CAD/CAM
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Lecture No. # 2
Computer Aided Manufacturing

So as a part of this CAD/CAM course, today's lecture is concerned with the computer aided manufacturing.

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Last time we looked at some of the applications of computers in design process. Now this time we will look at how computers can be used in various ways in a manufacturing process. Now first thing is let's look at a very general definition for a computer aided manufacturing.

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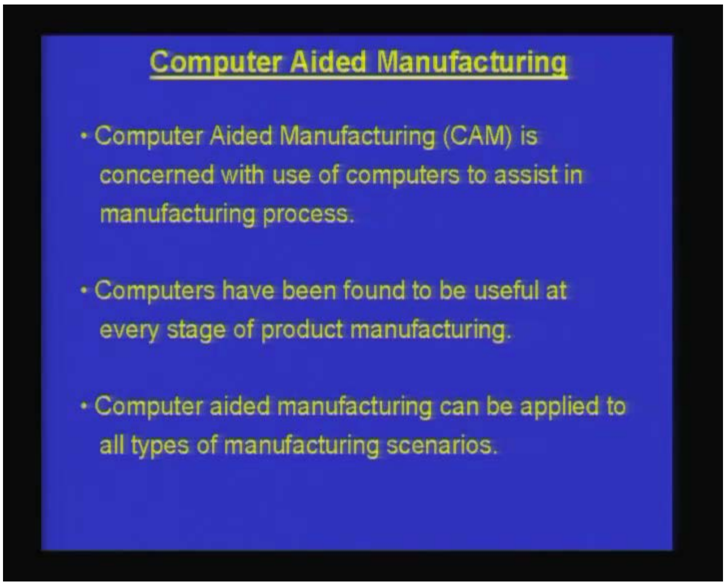

The definition which I have put is a very very generic. It's like if I am using a computer to assist in any stage of manufacturing or any aspect of manufacturing process, I can define as a computer aided manufacturing. Many a times computer aided manufacturing is usually referred to basically concentrate on certain small domain like for many people computer aided manufacturing refers to use of CNC machines and CNC software. But I would like to put that basically a computers, if I am able to use computers in any aspect of manufacturing, I can call it as a computer aided manufacturing. And lastly the computer aided manufacturing can be applied to all manufacturing scenarios. It's like you are aware of many manufacturing, various types of manufacturing systems like you have a mass production system and a batch production system. So in all these situations, computers have been found to be useful in some way or the other in the entire this thing. So you can say that this definition is a very very generic as far as…

Now what I will do is the best way to study about what computer aided manufacturing is to go through a few examples like taking examples like these are the ways a computers have been found to be useful where they are being used in industry. So that's what we will do as a part of this particular lecture.

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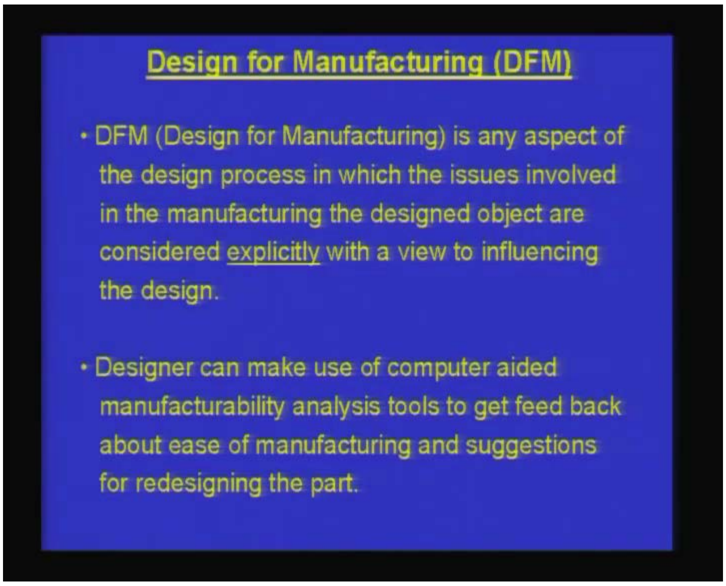

Now the first aspect which I want to cover is what is called as a design for manufacture or DFM. Now, when the manufacturing consideration should start in let's say a typically a new product design. The conventional method is that manufacturing starts once the design is over, once you have a design which is ready. But if you really look at the way things are done now a days in industry, the manufacturing considerations come at a much early stage in the design. So last time we looked at there are three stages of basically a design process. One is a conceptual design, second is a configuration design and third is a detailed design. So in fact the manufacturing consideration should come as early as a conceptual design stage. And, if I am trying to bring manufacturing considerations explicitly like in many of the situations when a designer is to trying to design a product, let's say new product or a component, he or she is aware of like where the manufacturing problems are likely to occur. So that is an implicit way based on past experience and past designs, one can try to look or one can try to account for manufacturing related considerations.

