Rapid Manufacturing
Prof. J. Ramkumar
Dr. Amandeep Singh Oberoi
Department of Mechanical Engineering & Design Program
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture – 11
Subtractive versus Rapid Manufacturing

Welcome to the next lecture which is more focus towards Subtractive Process and Rapid Manufacturing. So, here we are going to just compare subtractive versus rapid prototyping. I am sure the two lecture series whatever we saw on rapid manufacturing and product development, you would have gone through it. And you are most welcome to note down your queries and send it to us, so that we will start working on it. And feel free if you have any more suggestions and observations please let us know about it.

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So, in this lecture, we will have contents on benefits of rapid manufacturing, effectiveness of rapid manufacturing. And finally, we will try to talk about rapid manufacturing versus CNC machining, where and which we talk about material, speed, complexity, accuracy, and geometry.

We will broadly discuss the difference between subtractive and additive manufacturing. Many people have described rapid manufacturing technology as revolutionizing product development and manufacturing. This is basically they say that it is going to reduce the product life cycle time. Some have even gone on to say that manufacturing, as we know it today, may not exist if we follow RM to its ultimate conclusion. So, as we know it today, may not exist if we follow RM to its ultimate conclusions. We might therefore, like to say why is this the case, what is it about RM that enthuse and inspires some of to make these kinds of statements.
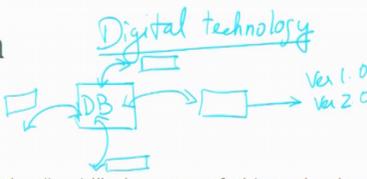
The benefit of RM; first let us considered rapid character of this technology. The speed advantage is not just in terms of time, it takes to build a part. The speeding up of the whole product development process relies much on the fact that we are using computers throughout. The rapidness is speed, the speed is because of the computer. So, I would redraft it, and call it as digital technology.

So, the advantage in digital technology is you have a database, which can be used by multiple departments or personalities. Since the database is universal, so what happens is people when they work on it, they can individually work on it and take it further or they can edit the database, and try to improvise the database to your specific requirement. And this becomes easy, so the to communicate to the other departments without any wastage of time. And since their data is unique present, there in the form of digital, so all the software's which further work on it can be developed on top of it. So, this makes the life very very easy.

The CAD packages today which is available has this freedom. So, once you draw the component inside, and then put it in this database. The manufacturing engineer, the design engineer, the marketing engineer, and the sales all of them get to see the same data, all of them work on the same data if there is a need based, then release it as version-1, then version-2, they try to go advance and then try to improvise the database and start using it. This reduces the product life cycle development time.

Since, 3D CAD is being used as a starting point. And interestingly, this CAD data can be used for CAM, can be used for measurement, can be used for quality, it can be validated, whatever they wanted is it available or not. And second thing since the data base is unique. Next time when there is a new revision of product or advanced product is coming, they do not have to start right from scratch from their library, they can pull up, and start developing existing machines and existing drawing, existing technology, they can do. And based upon the drawing, it is already available. There will be a process plan which is existing in the system, this makes the cycle time much much faster and lesser.

Since 3D CAD is being used as a starting point and the transfer to RM is relatively seamless. Seamless means without any disconnect, it can be transferred. And people do not play an important role; it is always the data which is getting transferred. So, tweaking of the data or noise adding to the data is reduced to a large extent. There is a much less

concern over the data conversion or interpretation of this design intent. We shall discuss about the CAD and CAM, reverse engineering in the coming weeks, so that will try to give you more insight and details.

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Just as 3D CAD is becoming what you see is what you get, so this is what is now talked about very much. And interestingly, today what has happened, you do not even need to generate a CAD 5, you take a photograph. And in the photograph if it is 2D, immediately the photograph can be used as an input the CAD is automatically generated. And today the technology has gone one step more than that also if you have a 2D photo taken from various angles, they stretched back and then they try to get a three-dimensional image. And this three-dimension image directly when you feed it into the CAM system, you do not have to draw, it directly gives you the x, y, z coordinates. So, today CAD has become very advance, CAM has become very advance.

So, today people use this acronym what you see is what you get in the system in the virtual system in their system, where you draw virtual drawing, what you see is what you get. So, it is the same with RM, and we might just as easily say that what you see is what you build. I have just changed what you get to what you build, because your starting data is CAD, so where in which you try to have all the data which can be used by rapid prototyping, which can be used for rapid manufacturing, which can be used for rapid tooling. So, you can choose many things right.

So, what you see is what you build. Seamlessness can also be seen in terms of the reduction in processing steps. As I told you for every CAD part whatever you have drawn, you can have your livery function of process plan for that part. So, this process plan includes machine, machine layout, and quality checking process plan for each machine. And finally, it also tries to say whereas need to be shifted to a warehouse.

And second thing once you know the CAD file, you have drawn the CAD file, you know the process plan. There might be some parts in the layout, where it is in the inventory state. Now, all you have to do is this is shop floor-1, floor-2, floor-3 that means to say it is an individual work centre. So, in this work centre you might have a group of machines whatever it is, so there that every work centre you might have some inventory.

When you start developing the CAD, and you see the process plan you might even figure out in the existing running product at a semi-finished state, you might get the products. So, this tries to tell you also where the product exist or the part exist in the semi-state, and what all has to be done such that we can take it to the market very fast to get customer feedback or to deliver to the customer.

Regardless of the complexity of the part to be built, building within yeah RM machine is generally performed in a single step. So, it has come to RM machine has come today to a level that it is called as one shot process, like earlier we used to call injection molding machine, metal forming machine. So, in the same way RM machines are also talked about in a one-shot or a single-step process.

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When you look at the counter, the subtractive process; most of the manufacturing process would require multiple and iterative stages to be carried out in subtractive manufacturing process. Initially, subtractive manufacturing process was used for one for complex surfaces, we used to exhaustively used machining process, where we need to have a few in number products or parts, we always go for subtractive process. Third thing where there is a assembly dominating factor, we used to go for subtractive process. These are the places where we were going.

Today, all these advantages are been taken over by rapid manufacturing ok. So, most other manufacturing process would require multiple and iterative stages to be carried out in subtractive. As you include more features in the design, the number of the stages may increase the drastically. Even relatively simple change in the design may result in a significant increase in the time required to build using conventional methods why, because every machine every machine might have a might have a fixture. The fixture if it is modular, it is quick to change. If it is not modular, it takes lot of time non-modular concept.

So, you have to rein do all the parts which get into the fixture. What is a fixture? Fixture is a device where in which you hold the work piece while doing the machining operation ok. And on top of it, there is also a zinc where in which the zinc price to guide the tool.

When you try to change the small design change in the part, the guidance for the tool also might require a change. So, these things take a lot of time.

