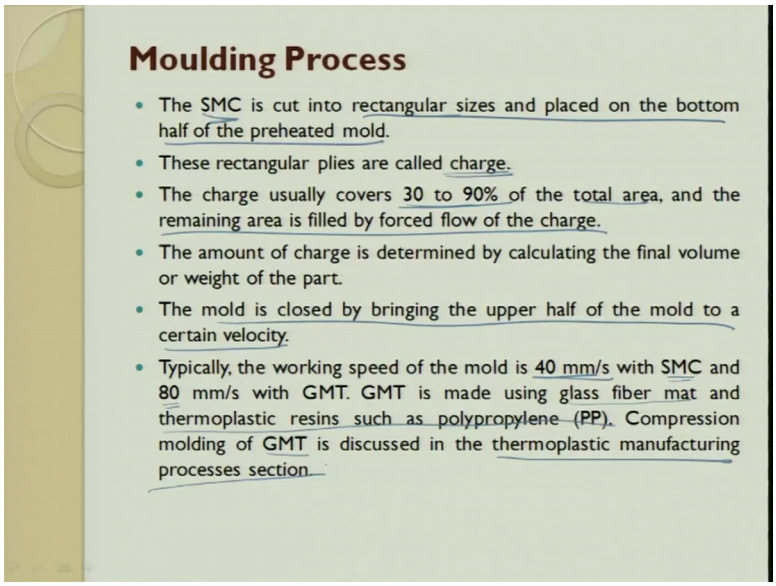

The moulding process SMC is nothing, but a sheet metal process is cut into rectangular size and placed at the bottom half of a preheated mould and here where is a heat applied the heat is applied in the mould. So, you can you will have heat the heaters which are here and this will heaters are there in the die it can be on the die or it can be on the plate also, you can have here heaters. So, that the uniform eating happens you can apply electricity or you can even apply oil, heat the surface die gets heated. So, that the work peace also gets the charge also gets heated.

The rectangular plies are called as charges, SMC sheet metal, here it is bulk, what SMC is we cut into rectangular pieces it is something like a bread loaf. So, you cut into several small thin layers and they are place on the bottom, each ply is there and then they are called as charge. So, 30 to 90 percent of the total area is covered by the total area and the remaining area is filled by force flow of the charge, I said there will be small amount of gap because of this pressure it goes off.

The mould is the mould is closed by bringing the upper half ah of the mould to a certain velocity it comes and rams over the die and then you get an output, here we assume that one is fixed one is moving you can have in real time both moving. The either the bottom is stationary top moves or top is stationary bottom moves or you can have both moving that is left to your requirement.

Typical speeds are 40 millimeters per second with SMC and 80 milli with GMT, the GMT is made up of glass fiber mat and thermoplastic resin such as PP, the compression moulding of GMT is discussed in thermoplastic manufacturing process we will see in the next section. So, please hold on with this GMT later we will discuss it, but as of now you have to record SMC sheet mode sheet moulding compound or a process SMC we are trying to do a 40 millimeters per second.

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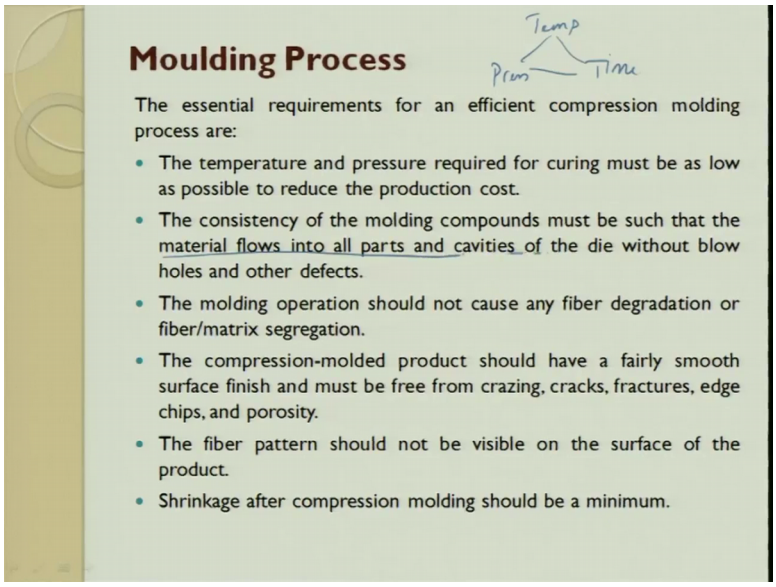