But if I am using explicit analytical and computational tools to analyze my design from the manufacturability point of view then this basically can be considered as a design for manufacturing. So the basic definition should include that there are explicit tools which are used to carry out the manufacturability process. And the basic idea of using a design for manufacturing is that designer can get a quick feedback about ease of manufacturing once the design is over or the during the design process itself. So as the feedback comes, one can take care of this feedback and try to redesign the component, so that the manufacturability requirements are made or ease of manufacturing can be taken care. So there are two aspects of you can say a DFM, one is to get a feedback and second is to get a redesign parts. There are situations where computer can give you only a manufacturability advice where the problems are likely to occur. There are also systems which are now coming up, particularly computational systems where a designer, computer not only analyzes a design from manufacturability point of view but also gives you a redesign suggestion.

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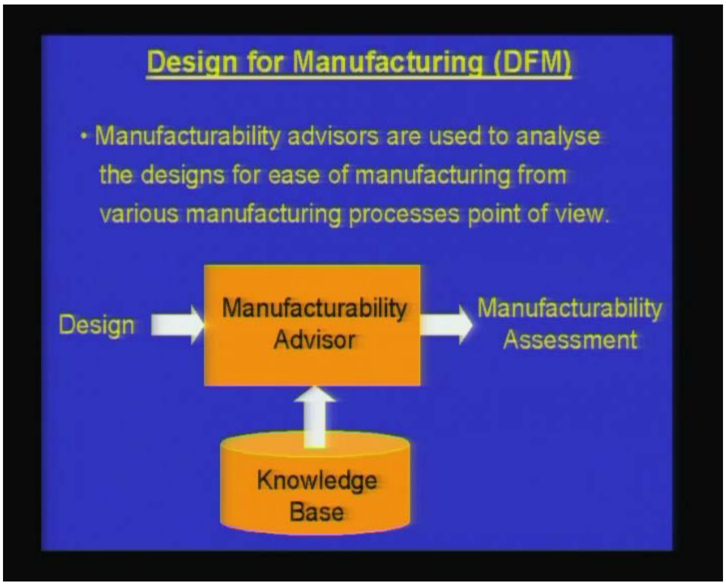

If you going to basically take care of a redesign in certain manner then you can basically account for ease of manufacturing, like I have just put a typical DFM scenario the way it happens. So basically a computer acts as a manufacturability advisor which I have shown here, so it takes a design as an input. Now it is assumed that in a scenario like this design is being carried out using computers. So a design is stored as a CAD model or a drawing. So a computer reads this particular design and then it gives a manufacturability assessment for example I may have a part, a plastic part which has to be injection molded. So, the design and the tolerances which have to be basically the geometry and tolerances which have to be realized as a part of the process is an input to manufacturability advisor. And once the analysis is done, you get an assessment or where there are likely to be problems or whether it can go through manufacturing easily or what would be a typical cost of manufacturing kind of this thing.

Now in order to have such system, the computer makes use of a design knowledge base where you have rules regarding basically a manufacturability assessment. So based on this particular knowledge base, the assessment is given. In some cases you get only a manufacturability advice but there are also situations where you can get redesign suggestion or redesign parts itself.