If you follow modular concept it is quick, so that is what people call using modular concepts in metal forming, we call SMED-Single Minute Exchange of Dies. So, single minute means, it is not literally meaning single minute. You the die is prepared outside, you just change push it into the machine, so that concept are used. So, modular if you follow, it can be reduced. If you do not follow, you have to take lot of time in fixing the parts which is required for the fixture.

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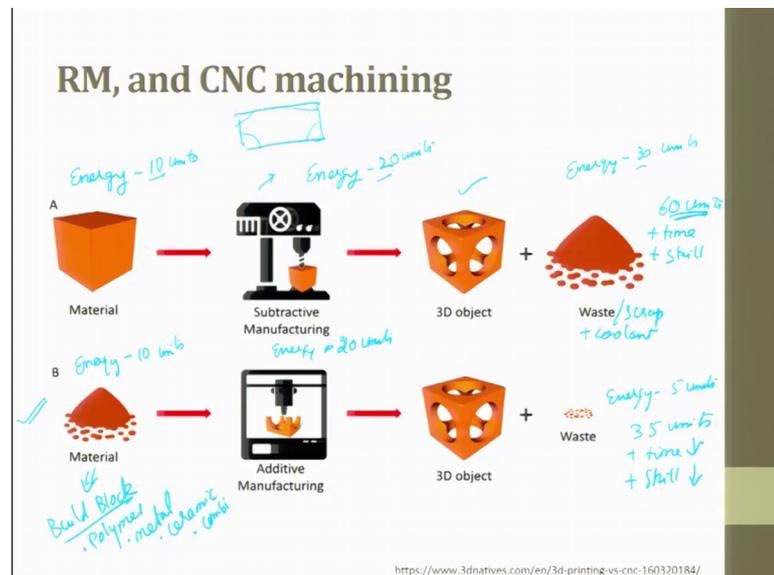
So, material, subtractive manufacturing; subtractive manufacturing is I have cube, I remove whatever I do not want. And I tried to take the rest of the material to my requirement right. So, here if you see, the subtractive process. First of all for making such a big volume we spend lot of energy. So, let us put that energy-1, some amount of energy supplied. Then in subtractive process energy-2, I mean to say in units in units are applied. Say for example, 10 units are applied, and here it is 20 units are applied. In converting the raw material to the finished part ok.

And then you see here energy-3 will be spend 30 units will be spend in terms of transportation, recycling, and bring it back to the system. So, if you see totally, you would have spent 10 plus 20 plus 30. So, 60 units of energy you spend to get this part. So, this is typically subtractive process. And making such a product object (Refer Time:

14:09) is very difficult in subtractive process. You have to use a CNC machine, you can using conventional, you have to do multiple settings.

In CNC machine also to do this part, this part looks to be very simple. What I have done, I have taken a cube, I have drilled hole on all four sides 1, 2, 3, and 4 all four sides. So, it is a it is a cube having all four sides or all the faces, it has a hole. To do this in a conventional machine, first of all what I have to do is I have to first take the part. And then what I do is I claim or I mill all the four sides if it is large, I plane or if it is small, I mill so or if it is it in between, then we go use for a shaping operation, we try to make flat faces.

And after you make flat faces, and making flat faces also you have to do it on the all 1, 2, 3, 4, 5, and 6. So, making this every time what you have to do in a conventional normal milling machine, we index every time, and try to make it. In a CNC machine, what you can do is you can have the and again a normal CNC machine cannot do, you should have 4-axis or 5-axis machine which indexes in the fixture, and you start machining it.

Then after you machine, you have to drill. Again in drilling what you have to do is you have to have one is milling, and then come into drilling. In drilling also you should have multiple set ups, at least you should have 2-3 times you have to shift the part to so that you try to get the final output. And after doing it, you also generate so much of waste. So, waste is whatever is this, I would say scrap which comes out of this. And on top of it you will also use coolant ok, and all this things are collected. So, these are based which is generated.

Now, there is two possibilities from the waste, you can go back recycle and go back or you should discard. When you discard, it is not called as a sustainable manufacturing. So, in this you see so much of unit suspend, and it is not only unit, it is also plus time lot of time. And though it looks of square with some holes, it also needs skill to place it ok. So, these are the challenges. You can do it in conventional, you can do it in CNC, but still this will be the amount of energy you will spend, this will be the time you spend, and this literally needs a skill also.

When you go by the additive process, you have material. These material are nothing but building blocks, this can be polymer, this can be metal, this can be ceramic or you can also have combination of whatever you want. So, these material are spend. And first of

all we try to make this let us take an energy of 10 units are spend here ok. And then this is fed into an additive manufacturing machine. In additive manufacturing machine, you build a block by block by block, so the complexity of milling and drilling is not there. So, here you spend an energy of even let us take 20 units, whatever i said here machining all machining.

So, you get your part and look at the scrap, you can see from the pictorial diagram itself, energy what you spend will be 5-units. And here if you see 10, 20 so by 35 units, this is only a just a figure I am giving a fictitious figure. If you work on the true calculation, this b will be very very energy efficient, so 35 units. And then you see that whatever time for building is reduced, and second thing skill today rapid prototyping techniques have come up. So, well even a semi-skilled labor can start working on these machines and developing it. Because, when you start doing this rapid prototyping part, the strength place a very important role, finished place a very important role.

So, the strength and finish can be decided by the orientation of the part, which also can be given by CAD today. It gives you multiple options, you have to pick which one which will also tell you if you do the orientation like this, this is what is a time going to take. So, all these things you yourself can optimize, and then start firing the machine. So, you look at it. So, this is the difference between ordinary subtractive manufacturing, and this is rapid manufacturing.

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Effectiveness of rapid manufacturing; so, RM can be seen as a way to more effectively predict the amount of time to fabricate models regardless of what changes may be implemented during its formative stage of the product development. So, this is very important, predicting the amount of time to fabricate models. This can be done, when you are using the RM. Suppose, if there is a small change in the design, and if you follow the conventional road, it is very difficult for you to figure out, when will you be able to give the delivery of the product or show it to the customer.

But, whereas here when you call a rapid manufacturing, you can clearly tell him this is what is the time of delivery, and we will try to do it. See today what is happening in manufacturing, there is a big paradigm shift. Earlier in manufacturing people were talking about products production or they were talking about only producing, but today there is a major shift in the focus of manufacturing is products or product products delivery that is a paradigm shift you produce. Today we do not talk about your production, we talk about your delivery to the customer your delivery.

If you say I produce in Jammu and Kashmir and keep it for keep they are ready, but if somebody wants to get it a Kanyakumari, the travelling time and all those things are there, and it also has how to protect and move, but today the production is replaced by delivery, when can you deliver to the customer. So, in this when you have a paradigm shift, rapid manufacturing is going to be helpful in your way.

Similarly, the number of processes and resources required can be significantly reduced when you are using RM, because in one machine where you fired the CAD model to get the part that is only one machine. So, you have to do lot of optimization, I do agree it is not so easy as like what I say if it is polymer yes, but in polymer also polymer there is shrinkages which come, polymer there is a strength component ok. And polymer sometimes what is happening, delamination happens. When you shift into metals, it is almost the same, you will have porosities made.