These are some of the things, as I told you temperature, pressure and time; these 3 things play a very very important role the weightages need not be uniform. The temperature and pressure required for curing must be as low as possible to reduce the production cost right because if the temperature goes high or the pressure goes high immediately it needs a power pack it needs a higher temperature to control. These 2 fellows has to be properly done if the temperature his not properly maintain viscosity will not be there, if viscosity is not there impure quality, if the pressures are very high then the viscosity the flow will not be proper. So, we have to maintain a proper pressure such that there is a flow also happening in the charge.

The consistency of the mould component must be such that the material flows into all parts and cavities of the die without any defects, blow hole is one defect. The moulding operation the pressure should not be so high such that it tries to break the fiber or the temperature should not be very high to degrade the fiber and the matrix.

In compression moulding process we fairly get a very good surface finish and the crazing, cracking, fracture, edge chipping and porosities are some of the defects which can be avoided by choosing proper process parameters the fiber pattern should not be visible on the surface of the product this is a very important; that means, to say the marks which are there should not be there and shrinkage after compression moulding process should be as minimum as possible.

This is nothing but I was previously talking about warpage the same thing here see the interesting part of polymer is as soon as you make a polymer product inside a die it might have a shape which you intended to make, but over a period of time there will be a residual stresses. These residual stresses allow the polymer either to deform or to shrink. So, that it tries to it shrinks and it produces a poor quality output, when we try to do this compression moulding process we try to add ingredients and maintain the shrinkage to as minimum as possible

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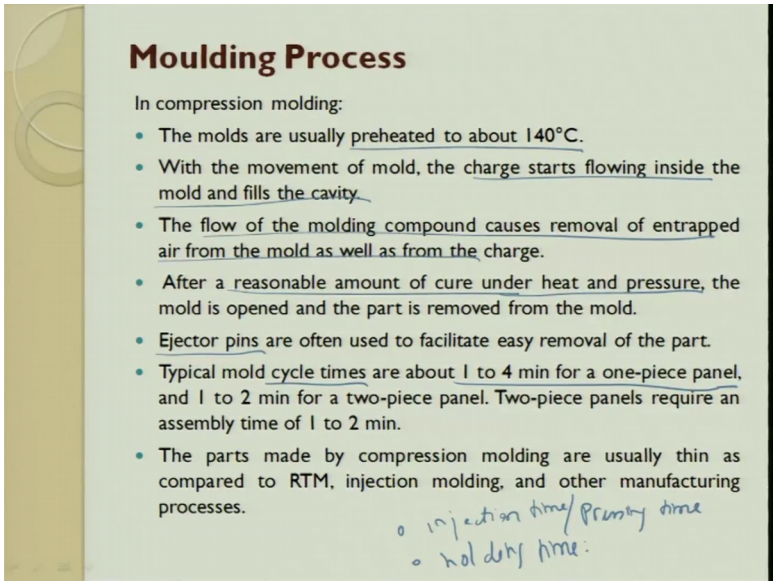

The preheat, you can definitely put the charge and then heat, but when you have a preheat already done, then the thermal gradient is not very high maintaining a thermal gradient is a low thermal gradient is very very important. We always what we do is we preheat the die and then we put the charge, when the mould in when the with the movement of the mould the charge starts flowing inside the mould and fill the mould the flow of the mould component causes a removal once the flow happens. So, there will be

enough of air gaps, this gap has to be released, there will be small vent holes on the dies through which it can go out.

There is a reasonable time for curing so; that means, to say you press the component the 2 dies close it and then you will not immediately release we wait for some for some time. This time is basically given for curing time, during the curing time there will be very high heat and pressure also applied. So, that we make sure that there is not much of shrinkage. Once the die for the top half and the bottom half of the die are released, then the ejector pins gets into action and releases the component. We always have a cycle time of 1 to 4 minutes.

So, for us you can this cycle time includes the injection time or the pressing time injection time or the pressing time whatever it is pressing time and the holding time, holding time is very important. If you do not hold a polymer it tries to take back the old memories; that means, to say that it tries to shrink, it tries to revolve, it tries to twist, all these things happen. So, holding time is basically to make sure the polymer losses it is memory that is the analogy they say, holding time is given, because of the holding time only the cycle time goes to 1 minute to 4 minutes.