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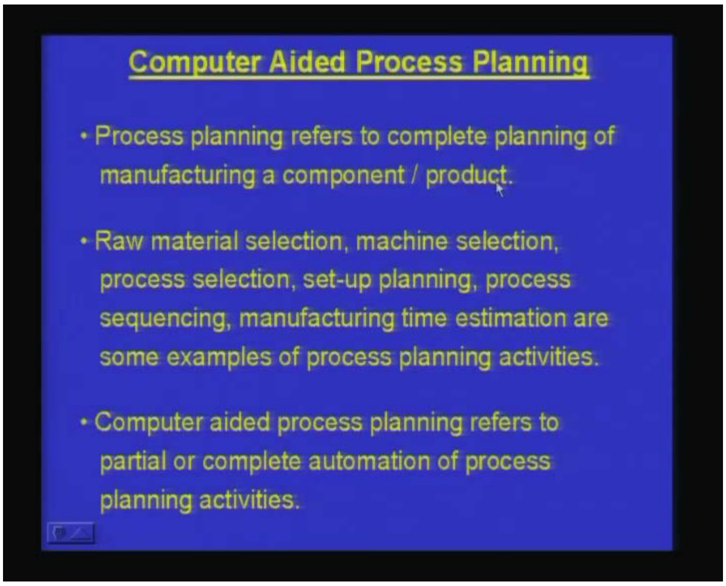

The next application which I have taken is a very wide application in any manufacturing process is computer aided process planning. Process planning is one stage in a product development, product design and manufacturing where process planner makes a detail plan of how to go about manufacturing a component or a product. Now if this is one area where computers have been found to be extremely useful and they are used extensively. I have just put down a few examples of process planning activity, like a process planner may have to select a raw material. When I say raw material it may be a geometry or it may be like what would be the shape and size of this particular raw material and has to select appropriate manufacturing infrastructure like machine or if there are number of ways a component can be manufactured which process to use or what combination of process to use. Then it may be a set up planning, if for example if I am in a scenario like a machining then I would also like to a plan how to, like in how many set up all the machining can be carried out or whether it can be done in one set up or two set up or multiple set up.

And in each set up how the part should be held using fixturing and kind of things. And also process sequencing, if there are number of operations which have to be carried out on a part, the sequence is very very important. It not only has a cost implication, it also has a serious quality implication so that's also a part of a process planning. And many a times you have to estimate manufacturing time a priory before you actually go for actual manufacturing. So all these things or you can say typical examples of a process planning activity and computers can be used in these situations.

And there are two ways of looking at a computer aided process planning. One way is I am using a computer for individual activities like this or it may be an integrated manner where I have a complete computer aided process planning automation where I give a design and I have a process plan as output. I would say that the complete automation is still not a reality but it's coming fast in many ways. Many industries are trying to automate at least a class of components for which the process plans can be generated automatically using computers.

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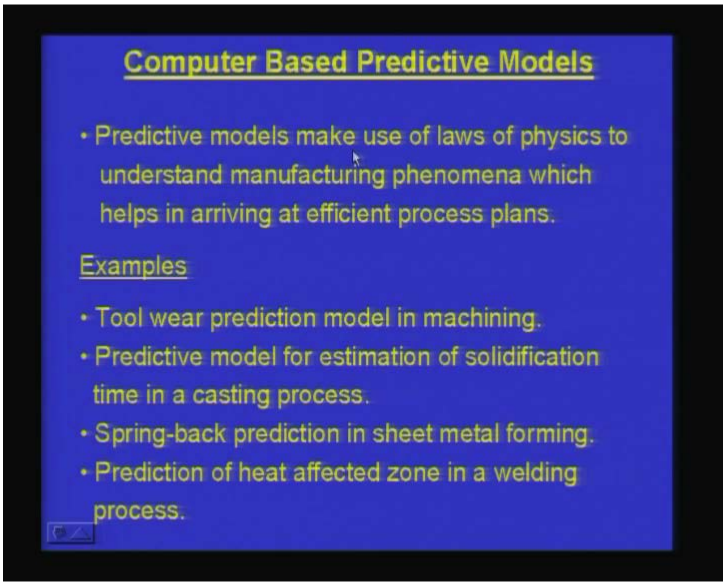

Now as a part of process planning, many a times the process planner has to take decisions which require going into understanding the manufacturing phenomena or you can say the science based, the scientific basis of a manufacturing process. Now in these situations one can use what are called as a predictive models. A computer can predict based on let's say a loss physics or loss of mechanics like basically in terms of taking certain decisions. So if I am using a computer to basically take care of this aspect, I can call it as a computer based predictive models. I have put down a few examples; probably these will illustrate what I mean by predictive models in much better manner. For example a process planner who is trying to let's say prepare a process plan for a component which has to be machined would be interested to know what would be the like kind of tool wear.