And if I want to make alloys, it is very difficult. And after making these too, I have to finish the surface that is also a big challenge. So, using RM we can try to reduce the number of processes, and also the resources what is required. Because, the building block whatever you want, you decide whether you want a polymer, whether you want a

metal, ceramic, your combination, whatever you want to do. And on top of it, when you use this building block, you can also use inserts whatever you want.

For example, the plug what we use for laptops; say if you see that there is a steel rod, which comes in contact with the electrical supply, and then you will have a plastic or a rubber which is which is covered. The rubber is only to hold the connection from the metal connection from the pin to the rest of the traveling whatever it is and also to connected to the main plug point. So, if you see there, you these steel rods are inserts which are placed, and then you will have a cover which is injection molded.

So, in the same way in rapid prototyping also or in rapid manufacturing also, you can try to have inserts. And depending upon your firing, you can try to make parts to your final requirement. If a skilled craftsman was requested to build your prototyping according to a set of CAD drawings, he may find that he must manufacture the part in number of stages. Even may after making CAD, if you try to use a manual operation there, then also it is going to have number of stages, which is not going to reduce the product life cycle time.

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In the subtractive cases, this craftsman must have to employ a variety of construction methods, ranging from hand carving, through molding, forming techniques to CNC machines. Everything the skilled man has to understand. Hand carving and similar

operations are very tedious. If you feel hand carving is for artist, but if you look at the challenges today, even after using CNC machines.

Suppose, let us assume you want to make a die, this is for a part which you use for Pepsi bottles, where you use all these aerated drinks to drink. So, in the bottom you will have, you can see that they have something like a shoe. So, you can have three shoes, sometime they have five shoes ok, you can see that. So, if this bottle has to be made it is a plastic bottle, so it will be made out of injection molding you made out of injection molding.

So, if you see the bottom part of those shoe, wherever it is there inside? This has to be first machine, and many a times since it is very difficult for us to machine we use EDM process for making a die. The die is used in injection molding. So, here we spend lot of time after doing EDM, we spend lot of time in finishing. Sometimes people say that it takes also 30 days to finish your die. So, they say the major bottleneck in all those die manufacturing is only finishing operation.

So, if you go on the other side hand carving, it is very tedious, difficult, and it is prone for error. Molding technologies can be messy, and obviously requires the building of more one or more molds, because it is not so easy right. CNC machining requires careful planning, and their sequential approach that may also require construction of fixtures before the part itself can be made. See what we teach in academia is making a single part using CNC machine (Refer Time: 25:53) or we say make a square or we say make a blind pocket, so it is very easy. Suppose, if I say please make a Geneva mechanism ok, the Geneva you make it is little difficult. So, you the program might run to somewhere cross 200 lines 200 lines, then it is how do you fix the part all these things matter.

So, once you have a real complex part or a live part, it makes CNC programming itself little challenging. And it is not the programming, it is also the tooling. Many a times you will not have the exact tool, what you want. So, then what you do is you try to work on a tool path. So, the tool path we will be used to make the features. For example, if you want to make a slot, and this slot if you have a end mill you have an end mill, it is easy right same end mill to the required features size. If you have of a smaller end mill, so then you have to do multiple passes, and try to offset the tool try to get this featured on.

Exact to the feature size, it is very difficult to make tools. So, you use standard have optimized tool paths, and then start machining it.

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All this presupposes that these technologies are within the skill set of the craftsman and readily available. RM can be used to remove or at least simplify many of this multi-stage processes; when the addition of some supporting technologies like silicon-rubber molding, drills, polishers, grinders etcetera. It can be possible to manufacture your vast range of different parts with different characteristics. So, this is the effectiveness of RM.

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So, if you see here from a solid block this is a solid block, so this is subtractive process. So, in subtractive process we remove materials by physical or chemical processes. A solid block is there, we try to use contact machining where and which the tool is harder than the work piece, we use it by milling, turning, grinding if you do not want, you can also do sawing. And you can also try the non-conventional machining process, where tool is not is not harder than the work piece, and tool is not in contact with the work piece. So, in the sense like 100 percent contact, so that is water-jet. Jet machining techniques can be used for making such slots, this is subtractive process.

When you go on additive process, building blocks; building blocks directly you go to the layer to the same of die or same object whatever you want after doing a rapid manufacturing. So, it is interesting from here you should understand, these are building blocks. So, the building blocks are 1D. So, what happens from 1D, you convert them into 2D, and then from 2D you convert them into 3D. So, these are building block powder building block, so I take a powder here. Then these powders are joined together to form here straight line ok, these powders are joined. And this are then what they do is it is only following boundaries, and then inside also you will have hatching. And finally, what you get yes two and a half D structure, which is a layer because the half is in Z-direction which is of a smaller thickness.

So, then when you start several of the 2D, you get a 3D object, so that is nothing but additive manufacturing adds layers of material. Again here it can be metal, polymer, ceramic, and of course you can also have liquid. If we have liquid as a starting material, then what we do is we first create this 1D liquid. When it is cured a single dot 1D, so then it goes to 2D then from 2D, it goes to 3D.
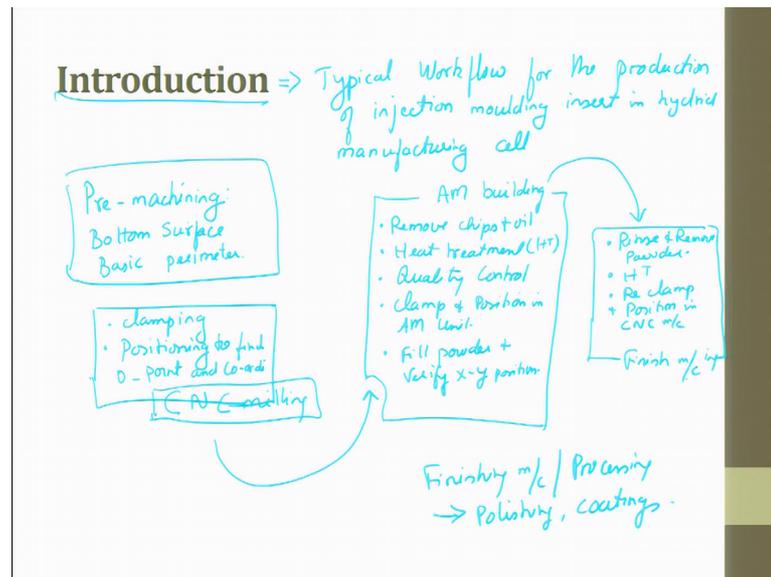
So, let us see the typical workflow for the production of production of injection molding insert in hybrid manufacturing cell, later late we will see what is cell. So, here let us notes of pre-machining bottom surface, so because we are trying to make a reference surface basic. So, we just have to make a pre-machining done, so that suppose you want to make a cuboid.

