Manufacturing of Composites
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Lecture – 19
Processing of MMC: other methods

So, welcome back to lecture number 19. So, in this lecture, we will see the other processes which are covered under metal matrix composite. There are few doubts which students have asked, so based on the doubts, I just wanted to put first 3 slides explanation on some of the concepts which we have to know very clearly before making this processes. The first thing is interface they have asked what is the difference between interface and interphase.

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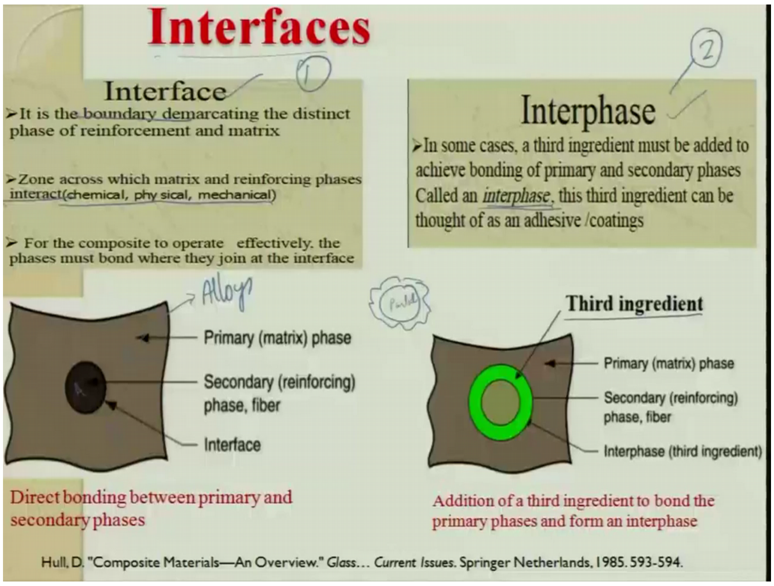

So, I thought let me explain to them because these 2 terms are used swap and used many a times and many people make mistakes while using these terms this interface why is this interface very important because this whatever is there is a reinforcing agent it can be a ceramic it can be a metal whatever it is. So, this property is material property is different and this is a matrix property which is different. So, between these 2 a, but; that means, to say this is a material b material between these 2 persons there has to be an interface this interface is nothing, but a boundary and this boundary we should have a proper locking or proper adhering between the 2 surfaces if we do not have for example, I have a reinforcing agent and let us assume I have a matrix something like the setting.

So, in between there is a void space. So, now, this particle ceramic can easily come out and second thing is the addition of this ceramic which is going to take the load will now never take the load because the load is not getting transferred from the matrix to the fiber. So, this is interface in composites what you are discussing is we would like to have intact interface. So, let it be metal matrix composite let it be ceramic matrix composite let it be polymer matrix composites thermoplast thermoset let the reinforcing agent be fiber let the reinforcing be particulate or let it be whisker anything you take you should make sure that it has a proper interface.

If the interfaces weak then the composite whatever you have fabricated will not work to your expectation or it might have early failure because of this interface problem. And how do you enhance the interface I will understand what is material a properly I will understand material b properly and then I will try to do some gelation in between a and b; that means, to say I will try to functionalize a such that it tries to make a proper interface with b. So, now, what happens that is in between a coating in glass fiber I said saline in coating in metal matrix composite when I said the agglomeration has to be avoided. So, we try to functionalize the particulate.

So, all these things are done to make sure you get a proper interface. So, this is the zone across which the matrix and the reinforcing face interact physically chemically and mechanically interestingly. Last class I was discussing about scanning electron microscope if you are going and if you want to understands still more final details if you see in metal matrix composite there are lot of beautiful images which are available in the literature which talks about a very good mechanical locking between the ceramic particle and the matrix. And by the way it is not only functionalizing the particulate we do we can also add alloys for example, silicon is added and you can add alloys and this alloys what we do is we can add a alloy and make sure that it does a proper wetting. So, this interface is predominantly to make sure that there is a proper interaction between came between the matrix and the reinforcement chemically physically and mechanically and for composites this interface is very very important. So, this is a direct bonding between primary and secondary.

This is a nether interface there is a spelling difference interface p h a s e phase different phases which we see in alloys in metals right. So, this is phase phase. So, in this case a third ingredient this is what I said you functionalized a third ingredient is added to achieve a bond between primary and secondary. So, what is the disadvantage of this fellow? Naturally you have to have a small sacrifice in the mechanical properties. So, this is nothing, but you add third ingredient which will try to functionalized is this green ring which will try to functionalized the particle and then you try to have a proper adhering.

So, in some cases the third ingredient must be added to achieve bonding of primary and secondary which is called an interphase; this can be brought by coating this can be brought by reaction depending upon the choice. So, now, I have made it clear interface and interphase. We would love to have this first and if it does not happen we would love to have this, but whatever set and done there has to be a proper interaction either chemically mechanically or physically between these 2.

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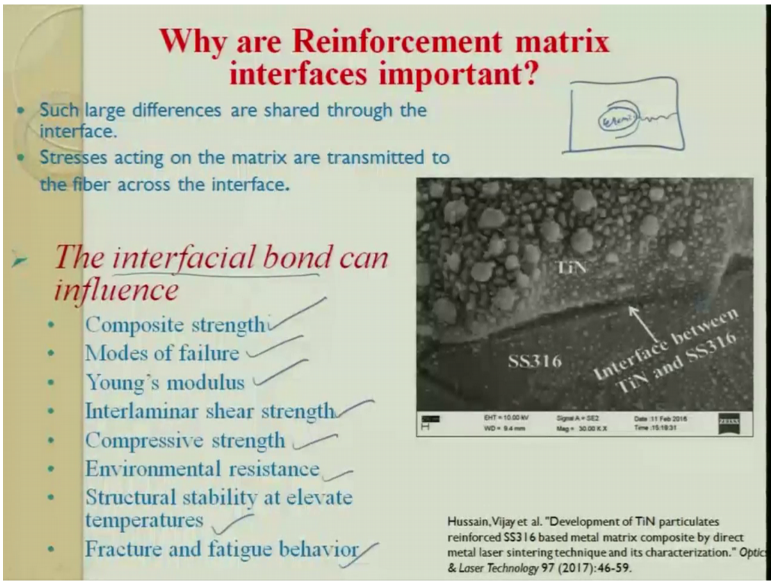

The next point, so here I have just put the sem figure. So, that you can understand; what is that? So, we can see large why is this difference coming why is this interface very important because the alloy whatever you choose as a different set of mechanical properties physical properties and the particulate whatever you choice that also has a different set of mechanical physical properties. So, because of this difference and properties and when you want to ask these 2 fellows to join each other; they have this interface problem.

The interface bonding can very strongly influenced composite strength modes of failure; I will tell you if you have a matrix; a reinforcing agent and if a crack is propagating. So, what happens is this crack strikes the reinforcement and then the energy is getting distributed over this is the ceramic. So, you see it gets distributed over the energy is getting distributed over the surface and it what it does is it tries to break the interface and the energy gets distributed.