Suppose if I am using a tool wear there is a insert and this insert has to be replaced after certain time. If I have a model let's say if I have a mechanics based model which can tell that like a insert is going to, the life of insert is going to be so many minutes. Then that will help in terms of when the tool replacement should happen or when the insert should be replaced, a kind of situations. So you are using a mathematical model which may be analytical or computational or numerical to predict what would be the tool wear kind of a thing. So this is just an example of a predictive model or I may have a predictive model for estimation of solidification time in casting process. So I use basically a principle of heat transfer and let's say the process of conduction, conviction and radiation to estimate like suppose once I pour the molten metal in a mould, how much time it will take for the complete solidification or when can I actually take out the part from let's say a mould.

Now this is important if I do not have a good estimate then I have to purely do it based on once on past experience which may be very conservative in some cases. So the actual solidification time may be x but you may be keeping the, let's say you may be removing the part after time like 2 x. So it's not a very productive kind of a situation. If I have let's say a predictive model which can tell if this is a material, this is the volume of the material, this is a geometry which is being cast so what would be let's say a solidification time that helps me in terms of efficient process planning or arriving at optimum process plans, like third example I have put is like a spring-back prediction.

We know that in many of the, for example a sheet metal forming spring-back is a very common problem and so one has to account for a spring-back in a dye design situation. Now what is usually done is a dye design is an experimentally iterative process. So I design a dye for a sheet metal component then carry out the sheet metal forming operation then based on let's say the component which comes out of this particular manufacturing scenario, I would like to correct the dye shape to account for the spring-back. Now these iterations can be carried out using a computer instead of doing it in a real life situations.

So, if I am but what you require is basically a very good model which can, for a given situation which can predict what is the spring-back. And naturally you have to go into basics of theory of plasticity and strain hardening etc in order to develop one such analytical or computational model. Another example could be like, one would like to know what would be a heat effected zone in a welding process, given a welding parameter or a given welding process what would be a kind of heat effected zone one is likely to get. So that also helps in terms of how to improve the quality of a products or getting the desired products. So these are like a typical examples of a predictive model and computers are used basically at, like computer based predictive models are used either at a process planning stage or later to do this.

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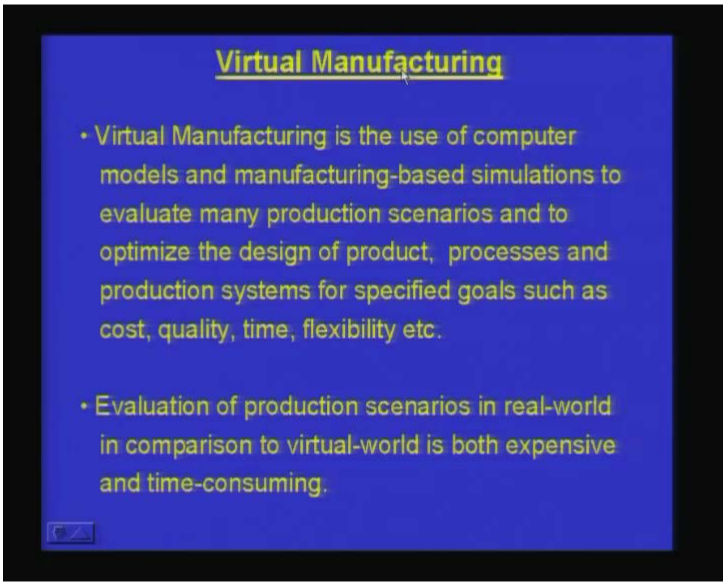

Now going back to a little more further, now if I am basically carrying out process planning decisions further I can also use what is called as a virtual manufacturing tools. The virtual manufacturing I have put the definition here. It basically refers to use of computer based models which may be predictive models and manufacturing based simulations to evaluate many production scenarios like you have a multiple scenarios in front of you in order to manufacture a product and I have to select one of these, one scenario among many which are available which is an optimum one, either to design a product or let's say to design a process or to design a production system itself. Our concentration here is more on processes which we are looking at that. And whenever you are selecting one scenario among many, you are also looking at certain goals which may be either cost, quality, time, flexibility or you may have a multiple criteria other than this or combination of this.