So, when you take it to make a fixture or something, first we have to make references. So, then what we do is then we try to make pre-machining, so in pre machining what we do is we try to clamp clamping, then we try to make positioning to find 0-point that is means to say reference point and coordinates ok. Then comes CNC milling, this is all part of CNC milling.

Then from here it tries to get into additive manufacturing building, this is Am building ok. First is we remove chips remove chips, and oil whatever it is on the surface, then what we do is we do heat treatment. These are the some of the processes we do to get the part, I am just making a generic thing. So, then what we do is we check for quality control, whatever we have machine in CNC if it is ok.

Then what we do is we clamp and a position in Am unit, because the inside is getting ready, and then Am started doing. So, then what we do is we try to fill powder, and verify x and y position ok and then after this comes, the process of finish machining. So, here again what we do is we do rinsing rinse and then remove extra powder rinse and remove

powder. Then we do again, if needed heat treatment. Then we try to re-clamp, and position to get a position to in CNC to just do small CNC finishing or machining whatever it is so this is part of it.

So, the finishing machining generally will be finishing machining slash processing will be polishing and coatings, because you did the initial part. And then after this initial part, you did additive manufacture building, then these are these things which happen in the finishing machines right.

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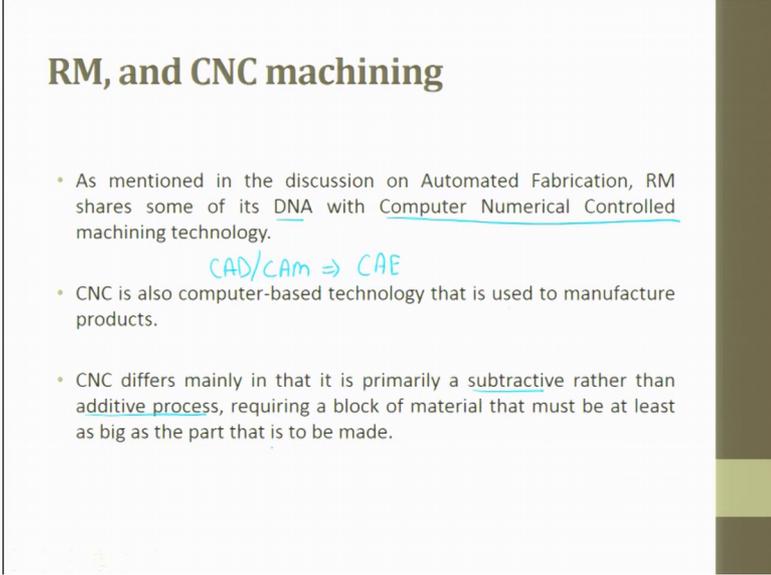
So, the RM and CNC machine, as mentioned in the discussion of automated fabrication, RM shares some of its DNA with computer numerical control machine technology. CNC is also computer-based technology. So, this tries to CAD and CAM when we try to talk together, people call it as CAE where simulation also comes. It is the same CAD which is used for all these things. The CNC is also computer-based technology that is used to manufacture products. CNC differs mainly in that it is primarily a subtractive rather than additive process, requires a block of material that must be at least as big as the part made that is to be made first.
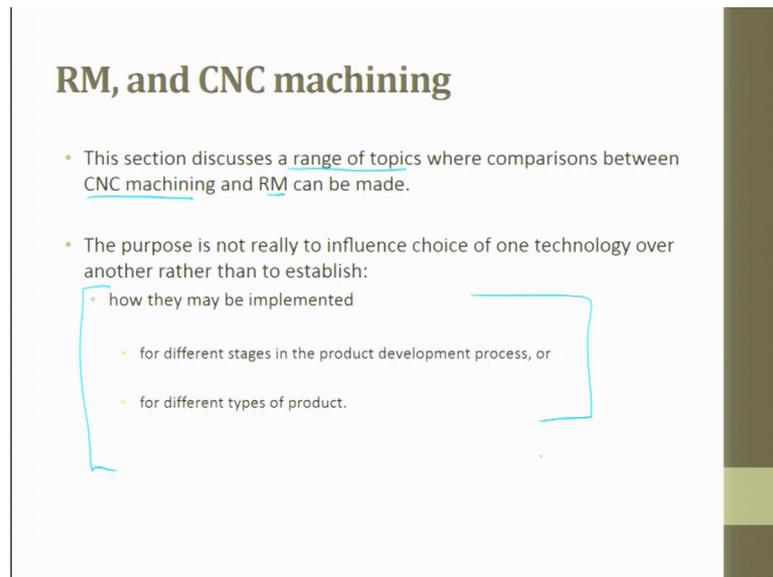
We will discuss a range of topics where comparison between CNC machine and RM can be made. The purpose of this comparison is not really to influence choice of one technology over the other rather than the other established. Rather to understand the merits and demerits of the system. How they may be implemented.

For different stages in the product development process how are these technologies used or for different types of products how are these technologies used. So, this is what we wanted to impress you rather than saying CNC is good or RM is good or additive manufacturing is good. So, every process has its own capability plus and minus. We have to choose what we want, and you should also keep in mind we cannot completely go for one process, we have to look always for a hybrid process.

So, the material plays a very very important role, when we talk about RM. RM technologies was originally developed around polymeric material, wax, and paper laminates why, because it if you look at it, all these things where heat you apply heat flux you apply was easy or it has to be small. So, basically we were trying to use laser for polymeric materials, whatever it is. And wax basically what we did was we started with liquid, and then from their we shifted. And machining wax is also easy. So, we started with polymer material, wax, and paper.