So, what happens is the crack propagation is stopped. So, the modes of failures are changed or the modes of failures have a strong influence on the interface. Young's modulus has interlaminar; shear strength has compressive strength environmental resistance; if it is open and water can go inside its starts reacting or corroding whatever it is tries to weaken structural stability at elevated temperatures also goes down fracture and fatigue behavior also falls down drastically; if we have a very poor interfacial bonding. So, now, it is clear that interface is very very important;. The next thing which I was talking again and again let it be thermoplastic composite.

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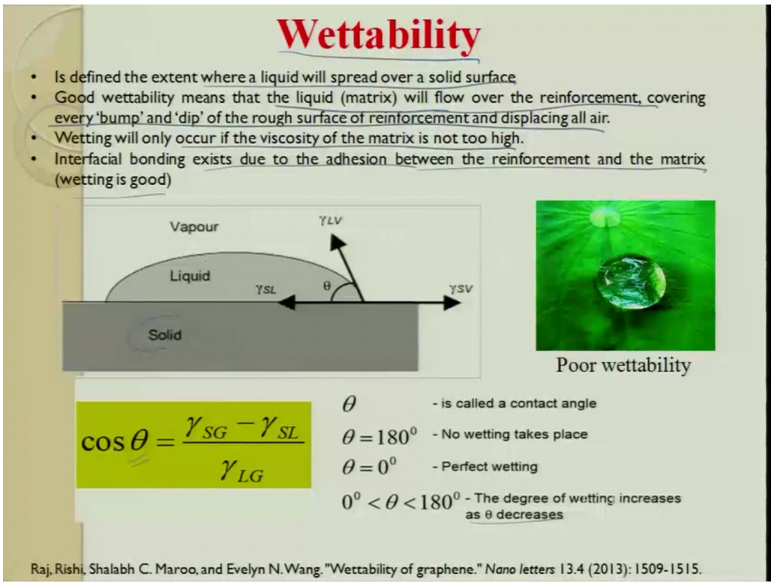

Let it be thermoset composite; let it be metal matrix ceramics which will see later. So, all these things basically depends upon a property call wettability; wettability means how good a the polymer can spread or can the matrix spread around the reinforcement. If we have very good wettability, then naturally you will have a very good interfacial bonding if you have very poor wettability and suppose if the polymer or the metal does not wet the ceramic. So, then it will try to roll of like this and you will have very poor wettability. So, it defines the extent when a liquid will spread over a solid surface this is wettability.

So, wettability in lotus leaf you would have seen. So, this is and this is now this idea is duplicated or mimicked in lot of engineering applications today to avoid corrosion right. So, in metal matrix composite they make very small textures on the surface and then the water droplet does not stick on to the surface; it changes from film condensation to drop wise condensation it roles of and there is no corrosion a good wettability means a liquid matrix will flow over the reinforcement covering every bump and dip on the rough surface of the reinforcement and displays all air. So, for this property for polymer to some extent it is easy to achieve, but when you do metal matrix you are trying to take the temperature of the metal alloy to a higher state and convert into liquid. So, viscosity plays a very important role. So, this wettability intern is linked with that and then it tries to wet the surface. So, wetting will occur if the viscosity of the matrix is not too high. Again it is the relative term; there is nothing called because it depends on the combination you too and interfacial bounding exist due to adhesion between the reinforcement and the matrix.

So, I have said theta is the contact angle, sopeople try to measure it by using contact angle experiments. So, this they always talk about angle; the angle should be greater than 90; angle should be greater than 180; they keep talking about all this angle; what is this angle? This angle is nothing, but a wettability angle or it is called as contact angle. So, if it is if the theta is 180. So, no wetting takes place; if it is 180; no wetting takes place, if it is between this; if it is 0, it is perfect, wetting you would love to have it; if it is falling between 0 to 180; then the degree of the wetting increases as the decrease in the theta.

So, there are lot of people have done lot of this thing experiment and they found out for various combinations it depends on the solid what you take it depends on the liquid what you take in the ambience what you play so many things come into existence. That is why you see when we talked about metal matrix composite last class when we are discussing about diffusion when we are trying to talk about squeeze casting and we will be trying to where you are trying to infuse metal inside the reinforcement; we said there is one more factor called as atmosphere which is present the atmosphere also tries to play a role changing the wettability property.

So, these are certain things which I thought I should share with you because I have a lot of queries asked by students what is interface how is it defined and what is wettability. So, I thought; I will explain to you and then go back to my lecture series.

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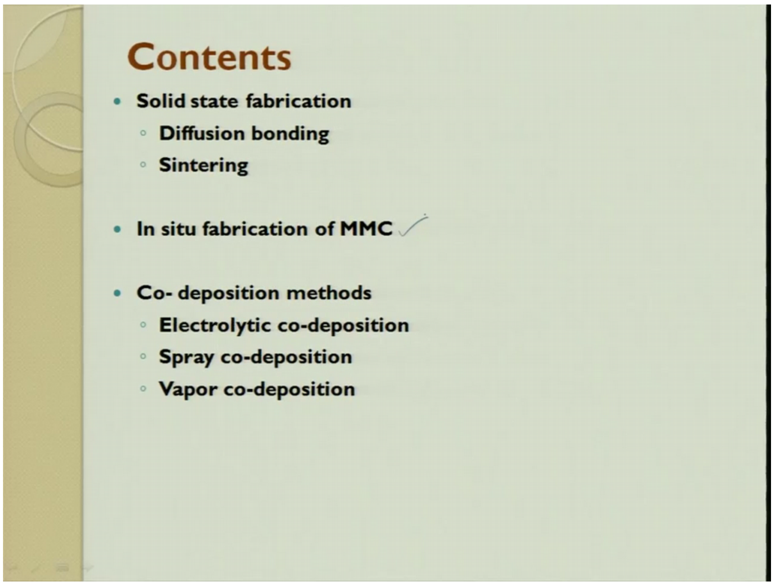

So, last class what we saw was; we saw different types of a liquid state fabrication in metal making metal matrix composite. So, this class we will try to focus predominantly on solid states fabrication; that means, to say I will not change the state solid state I will use it as a solid state of a metal and still I would like to make a metal matrix composite again to just for the reputation the reinforcement can be in terms of a mat the reinforcement can be in terms of a terms of particulates or lump of particulate join together and then they form a given shape.

So, what we do is we take particulates of may be ceramic and then what we do is we try to add some wetting agent to it then we try to consolidate we call this as a green compact and then what we do is this green compact be slightly burn it. So, all the binders; what we have added gets vaporization and it evolves out giving lot of space for now when you pour a metal to enter inside. So, what those things are called as pre-forms. So, pre-forms of ceramics are made and then you try to have some (Refer Time: 13:24) there through which the liquid diffuses inside.

So, today what we will do is we will try to see solid state and then we will also try to see in situ fabrication of MMC; that means, to say when we try to add 2 ingredients it reacts of its own and it makes both of them distinct and it evolves. So, the other way is co deposition method we would like to talk about electrolytic co deposition spray co deposition and vapor co deposition. So, this is what we will try to cover in this lecture.