So if I am using let’s say, so virtual manufacturing is slightly more than predictive models in a sense that you are actually trying to basically create a virtual scenario simulating exactly what is likely to happen in a real life or when you go for actual manufacturing process. So that the evaluation of various manufacturing scenario need not be done in a real world but it can be done in a virtual world and a decision can be taken based on that. I would like to basically clear this, giving a few more examples this thing like I may have a virtual machining system.

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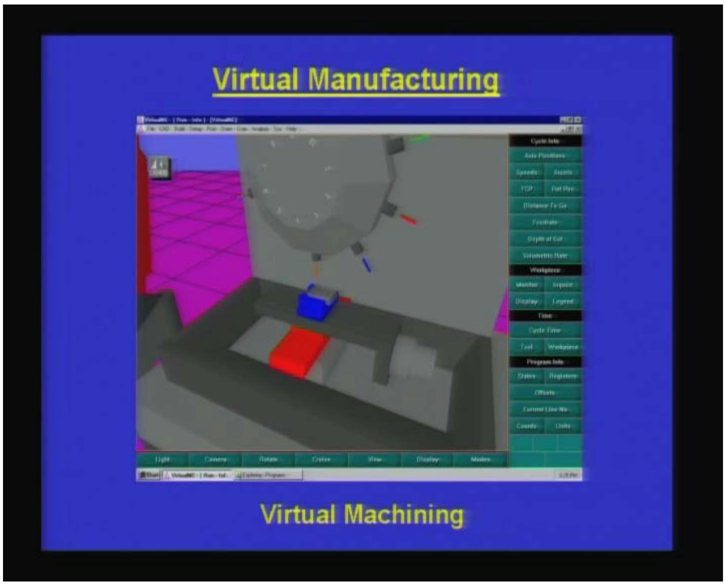

Now what happens is that let’s say I am trying to machine a complex geometry on a CNC machine. Somebody writes a program or let’s say a program is generated using a computer aided manufacturing software and then you take the part, load it on the machine and then start cutting the part. Then you may realize that there is a problem, there is, the problem has come because as a part of a tool motion, there is the tool collides with let’s say some portion of the part so that is which is an undesirable.

Now that means you are not taken care of these collision which are likely to happen when you are planning this particular thing. Now if I can exactly simulate the same manufacturing or machining scenario in front of my computer where I can build a model of a machine tool where I input my program which basically is written to cut the part, give the raw material geometry and carry out let’s say machining simulation. Then if there are any collusions which are likely to happen then you can visualize this or computer can basically tell you that here are the problems which are likely to happen. So in a virtual machining what you are trying to do is basically create a virtual environment where you have the same type of machine tool which has same dimensions as that of the machine tool which you are likely to use once you go for a manufacturing. And all the data and the geometries which are given correspond to the real world. So I am able to predict a few problems which are likely to happen then I go for actual machining.

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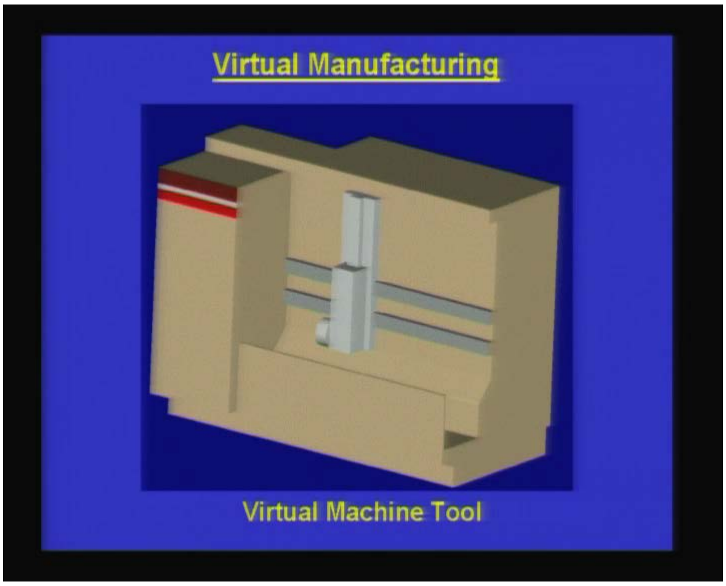

So, here is basically a model of machine tools. So, in a virtual machining system also allows you to build your own machine tool giving the same dimensions as that of your machine tool, same configuration, same kinematics as that of a machine tool and you can build and carry out.