Subsequently, there has been introduction of composites, metal, and ceramics. Today, metal prototyping is something which is a rapid manufacturing is very exhaustively used. CNC machining can be used to for soft materials, like MDF-Medium Density Fiberboards. These are basically fiberboards which is just like your wood ok, these are fiber these are fiber metals lightweight easy to machine, machinable foam, machinable wax, and even some polymers were used. So, CNC machining was easy, when you started using softer material. So, material plays a very very important role whether to go for RM or CNC.
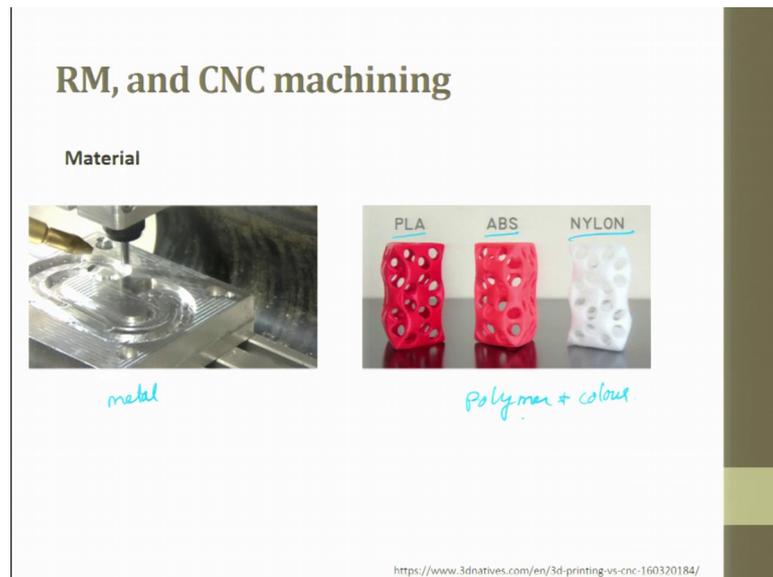
So, this is material for metal where it was used, and these are all polymer materials. So, this is nylon, this is ABS, this is PLA ok, and interestingly you look at it. All these today polymers are now added with colour also. So, you can try to get colour parts, if it is earlier was not possible. Today polymer when the collect material itself, you have a mixture or you tried to add ingredients such that it gets the colour form. So, today this advantage has also pushed polymer in rapid manufacturing techniques.
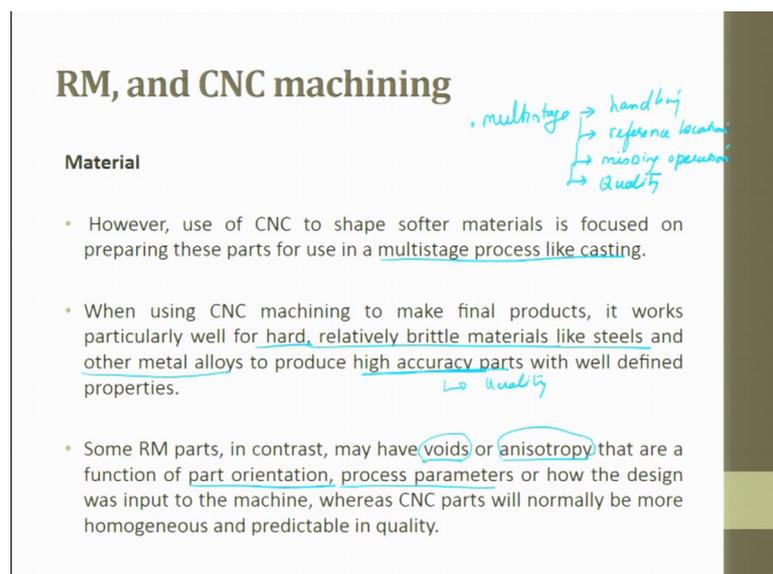
However, use of CNC to shape softer materials is focused on preparing these parts for use in a multi-stage process like casting. So, if you want to make such thin objects, then if you do it by if you do wanted to do apart from rapid manufacturing, it involves multi-stage. When we do a multi-stage process multi-stage process, it has handling there is going to be a damage, it has lot of reference locations, which is always a challenge reference locations this is a challenge. Third thing is there might be a possibility of missing operation. And quality of the product is always a challenge, if you have to do in multiple stages, both in terms of metallurgical as well as in terms of dimensional.

When using CNC machines to make final products, it works particularly well for hard, relatively brittle material like steel and other metal alloys to produce high accuracy parts with well-defined properties. Some RM parts, in contrast, may have voids and anisotropic property, because your if you doing it by layer by layer by layer, so it is it is good in x, y plane. But, in the z-direction, it does not have the same strength what was there in the x, y plane.

So, you may have voids, you may have anisotropic properties that are a function of part orientation, process parameter or how the design was imported into the machine that is why, I was talking to parts orientation. And process parameters plays a very important role in deciding the quality of the output in rapid manufacturing or how the design was input to the machine. Whereas, CNC parts will normally be more homogeneous and predictable in quality, because here it is high accuracy. As I told you, it is quality is also good, if it is a single-stage. If it is multiple-stage, dimensional and metallurgical properties has to be checked.

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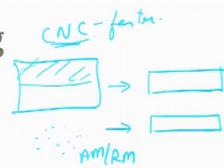
The speed of making the part in using a CNC machine is always high. High speed CNC machines can generally remove material with faster than RM machines can add a similar volume of material. You have this from here if you have to go for this by CNC, this is faster, you are just subtracting this portion to get to this parts CNC is faster.

Suppose, I have this part going to build up to the same volume, it is going to take back to it is going to take time lot of time ok. So, if the high speed CNC machines can generally remove materials much faster than the RM machines can add a similar volume of material. So, this is additive manufacturing or RM machine, where it is going to take time. But, you should understand we are not worried about just machining, we are worried about the final part. So, there is the sacrifice or the advantage you see in RM as compared to that of CNC right.

However, this is only part of the picture, RM technology can be used to produce a part in a single stage, so that is what we said in the beginning in you have you cannot take one technique over the other and say this fellow is the best. So, in the in this lecture also, I told you in the slides, we are not here to say CNC is advantages, RM is not or RM is advantages than CNC. We are saying you should know exactly which technique to use or which technology to use at which stage, so that you can reduce your product lifecycle that is all ok. CNC machines require considerable setup and process planning, particularly as part become more complex in their geometry.
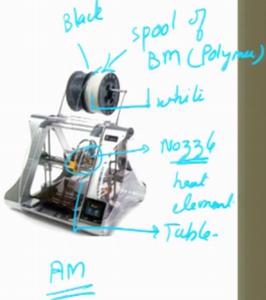
So, this is for the CNC machine, this is a AM machine where in which you have spool of building material which is nothing but a polymer. Also note there are two different one is black, other one is white. So, you have multicolor, all these things passes through a this portion is your nozzle, where in which in nozzle you have a heating element. So, when this fellow flows, this is the table ok. This is the table. This is a AM machine or rapid manufacturing machine or rapid prototyping machine, so which is used for building parts very fast very fast as compared to the complete cycle, do not compare it with a single part.
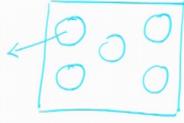
Speed must therefore be considered in terms of the whole process rather than just a physical interaction of the part material. CNC is likely to be multistage manufacturing process, requiring repositioning and reallocation of parts within one machine or use of more than one machine. To make a part in an RM machine, it may only take a few hours; and in fact multiple parts are often batched together inside a inside a RM build. So, what we are trying to say is when we try to have a table like this, you can have one part made like this, 2, 3, 4, and 5 parts can be build simultaneously. For example, for building up one part, it takes 20 hours.

So, now if I want to make 5, it might take 25 hours that is all or 30 hours. So, by 30 hours I am able to make 5, so that is what is saying repositioning on the machine. So, parts with one machine or use of more than one machine. To make a part in RM machine, it may take only a few hours. And in fact, multiple parts are often batched together inside a single RM building. Finishing may take place a few days, if the require is for high quality using CNC machines, the same process may or take weeks time. So, this is what I was trying to talk about in die finishing. Just for machining part flat it is ok, but die you have to finish it.