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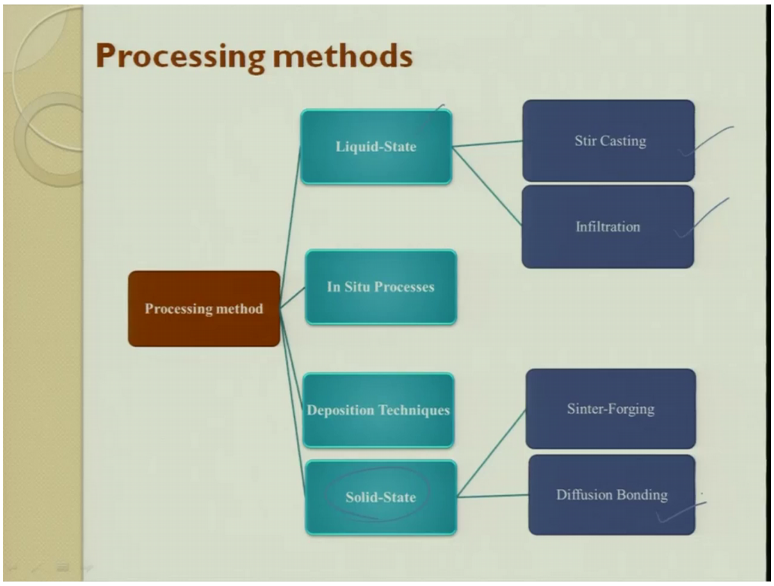

So, processing methods we had liquid state last class we covered stir casting method and infiltration method. So, now, what we will do is we will get into solid state. So, solid state; we will try to see diffusion bonding and sinter forging in solid state fabrication metal matrix composite.

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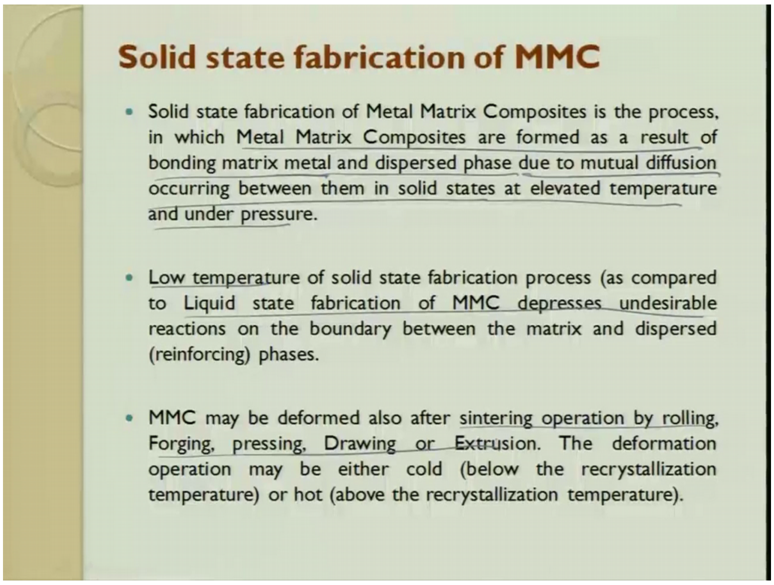

Here the metal matrix composite are formed as a result of bonding matrix metal and dispersed phased due to mutual diffusion occurring between them and the solid state at elevated temperatures and pressure. So, this is what happens here.

So, here we will try to take is a result of matrix bonding of matrix material and dispersed phase right dispersed phase is nothing, but the reinforcement due to mutual diffuser and occurring between them in solid state as well as in solid state at elevated temperatures and elevated pressure the low temperature of solid state fabrication to even when compared to liquid state is undesirable here. So, here the temperatures what we use in solid states are very high as compared to that of your liquid state. So, metal matrix are formed after sintering operation and they are done by rolling what we do is once we make accrued bulk form then we try to do a secondary operation to make sure that the composite is formed and the matrix and the reinforcement is uniformly distributed. The deformation operation can either be done in cold or hot.

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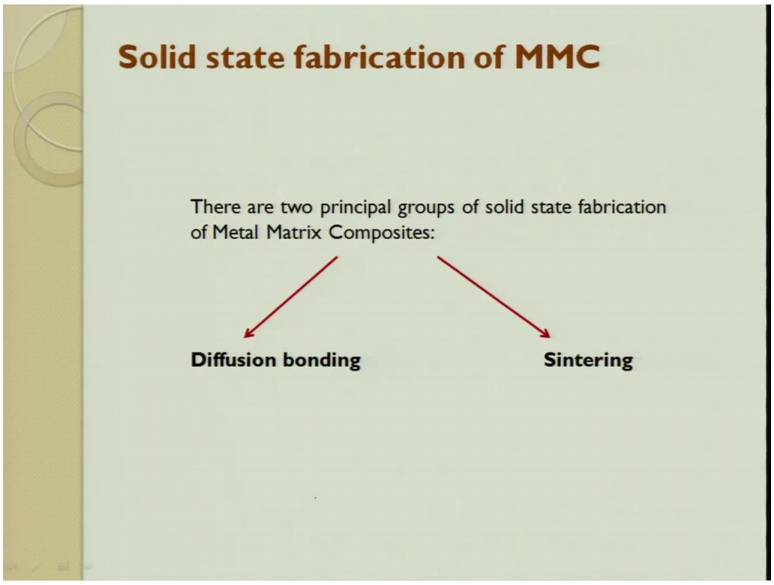

So, there are 2 principal groups of solid state one is diffusion bonding the other one is sintering; what is diffusion bonding.

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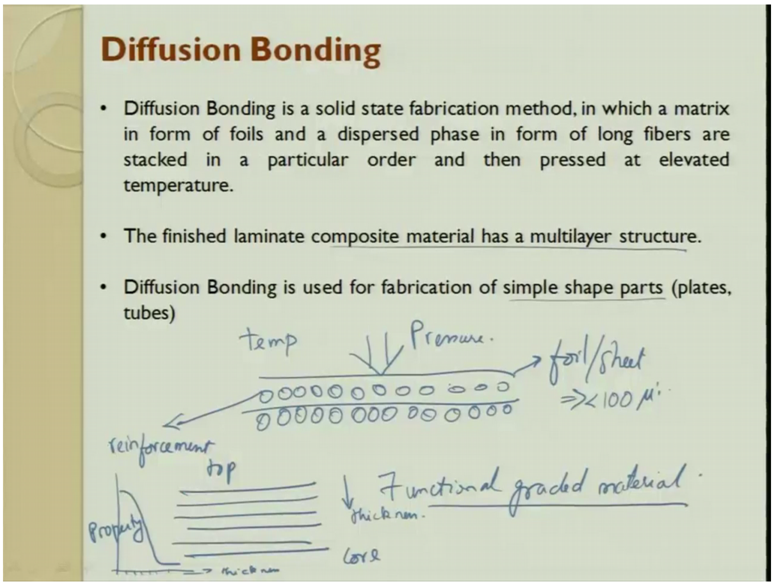

Diffusion bonding is a solid state fabrication method in which a matrix is in the form of a foil. So, we take a foil then we try to put some reinforcing agent whatever it is and then we try to have one more foil then we have reinforcement.

So, this is a cross section view. So, we have reinforcement. So, diffusion bonding is a solid state fabrication process in which we take a matrix this can be in the form of a foil or a thin sheet. So, what we talked about is less than 100 microns. So, this is and these are the reinforcement.