These parts may be made by compression moulding are usually thin as compare to that of resin transfer moulding, injection moulding and other manufacturing processes.

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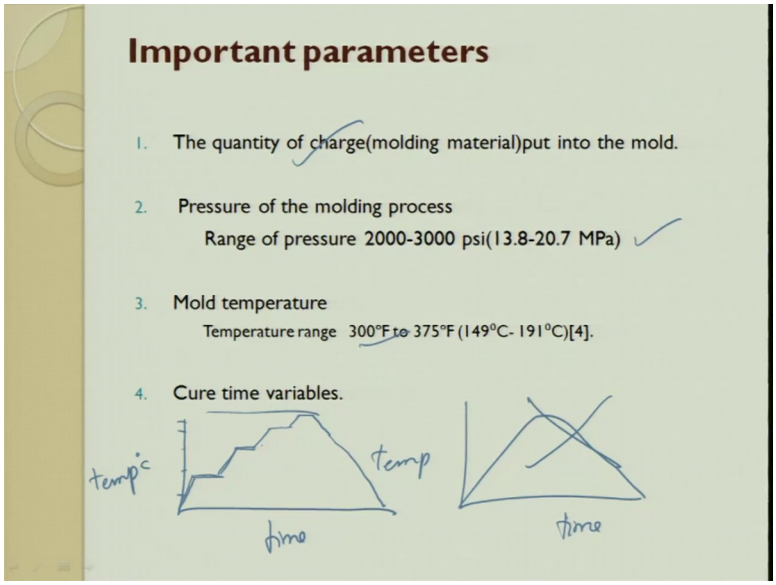

The important process parameters are charge which we all already know then we have pressure what is the pressure we apply then temperature and then time. So, generally what happens we do not see if you take this is the time and this is the temperature we do not go drastically like this and then we do not drastically come out. What we, this is not good, what we do it we try to take temperatures and we try to take time and this I am not giving you the value this is all in degree Celsius. So, what they do is they try to take it to sometime maintain it for some time, ramp it for some time, maintain it for some time ramp it, maintain it, ramp it, maintain it, and then slowly they allow to cure.

So, by this way what happens you have a uniform heating of the die and also the charge and they always try to maintain it from sometime this is nothing, but the holding time. This is a better cycle as compare to this cycle, here the cycle time is less here it is large, but still this produces a good quality output.

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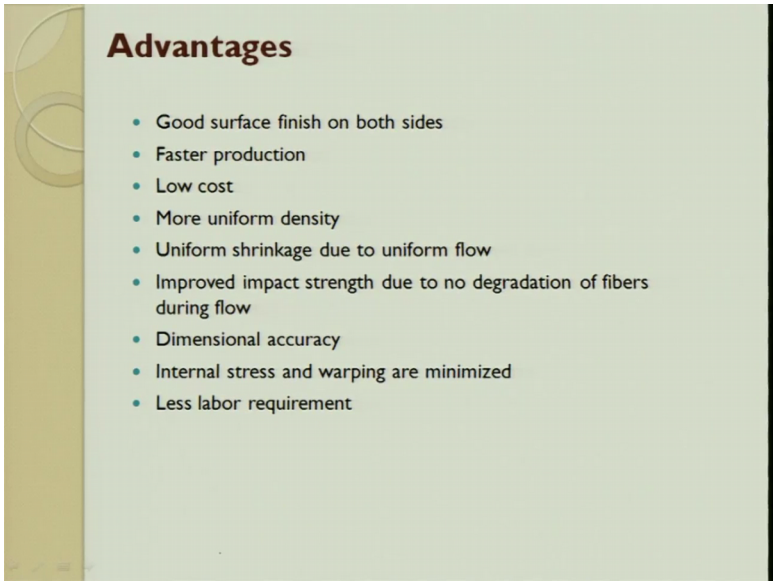

What are the big advantages of this process, we have one it is a good surface finishing process, it is a faster production process, it is low cost process, just like hand layup process, you can have uniform density provided, your inner charge the reinforcement is uniformly dispersed, you can get uniform shrinkage, if you play with the resin and other properties. You can improve the impact strength due to this non no degradation of the fiber, you can start doing it the dimensional accuracies are high, the internal stresses and

war pages are as minimum as possible and it is less labor intensive and you can do it with a semiskilled labor.