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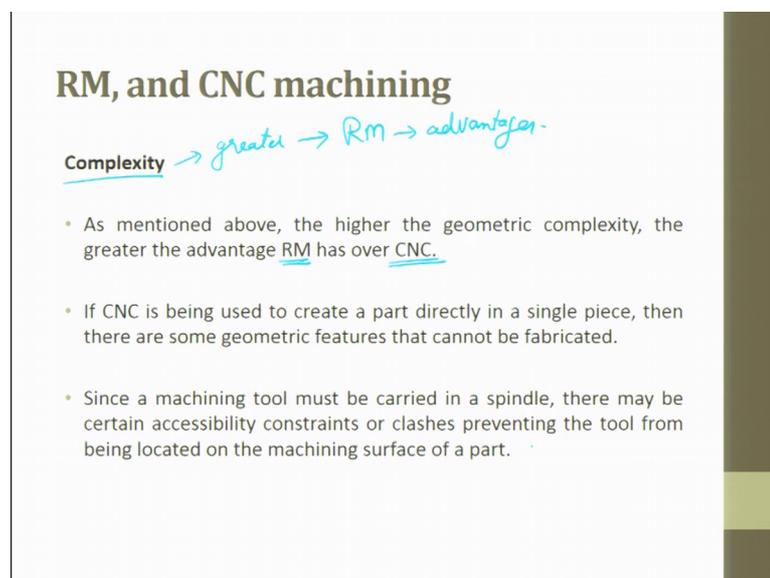
Complexity is another important role. As mentioned above, the higher the geometric complexity, the greater the advantage of RM over CNC, keep this in mind complexity greater RM advantages ok. If CNC is being used to create a part directly in a single

piece, then there are some geometric features that cannot be fabricated. Since a machine tool must be carried in a spindle, they may be certain accessibility constraints or clashes preventing the tool from being located on the machining surface of a part.

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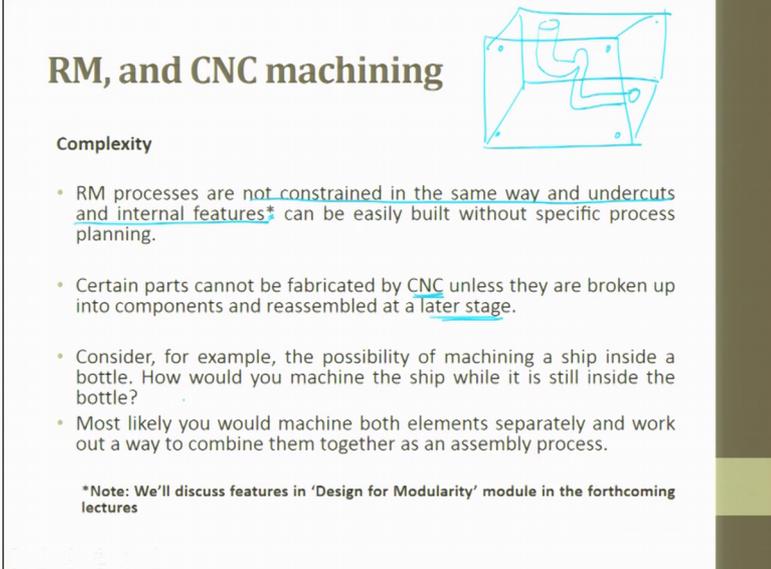
RM process are not constrained in the same way and undercuts and internal features can be easily built without specific process planning, constrains in the same way and undercut and internal features can be made. We will discuss features in design for modularity in the forthcoming weeks. So, feature we will define a feature, and see what the feature are just for crude understanding in your face eye is a feature, in your face nose is a feature. In your CNC part, your pocket is a feature, your whole is a feature ok.

Certain parts cannot be fabricated by CNC unless they are broken up into components and reassembled at a later stage. For example, assume that I have a block. In the block suppose internally, I wanted to make a make a hole or make a channel like this. If I want to make it, I have to split the die into two parts or the part into two parts do a channel at one, do a corresponding channel on the other, then I have to mount it together by a fasting method, and then I get this block. But, whereas in CNC, in RM, you can get the whole feature done without splitting the block that is what it is a certain parts cannot be fabricated by CNC, unless they are broken into components and reassemble at the large stage.

Consider for example, the possibility of machining is ship inside a bottle. How would you machine a ship while it is still inside a bottle? It is not possible, this is done by artist and craftsmen do it. But, if you want to do it on a CNC machine, it is not possible. Most likely you would machine both elements separately and work out a way to combine them together as an assembly process.

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Accuracy is other thing, which is very important, complexity, accuracy. AM machines generally operate with a resolution of a few tens of microns; this is the highest I am talking about, very precise 210 microns. It is common for RM machines to also have variable resolutions along different orthogonal axes right. So, you should also understand variable resolution and different orthogonal directions.

Typically, the vertical build axis corresponds to layer thickness, and this would be a lower resolution as compared with the two axes in the build plane. So, this one is a build plane, this is x, and y, and this is what we have talking z z-direction ok. The roughness in the z-direction is different from x and y.

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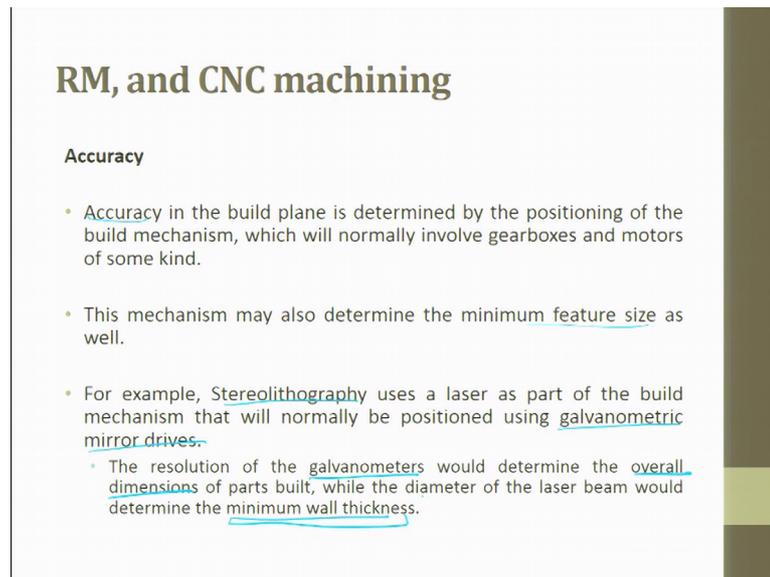
Accuracy in the build plane is determined by the positioning of the building mechanism, which will normally involve gear box and motor of some kind. The mechanism may also determine the minimum feature size as well. For example, as of today people start using belt drive for in all AM machines into manufacturing machines they use. But, moment you want to have a precise control, it people have to go back to their ball screw mechanism. And if you want to have very high speeds in additive manufacturing, it is not possible both by belt mechanism as well as ball screw. They go for f theta lenses, which is typically optical lens where there is no moving parts, but the beam can be moved using a galvo.