So, now, what you do you keep a foil then you keep this long fiber or mat or a pre-form of ceramic whatever you have made you keep it here and now what you do you try to apply pressure and then you also try to apply temperature what happened if you just apply pressure yes things can happen. But the only thing is you will try to you will still not get a proper consolidation in order to have a proper consolidation you go back and remember the wettability property if you want to do that wetting property then what you do you try to melt this fellow to some exchange and then it tries to take a shape. So, temperature and pressure both are applied in a die or directly on a component.

So, that they get; generally they do not directly apply, but we try to apply in a die and the die gives a shape of the metal matrix composite whatever you want. So, here interestingly you can also have functionally graded materials. So, what is functionally graded materials where and which along support this is a core this is a top. So, at every layer there is a gradation in your property whatever you want. So, this is a gradation in the property whatever you want and this is the thickness. So, you take this as the thickness and this is; what is a thickness I am talking about. So, this is a property which gets de deteriorated. So, if you want to make functionally graded material of different metals for examples 1 zinc foil I can give one aluminum foil I can give 1 silver foil I can give depending up air application start doing it.

So, you can have finished laminate of a composite metal having multiple layer structures the diffusion bonding is used for fabrication of simple shape part shape parts and here you can also have you can also integrate with another part. For example, you can add one more one more part which is third part which is to be added to the composite and you want to integrated as part of this composite you can still do it for example, you take a rubber tyre tube and then you wanted to have a nipple which is to be integrated in the same way then you can also try to add the nipple here and you can have this metal matrix. So, you can try to make integrated parts using this diffusion bonding.

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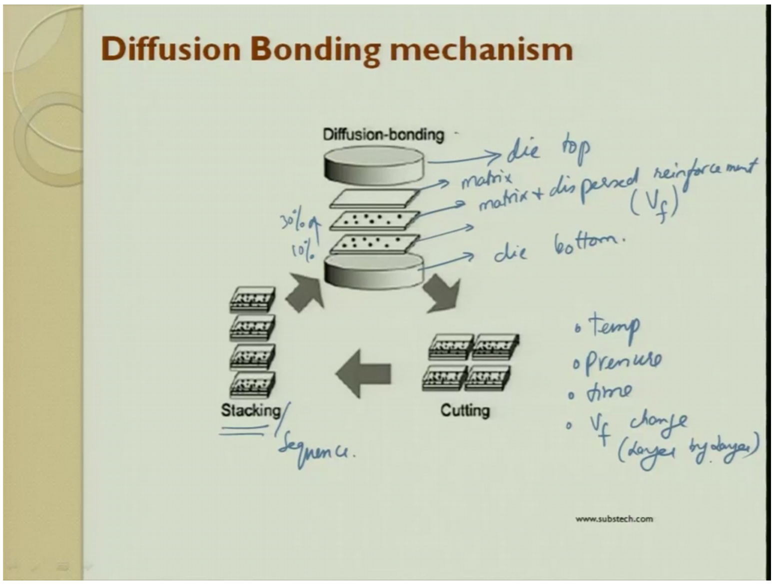

So, this is; what is diffusion bonding. So, I take this is the die on top die top surface this is die bottom surface and here it is a flat die and here you see that I can I have taken several layers. So, this can be exclusively matrix this can be matrix and then you have disperse reinforcement; this can be disperse reinforcement again here you can play with the disperse reinforcement volume fraction. For example, you can have ten percent volume fraction as and when you keep going you can have thirty percent volume fraction here and then on top you have a matrix whatever you want.

So, now what you do when you try to consolidate and try to develop it, you will try to have com metal matrix composite which is functionally graded. So, functional gradation can be brought in while making it and why is it very important because today when you are talking about multi sensor applications multi sensor in integration all these things. So, we always look for functionally graded materials. So, here is a stacking and again the stacking you can also have your own sequence you can have your own sequence in stacking. So, that you try to get what is it and once you stack you make a large piece then you cut to the required space to size and shape whatever you want to get the require output. So, here the important parameters are temperature pressure of course, time is also there and then you can also try to have volume fraction changing layer by layer, but this cannot be done in your stir casting method if you want to have functionally graded, but there also if you very wise you can do it.

So, what you do is you start dispersing higher density ceramic in the first then lower density ceramic. So, again you can still have a functionally graded metal matrix composite provided you think little and start working on it. So, this is how it is happen these are all the fibers you can have fibers made out of metal you want you can have fibers made out of ceramic you want and then try to get whatever you want.

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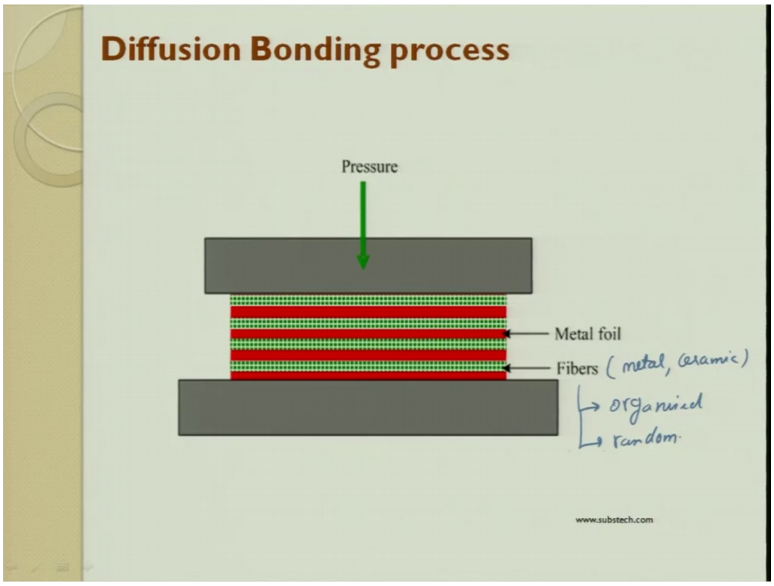

So, this can be fibers can be organized in some pattern it can be random in nature also. So, the next bounding process is called as sintering.

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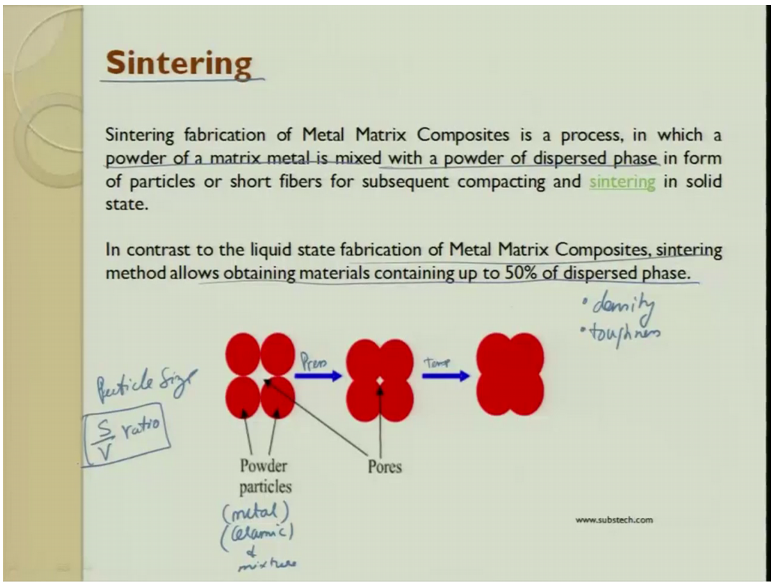

So, sintering is a process where in which you take you start with metal powders or you start with any powder metal powder or ceramic powder and you try to consolidate them and here when you try to consolidate you let us assume you consolidate only by pressing then what happen all this particulate whatever was there powder was there it gets consolidate. Now when it gets consolidate you see there is a small space getting found and you want to still close this space how can you close it; one you can push in something there to close it or you try to apply temperature. So, when you apply temperature the consolidation happens in a big way. So, you can if you have a ceramic material which is of very high temperature then what we do is naturally we try to go for a interphase; we try to give a coating and then try to join it if not you have to think of a very high pressure very high temperature and then do it I do not want to apply temperature.