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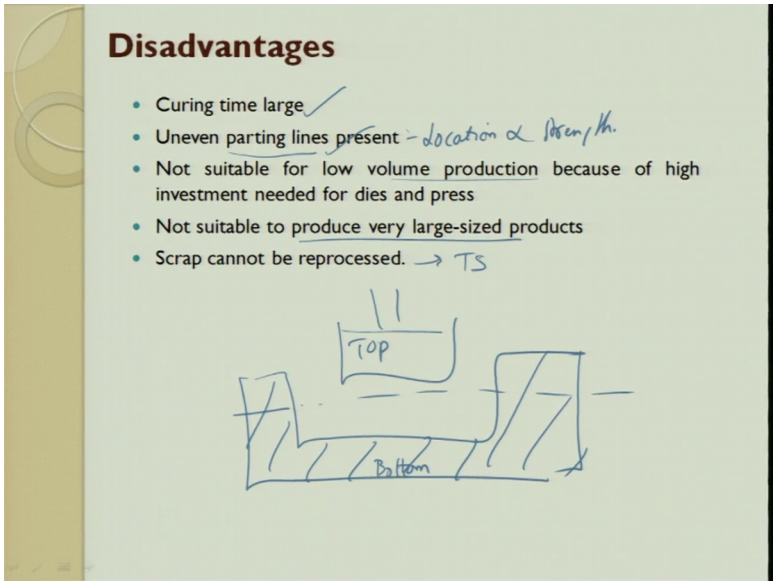

So, what are the big disadvantages the curing time can go very large depending upon the size of the part, there will be uneven parting line see parting line is one thing which is very important when you use 2 dies see the parting surface is very important. The parting surface is a surface this is a top die and this is a bottom die, the parting lines are lines where in which wherever you try to split the die into 2 halves. So, you will see a parting line this locating the parting line is very very important parameter if you because this parting line location is directly proportion to the strength of the product.

People try to first understand where to put the parting line and then try to maintain the parting line such that the strength is uniformly distributed. There is a big science, people who study polymers and then injection moulding process there is a big science behind it locating and there is lot of research also going on. It is not suitable for very low volume production and it is also not suitable for very large, it is only basically to suitable for batch production, here if you use a thermoset when you produce a scrap you cannot reuse it.

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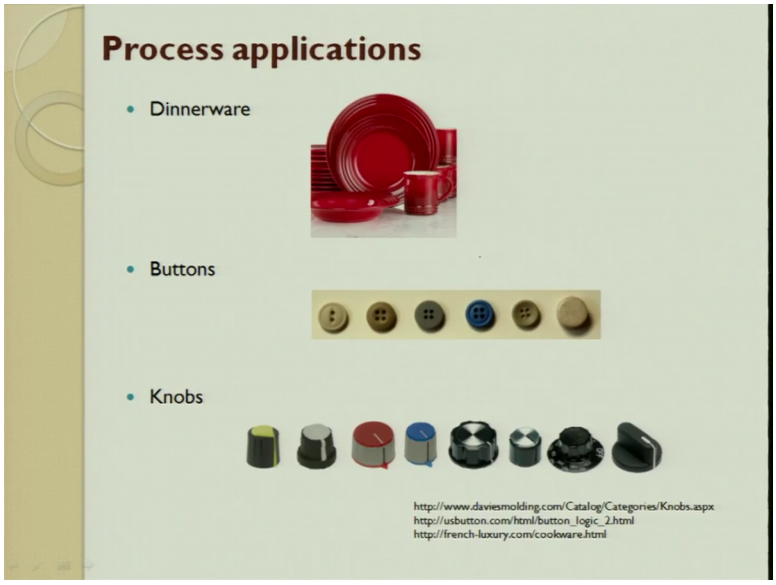

These are some of the components which are made out of compression moulding, in fact, these bottoms are not reinforced, but these buttons the interesting part is these buttons have internally they have also kept some fibers that is for may be the aesthetic purpose, but these are made out of compression moulding, you have this dining wares have been made, knobs have been made out of this process.