So, you see the mechanism changes depending upon the accuracy and the time, this mechanism may also determine the minimum feature size as well because, if you want to make small features, you try to choose any of this techniques. For example, stereo lithography use a laser as part of the building mechanism that will normally be position using a galvano mirror drive. So, we will see stereo lithography, when we see additive manufacturing. The resolution of galvo meter would determine the overall dimension of parts build, while the diameter of the laser beam would determine the minimum wall thickness. Overall dimensions by galvo, and the wall thickness by laser beam.

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RM, and CNC machining

Accuracy

	Tolerance (mm)	Min. Layer Thickness (mm)	Max. build volume (mm)
CNC Milling	± 0.025 – 0.125 mm	cutting depth 0.01 mm	2000 x 800 x 1000 mm
SLS	± 0.3 mm	0.7 – 1.0 mm	300 x 300 x 300 mm
Industrial FDM	± 0.5 mm	0.8 – 1.0 mm	900 x 600 x 900 mm
DMLS	± 0.1 mm	0.4 mm	230 x 150 x 150 mm

https://www.3dnatives.com/en/3d-printing-vs-cnc-160320184/

So, if you look at it, these are the accuracy comparison. We have put tolerance in CNC machine, in SLS you see SLS is higher than this industrial FDM is much higher DMM is almost close to this comparison ok. CNC milling gives a very good finish. SLS we will see in detail SLS process. But, here what we do is we will see SLS industrial FDM, and direct metal laser sintering. So, these are the minimum layers you see minimum layers ok, and see look at the build volume. So, how what being a part or what should be the working volume size you have to do, so you can see from here.

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RM, and CNC machining

Accuracy

- The accuracy of CNC machines on the other hand is mainly determined by a similar positioning resolution along all three orthogonal axes and by the diameter of the rotary cutting tools.

- There are factors that are defined by the tool geometry, like the radius of internal corners, but wall thickness can be thinner than the tool diameter since it is a subtractive process.

- In both cases very fine detail will also be a function of the properties of the build material.

The accuracy of a CNC machine on the other hand is normally determined by similar positioning resolutions along all three orthogonal axes and by the diameter of the rotational cutting tool. There are factors that are defined by the tool geometry, like the radius of the internal corner, but wall thickness can be thinner than the tool diameter since it is a subtractive process, but there it is not possible beam diameter, wall thickness, here you can have much smaller. In both cases very fine details, we will always be a function of the property of the building material.

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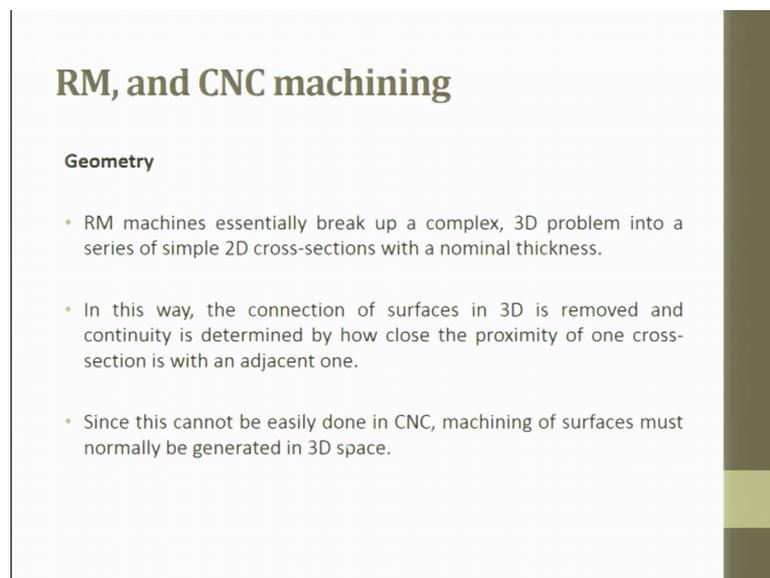
The geometry, when you talk about RM machine essentially breaks up the complex, 3D problem into a series of simple 2D cross-sections with the nominal thickness which we saw. In this way, the connection of surfaces in 3D is removed and continuity is determined by how close the proximity of one cross-section is with an adjacent one. Since, this cannot be easily done in CNC machines, machining of surfaces must normally be generated in 3D space. So, this is what is the major disadvantage.