So, naturally a pressure goes extremely high. So, that is why people do in hot press they do it in cold press they do hydro static pressing all this things are tried if you can do both that is good if you have only one parameter to do because of constrain in a material. So, then the other fellow; if it is not there the pressures have to go phenomenally high or temperature have to go phenomenally high. So, you have to think of an equipment for it the sintering fabrication of metal matrix composite is a process in which the powder of the matrix material is mixed with the powder of the disperse phase. So, here this powder whatever we have taken here you can think of taking only exclusively metal or you can try to take exclusively ceramic or you can try to take a mixture of both I take all the prerequisite prior mix it properly maybe in a ball mill to get uniform mixing, I mix it properly and then I try to consolidate. So, I then put it in a die and then apply pressure. So, that I get a proper consolidation and then I try to get this pores structure.

So, you can do it in 2 stages, you can do it if you do not want to apply temperature; it is called as cold or it is called as green right and then if you want to apply pressure temperature both, then you get the original output itself. So, here the disperse phase in the form of small particles or short fibers generally we try to use particulates alumina sic or we can also use whisker and same finally, you sinter it and then you try to get the output in contrast to liquid state fabrication metal matrix composite sintering method allows to obtain materials up to fifty percent dispersion phases. So, what is the advantage here the; it become a density goes very low.

So, it become a light weight material which can be thought of for high structural application you can also try to enhance the toughness if you want to large extant. So, all this things go. So, where we were struggling to get in solid state in stir casting method 30 percent, 40 percent; we were saying that 50 percent can be done, but here in sintering you can easily go from 50 percent to seventy percent depending upon your requirements use keep playing around and when you try to do it shows the particle size is also very very important particle size because particle size intern influences the surface area.

So, there is a ratio called surface to volume ratio have been repeatedly telling which place a very very important role surface to volume ratio. So, particle size is very important and the volume is also very important. So, that you try to get the best out of it sintering; sintering primary driving force for sintering is not diffusion of material.

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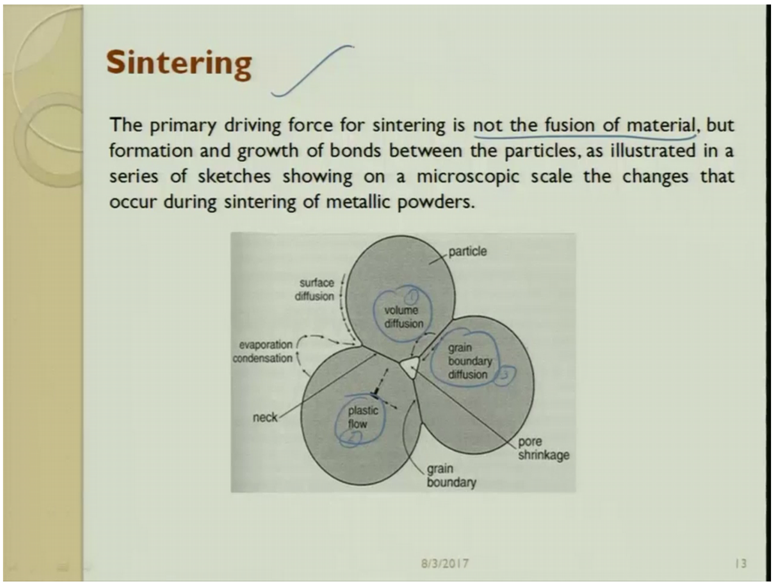

If a look at this figure you can see here there is a surface diffusion phenomena happening there is and evaporation condensation happening; then there is a grain boundary diffusion happening. So, here is a volume diffusion happening and this is a grain boundary and this is the plastic flow happening. So, all this phenomena happen during the sintering process. So, volume diffusion grain boundary diffusion and plastic flow are the 3 major things which are involved in sintering. So, around the surface you have surface diffusion then you will also have the grain boundary getting form and you will also have evaporation condensation also happening.

So, these 3 are very important please make a note volume diffusion of plastic flow and the third one is grain boundary diffusion all these 3 phenomena together happened to this sintering in process and if all these things are metal the mechanism is going to be easy if you have one particular as ceramic and the other 2 are metal then the this strategy has to be different.

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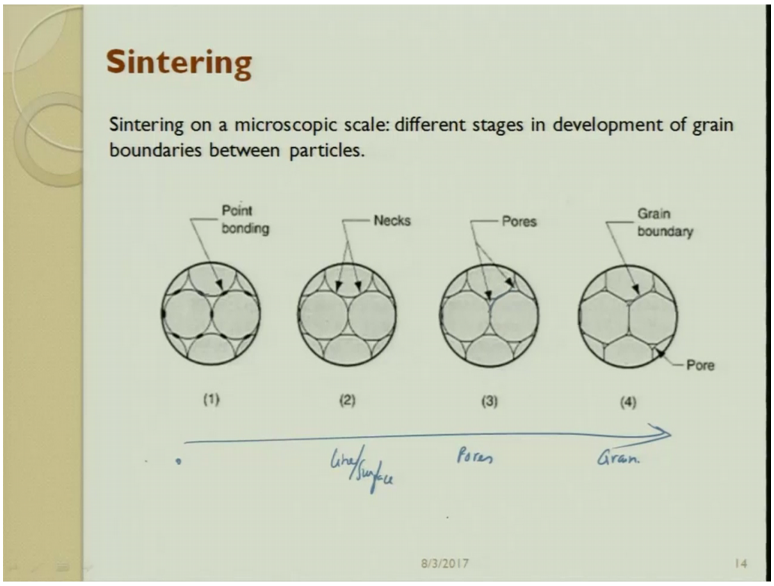

So, these are the stages different stages in which the grain boundary grows. So, the different stages are first you will have point bonding happening and then next thing what you happen is this point tries to grow and then becomes a neck and then this neck when it starts growing the pours get string and further if you go to the next stage there is a grain boundary getting form along the grain particle grain size. So, that you do the pore size goes much smaller generally these are the 4 stages which are involved in sintering process. So, first is point bonding well happen the point will show this is a point then the point becomes a line or then slowly line or a surface, then it becomes more of pores these pores are reduced and then you get a grain.

So, this is how these are the 4 stages which are generally involved in sintering process.