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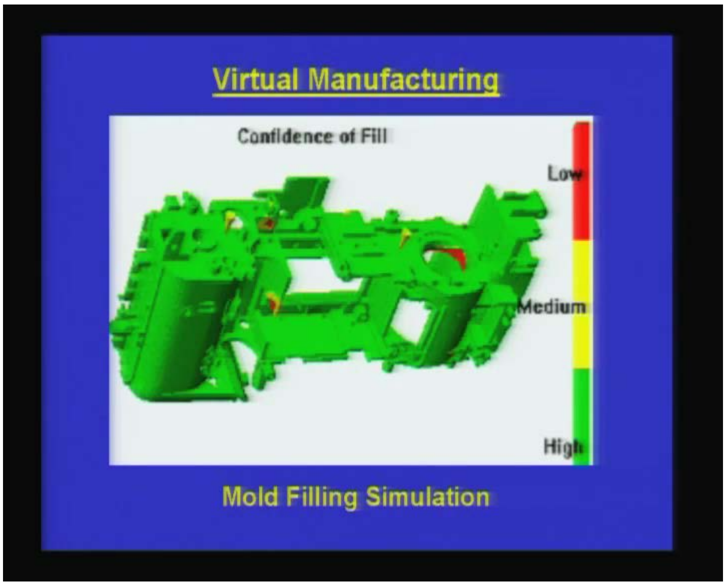

Here is another example of a virtual manufacturing where you are carrying out a mold filling simulation. Here is a part which is a plastic part which has to be manufactured by a process like injection molding. Now this part has many critical features. I am not very sure whether once I design let's say an injection molding dye for this and carry out the injection molding process whether the material is going to fill the entire mold cavity or there is a problem in terms of reaching certain places in the mould. So I can use a virtual environment to carry out this particular process. So what you see here is basically a result of a mold filling simulation.

It shows three regions, the region which is shown in green is basically that portion where the material can reach very easily, there is no problem but I have a portion which is yellow where the material reaches but there is a difficulty. Then red is a more critical portion where the material may not really reach for the kind of you can say the injection pressures which are used, the kind of mold which is designed. Now this gives basically a situation where there is a need for redesign in this particular part or changing the manufacturing process parameters either increasing the injection pressure etc so that this problem can be avoided.

Now this cannot be done in a you can say a real world scenario where I am trying to come up with let's say a different injection molding dyes because of the iterations which are happening so that is a very expensive and time consuming process neither its practical. So you do these iterations in a virtual world and then once you have correct dye shape or you can say an optimum dye design then you go and manufacture the dye.

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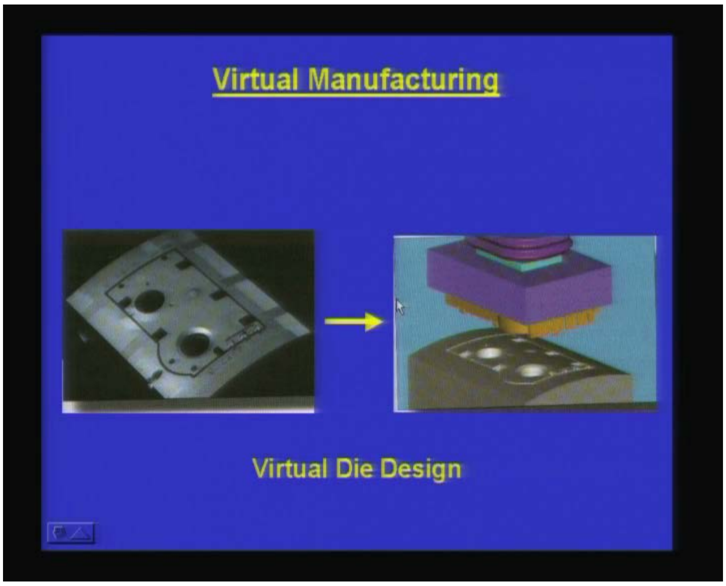

You can also apply a virtual manufacturing in a typical a sheet metal forming scenario like we were discussing about spring-back prediction. So a spring-back prediction can be combined with let's say a manufacturing simulation software where I am carrying out a sheet metal forming simulation. This is actually a real part which one has to produce for which you have already come up with a dye shape. Now I am actually carrying out a virtual forming operation and I can look at the part which comes and then compare with a desired part whether it meets the geometry and tolerances. If I have problem then I can correct the dye shape because of spring-back or some other reasons, I have a problem in achieving this particular thing.