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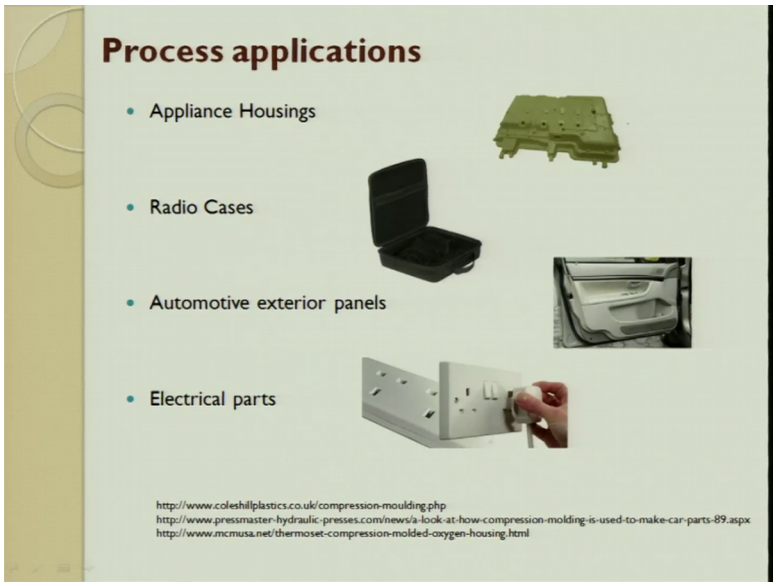

When you see large components like the covers which is used for machineries have been made, suit cases have been made through this automobile exteriors are through this process and electrical parts the fixtures for plug points have been made through this process, this process is very commonly used and it has wide set of applications.

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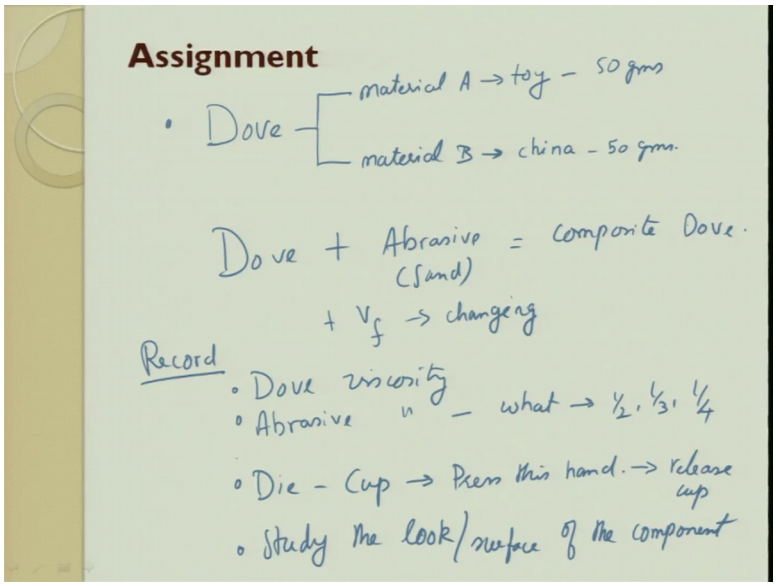

Assignment for today's class, what you will do is you will try to make a try to take a Dove may be a Dove which is of 2 different ingredients you take material A and material B, you choose whatever is your material B can be china clay and material A can be some toy which is available today. So, you can take those Dove and after taking this Dove may be you take some 50 grams and then take a 50 grams of china clay now what you do is you try to mix this dove with abrasives what are abrasives you can take sand mix it up with sand.

Now you will see what and then you mix it up with sand, first you will record what is the dove viscosity again qualitatively not quantitatively next after mixing the abrasives what happens to the viscosity and how much does it increase may be half one third in a very crude fashion next what you do is you try to take this dove which I will now say a composite dove this composite you try to take it and then put it inside a die again this die can be a small cup and then you press this with hand.

So, now you will see what amount of force you apply for these 2 materials and once you press it with hand release it from the cup and study the look I am mean to say the surface of the component. This will try to give you a feel how does a compression moulding process work in composites, the assignment I repeat you take a dove any 2 material it can be a toy clay or it can be a china clay you take any one, then you mix it up with abrasives you make a composite dove, this composite dove is put inside a cup and then you press it

with hand and then you try to make a part then after making the part release the part out of the die and then you start assessing which of the 2 dove is giving a better finish and here if you still have time you can play with changing the volume fraction of the abrasives. So, with this we come to a conclusion of compression moulding process from the next class onwards we will start moving towards thermoplastic processes for making composite material.

Thank you.