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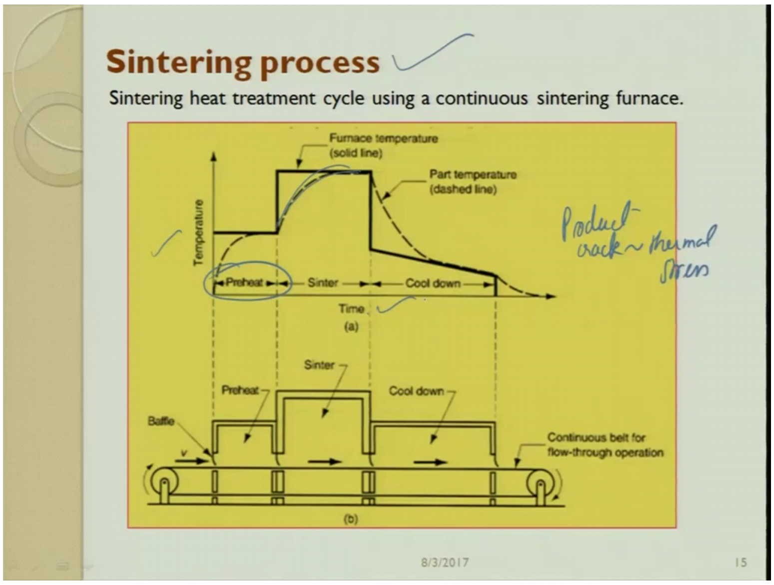

So, I told you earlier also; if you want to do a sintering process you cannot have direct ramping in of the higher temperature we divided into 3 stages. So, the first stage will be preheating. So, preheating will try to take; it was certain temperature not exactly towards the melting slightly less than a melting point we try to take the temperature and maintain it there.

So, that what happens if at all you have water molecules will go off if I have air which is there; any oil volatile oil which is there all these things in the in the ceramic particle or in the metal matrix or in the metal powder or in the die will all be just evaporated clean and so, you try to maintain a uniform heat distribution then once the pre heating stage is our then we start our sintering stage in the sintering stage we ramp of the temperature to such a level. So, ramp up the temperature with respect to time you see it is not done instantaneously it is slowly done. So, we try to take it to a higher temperature and then we try to maintain it for some time and then what we do is we switch off the furnace and allowed to have furnace cooling all along. So, when we do the furnace cooling.

So, that the particle does not the product whatever is made it does not have any cracks any cracks this which are induced by thermal stresses this is what we try to maintain. So, this is the heating cycle. So, this graph is very important as I told you in any furnace this graph is very important temperature time profile they will always ask can you show me the temperature time profile if it all component fails or product fails they always try to dig out and take the temperature time profile of the heating cycle and then they try to figure out where was a mistake. So, this is the furnace which is used or this is the heating cycle which is used for sintering process.

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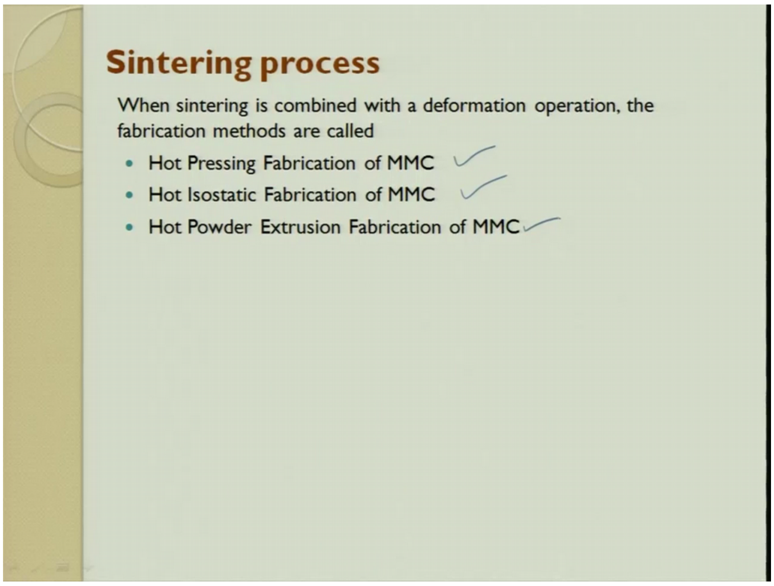

And the sintering can be done by hot pressing; it can be done by hot isostatic pressing. So, hot pressing means it is only pressing from 2 directions isostatic means with all along you apply uniform pressure. So, that you get a sound output then you can also have hot powder explosion fabrication of MMC.

So, these are the 3 processes which are done under sintering for metal matrix composite making.

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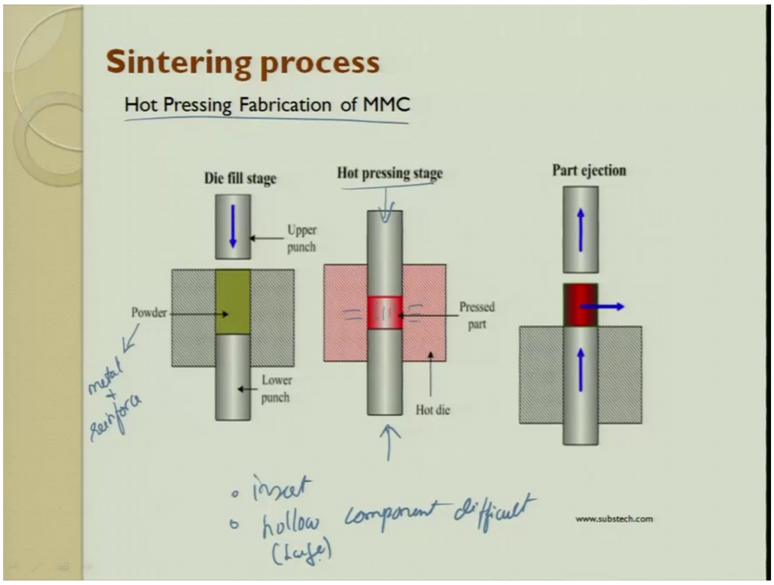

So, in hot pressing; what we do is we try to put up powder. So, in this powder what we do is we try to take a metal powder as well as the reinforcing powder we try to mix them properly and then we try to put it in a die and then compact it we try to put in die and then compact. So, then what we do is we apply hot pressure hot pressing stage means we try to apply heat here pressure is applied heat is applied heat and pressure is applied and then finally, what we get is an output.

So, this process is called as hot pressing here the pressing happens only in the 2 directions and since here it is a confine; it is die; it a confine portion. So, here we do not apply pressure. So, we make sure that it is a confine volume. So, it is that we get a uniform strength distribution all along. So, if you do not do a proper mixing then what will happen is you might have crack which are there in inside which is very difficult for you to visualize.

So, I am talk about not on the surface the cracks inside. So, this will lead to poor quality output.