So as I said like the iterations which you do in a real world can be done in a virtual environment to arrive at a correct dye shape, so this is an example. Now only difference between the predictive model which we discuss to spring-back and here is that you are also carrying out the simulations and at the backend, you have a predictive model which is trying to predict a spring-back. There can be many other things in a manufacturing simulation. You may arrive at let's say a part, an incorrect part or undesirable part not necessarily because of a spring-back, it may be because of deflection of a press or may be that you have alignment of the two dyes is not proper. So there can be many other problems which can be predicted in a typical virtual manufacturing scenario.

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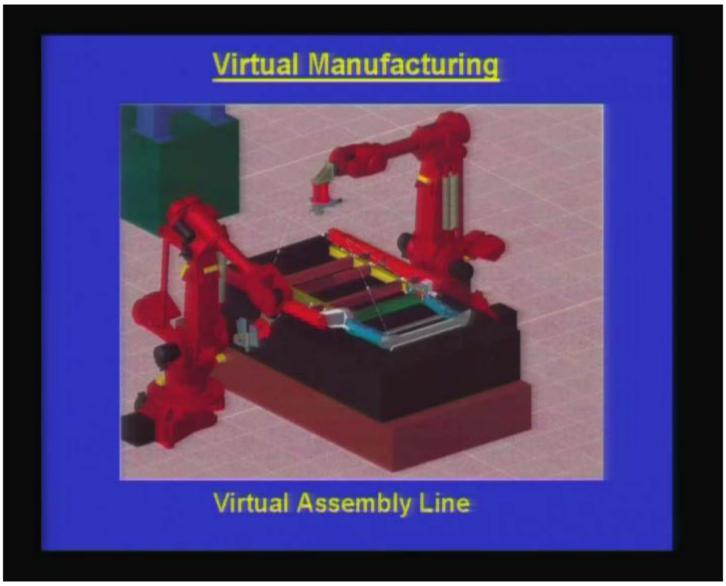

Here is another example of a virtual manufacturing applied to virtual assembly line. Now suppose let’s say I am manufacturing a part let’s say this is an, this is let’s say an automobile structural part where I put together many components and they are assembled using a welding process. And I am using like say an assembly robots or you can say welding robots to carry out this particular process. Now before I design my assembly line for this entire, you can say a sub assembly, I can carry out the complete assembly line simulation using a computer based models and software.

Now you have a commercial software which can help you to do this and it is also done commonly in the industry particularly large industries use. Now the idea of carrying out let’s say an assembly line simulation before you go for manufacturing is that you can optimize in many ways. For example I can do what is called as a line balancing. Isn’t it? For example, you are actually not carrying out this particular welding process at one stage, your number of stations where the welding is carried out, so you have number of welding robots which are carrying out this particular process.

So, I would like to basically minimize the total time which is involved in the entire fabrication and also look at what are the times which individual robot takes. When there are two robots which are welding the same part, are there any collisions among themselves because the welding parts may be such that the robot, some of the robot elements may collide with one another. So that can be taken care as a part of this particular scenario. And you can also look at how let’s say a structure is transferred from one station to another station in an optimum manner.

So this kind of virtual manufacturing helps to answer the questions which are called as a what-if scenarios. What-if this happens or what-if, if I remove one of the welding robots, am I able to let’s say still do the entire fabrication in the desired time or how much extra time is required if I use a let’s say 6 robots or let’s say 7 robots to carry out the welding process.

Even one can set what are the welding parameters and look at how the welding process is carrying out in a virtual manufacturing scenario. So this is you can say going a little one step further in terms of actual manufacturing process, you are looking at a virtual manufacturing environment for an assembly line which is this thing. Last time we also looked at as a part of our computer aided design lecture that assembly is one of the important aspect in product design and manufacturing.