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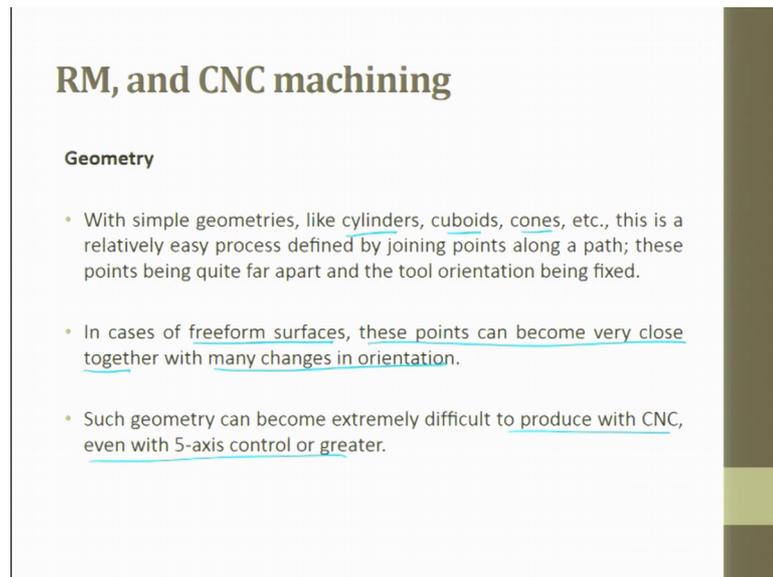
Simple geometries like cylinder, cuboid, cones, etcetera, this is a relatively easy process in CNC defined by joining points along a path; these points being quiet far apart and the tool orientation being fixed. So, it is easy to make by CNC, it is also easy in the similar way to make by RM. In cases of freeform surfaces, these points can become very close together with may carry or change in orientation. Such geometries can become extremely difficult to produce with CNC, even with 5-axis or greater axis greater axis or more axis's. So, in case of freeform surfaces, these points can become very close together with many changes in orientation.
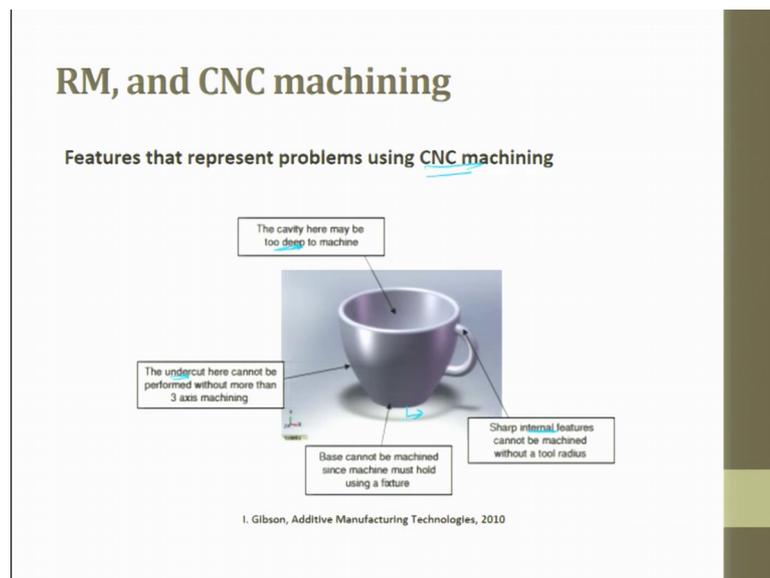
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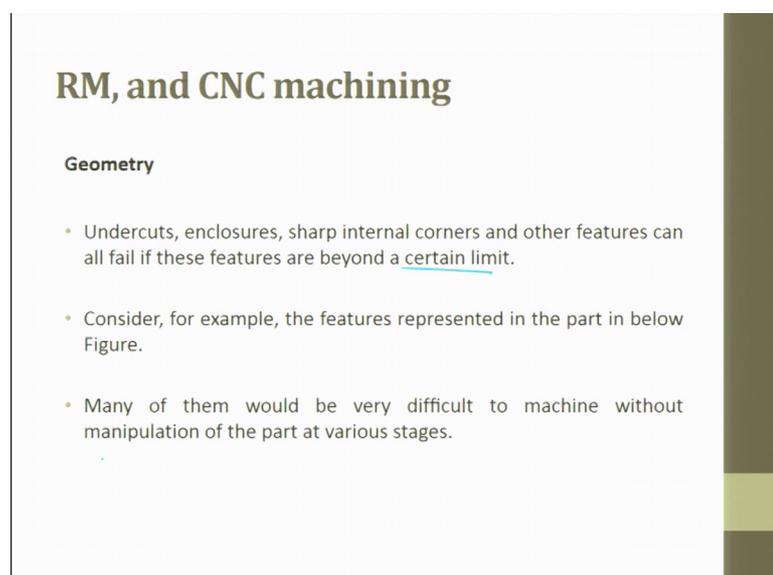
Undercut, enclosures, sharp internal features are other features, all fail to be created in CNC machines. Consider for example, a feature representing in a part is being in the below figure, next slide we will see. Many of them would be very difficult to machine without manipulation of the part at various stages ok.

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The cavity here may be too deep to machine. The undercut here cannot be performed without more than three axis machines the undercut. Base cannot be machines, since machine must hold using fixture, then sharp internal features cannot be machined without a tool radius. So, all these things put a limitation for a CNC machine. So, deep, and then undercut, then you have internal features, and then bottom features. So, all these things put a bottleneck for using of CNC machine.
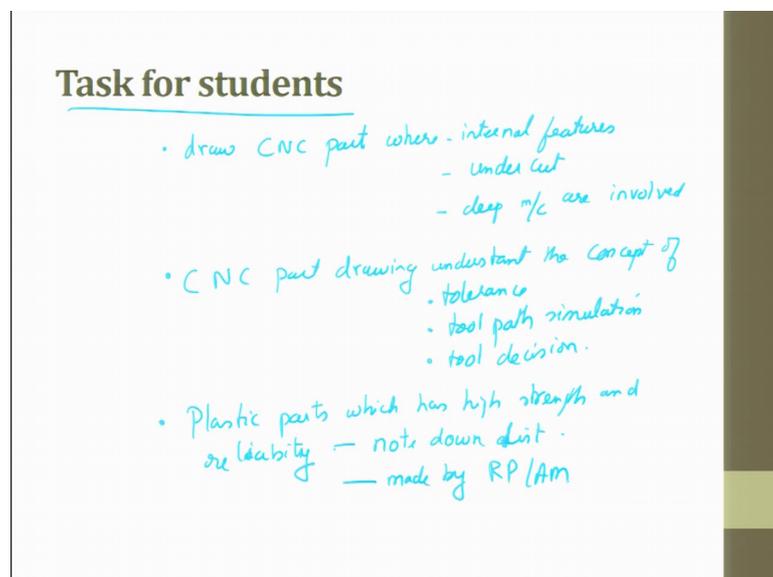
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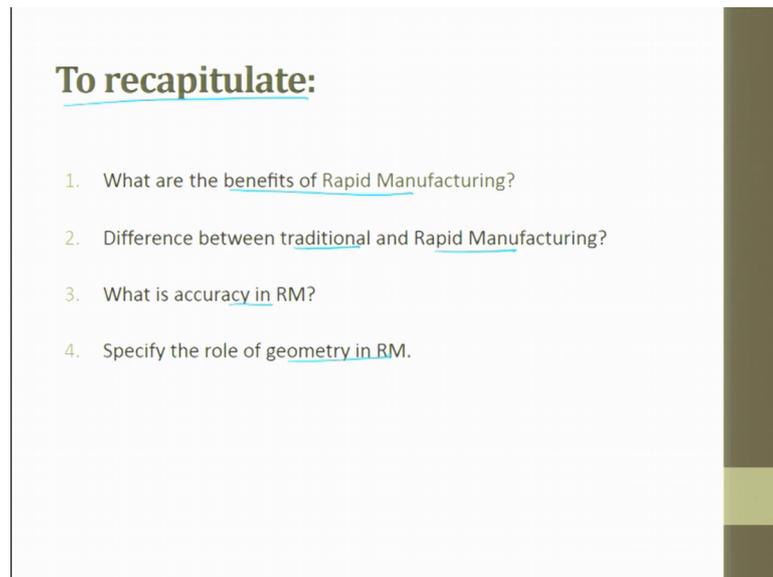
So, whatever we have seen in this lecture, we saw the benefits of RM. We saw the difference between traditional and RM. We saw the accuracies in the RM. And we also saw a specifying the role of geometry in RM.

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So, task for students. You will try to make or draw a CNC part where internal features undercut, deep machining are involved, do not try to copy the cup example. Think and do some other example, where the depth is not as deeper as the cup whatever we have shown.

Next is you have to see CNC part drawing, and understand the concept of tolerance, tool path simulation, and tool decision, for example which tool to use and what. So, the last one is going to be try to look at plastic parts which has high strength and reliability, note down the list part note down the list. And see whether this list can be made by RP or AM ok.

Thank you very much.