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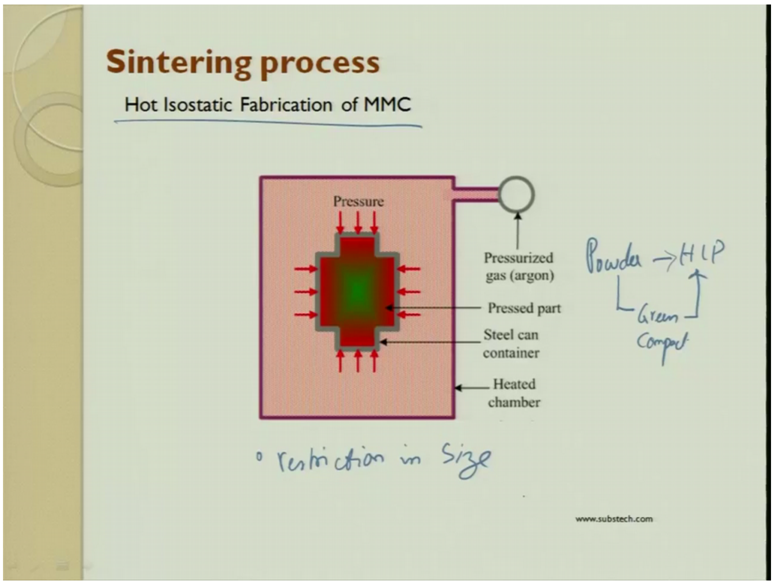

Next one is hot isostatic pressing hot isostatic pressing is whatever was the deficit there for example, I felt that in this directions there is no pressure apply if the pressures are not applied properly there might be a problem that at this precious the compaction is not proper. So, in order to avoid this and try to get the best out of it we try to do hot isostatic pressing in hot isostatic pressing the powder along with the mixture is put inside and then we put it inside a die this die can be a flexible die. So, what we do if we put it inside and then we are try to apply hot air or very high pressure around it.

So, now, what happened there is a proper consolidation happening and you also get the required output; quality output. So, here proper consolidation is very important again here it is not necessary that directly you; you put the powder the powder is not directly put into hot isostatic pressing they and they go a green compact where they give a shape and the few consolidation happening and then they go to hip this; this is very good compared to direct going, this is very good.

So, people try to prefer this and then get it done. So, here what is the biggest problem; the biggest problem is a restriction in the size; can I make a (Refer Time: 32:57) out of it; no, it is not possible can I make pin out of it may be possible correct. So, that is a problem. So, here in sintering also if you want to make something like an insert which is made out of metal matrix composite possible if you want to make a hall a big hollow component slightly difficult hollow component difficult heavy and; that means, to say large I mean; it is not small large hallow component. So, it is difficult.

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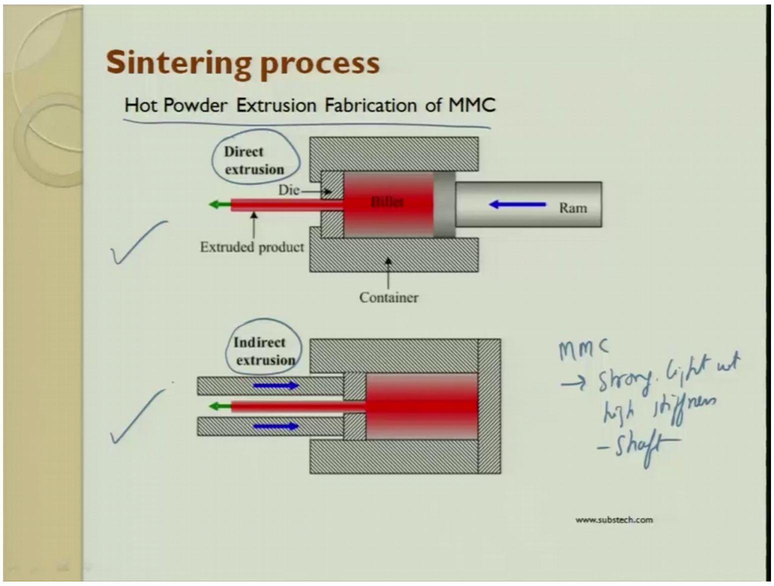

Next one is the hot powder exclusion. So, here what we do is we mix everything and then we try to do with we mixed metal particulate and then we try to apply pressure; we try to apply heat and then the pressure is given through this ram we try do an extrusion process through this. So, you can do a direct extrusion you can do indirect extrusion.

So, here what happens we get a hot powder extrusion fabrication of metal matrix composite? So, MMC; if you want to make strong light weight high stiffness shaft possible these are the process which is used for making those outputs there is lot of if you take every process we are just quickly browsing through the process each process has a fishbone diagram and each process has several parameters these parameters have to be properly understood and then only we can try to executed to get a good quality output.

So, the next one is going to be in situ fabrication. So, in situ fabrication means as I told earlier. So, what happen is I try to add both of this powder and there is a reaction which is happening or I apply heat from outside. So, the dispersed the reinforcing and the matrix get evolved at the same time. So, in situ fabrication of metal matrix composite is a process a where in the dispersed phase is in the form of in the matrix results as a precipitate from the melts during the during its cooling and solidification process. So, this is what is in situ. So, I repeat in which dispersed phase is form in the matrix as a result of precipitation from the metal during its cooling and solidification.

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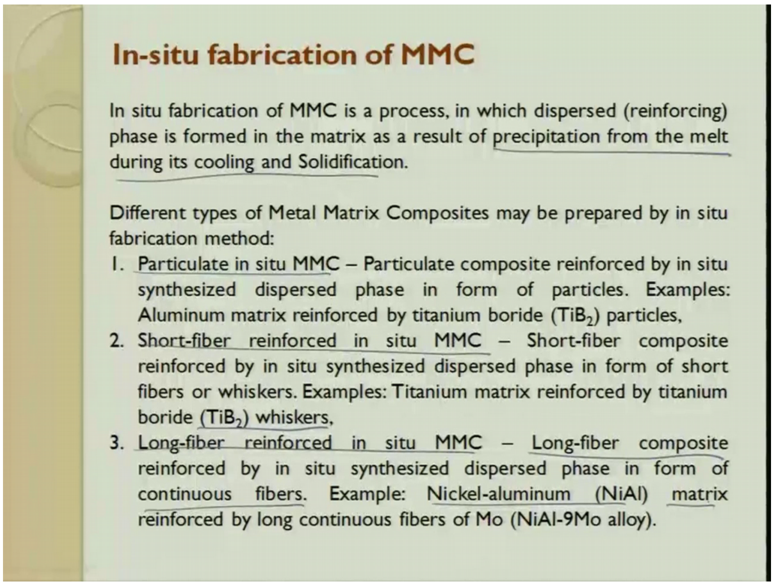

So, there are different types of metal matrix composite which are prepared by in situ. So, one is particulate in situ MMC short fiber reinforced in situ MMC and we have long fiber reinforced MMC particulate it can be alumina sic TiCnTb 2 tin; whatever it is you can try to take. So, in particulate compo composite reinforcement where in which by in situ sinters is disperse phase is in the form of particles the examples are given here. So, short fiber it is the same you can try to have TiB 2 whisker which is dispersed in titanium alloy, aluminum alloy, whatever it is; then you can also try to have long fiber composite which are which are disperse in situ in the form of a continuous fiber be dispersed. So, we try to get the metal matrix composite of nickel aluminum in NiAl matrix these are all matrix which finds lot of applications in the aerospace (Refer Time: 36:51) in the application in aerospace industry. So, this is how it is in situ fabrication

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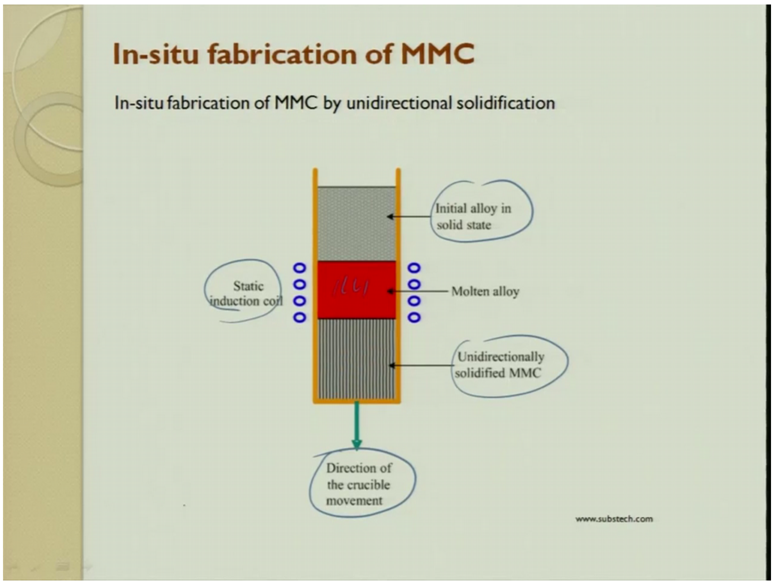

So, we have heat switch is getting applied. So, that is molten material which is there. So, we have initial alloy in solid state we have unidirectional solidification MMC we have and then what we have is a direction to. So, what we do is we try to have a initial alloy here and then we try to apply lot of heat. So, here there are unidirectional reinforcement whatever is kept here. So, this get gets defused and we try to form direction of crucible for the moment so; that means, to say from the bottom I remove and I try to take all the output and we get the required manufacturing. So, in situ fabrication of MMC is also gaining importance.

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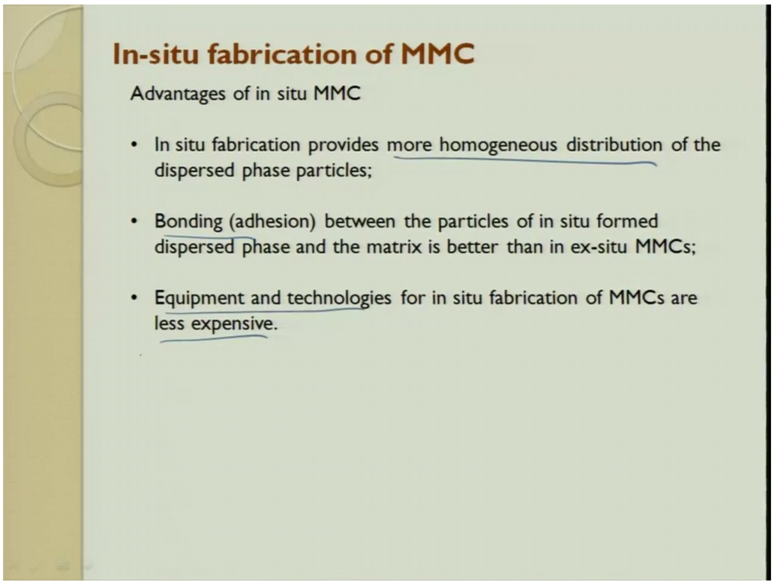

Today the major advantage; you can provide more homogeneous distribution as compared to the other the bonding is very good and the equipments which are involved for making this is not so expensive like hot processing its slightly economical, but the biggest problem is not everything can be done through this in situ fabrication method because of the material limitation. So, the disadvantages for this are the dispersion phase is limited by the thermodynamic ability of its precipitation in a particulate matrix the size of the dispersed particles is determined by the solidification conditions.

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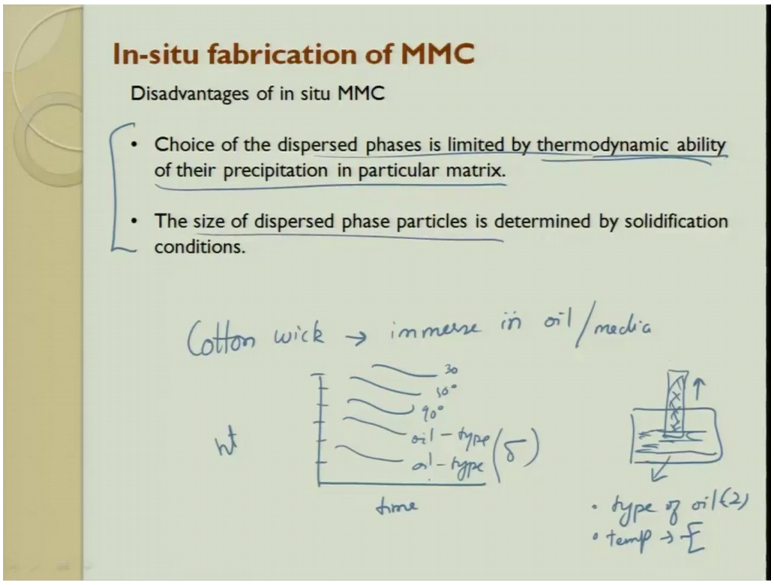

So, these 2 I do not have a control. So, this to the; this is by my choice and not many materials give me this; this thermodynamic ability. So, the other second thing is the particle phase whatever I want I cannot decide what is a particle phase getting formed it evolve. So, I have to live with what is getting generated. So, with this I would like to finish the lecture on metal matrix composite solid state fabrication I would like to continue with the co precipitation in the next class. So, I would like to give you a small assignment.

So, this assignment is you try to take wick or you try to take a cotton; cotton wick and immerse it in oil or whatever media you want or it will be good if you do it in a color media. So, then what you do is you try to plot the on then after you put it inside a bottle or a tank and then you put this wick inside. So, this is a liquid this is a wick and then what you doing is this wick will slowly start having by its capillary action you can see the color of the oil just going or color of the water going on media going high. So, now, kindly plot it with respect to time the height which is going high.

So, here you take 2 different types of oil. So, what is this going to tell you this is going to tell you what will be the influence of capillary action, if I could a capillary action of this wick to suck this liquid and then get inside and then. So, you take 2 different types of oil or then you try to change the temperature of the oil. So, types of oil will be try to take 2 and then you also try to take 3 different temperatures please plot it; say for example, it something like this; this can be at 30 degrees; this can be 50 degrees; this can be 90 degrees whatever it is and this can be oil a type a and this can be type b. So, what are we trying to do in the entire small experiment you are trying to see the influence of temperature on the capillary action that is point number one to wearing the media wearing the oil.

So, with this; what I am trying to trying to link with metal matrix composite wearing density. So, with this you will try to realize what is the influence of the capillary action on the formation of a metal matrix composite and then what do you do supposed if you want to accelerate reduce that time to a large extent. If you want to change the viscosity to a very high viscosity then what will you do that is what you have to think and then do it. So, we will catch you in the next lecture which we will talk about co precipitation or the other methods of metal matrix composite.

Thank you.