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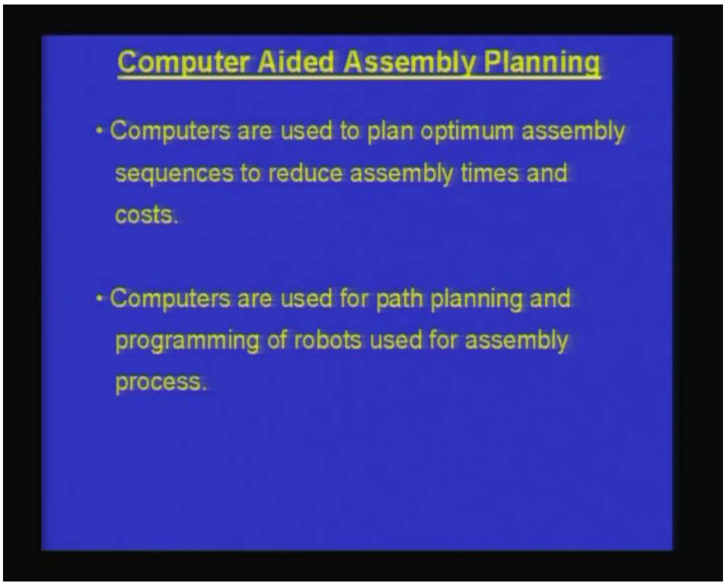

Now assembly execution is usually a part of a manufacturing process. Now if there are let's say number of components which have to be put together as a part of assembly and there can be a number of you can say assembly sequences which are possible. These assembly sequences can be generated as a part of the computer aided assembly planning so that the time which is involved in assembly can be reduced or the cost involved can be reduced or I am looking at both or I am also looking at if I change let's say a particular assembly sequence, I can basically eliminate let's say an assembly fixtures which are otherwise required. So, most of these planning can be done using a computer aided assembly planning software which can be classified as a one of the computer aided manufacturing activity.

Many a times like when it comes to assembly, you have commonly three different types of assemblies. One is a manual assembly, products or components are put together manually or you have a high speed automatic assembly and third is a flexible assembly or what you call as a robot assembly. A robot is used to carry out the assembly operation. Now when I am using a robot, one has to also plan a path for robot, an efficient path so that a robot can grip an object and take this particular component along certain path in order to carry out the assembly such that there are no collisions etc. So I can also carry out path planning for robot using an assembly planning software or computer aided manufacturing. So all these, you can say or again like part of a process planning in a general because assembly is also a part of a manufacturing activity.

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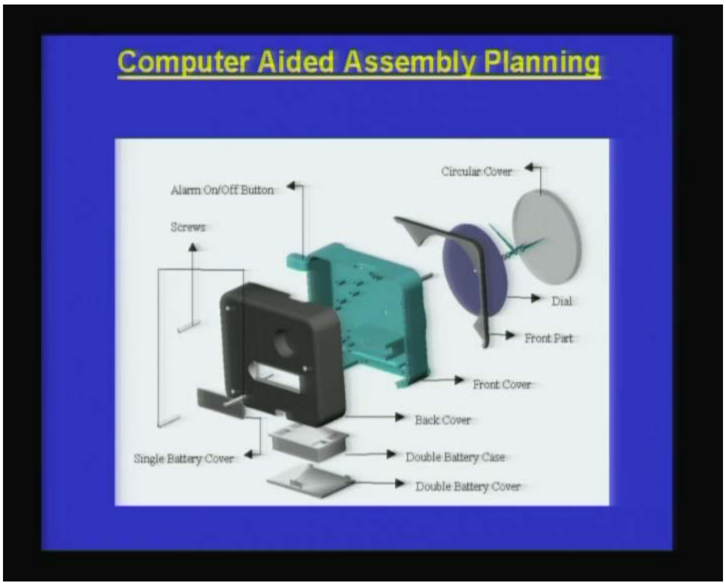

Here is just an example where I have few components which have to be put together and there can be a multiple ways in which these components can be put together and you are trying to basically find out what is the most optimum way to carry out an assembly process.

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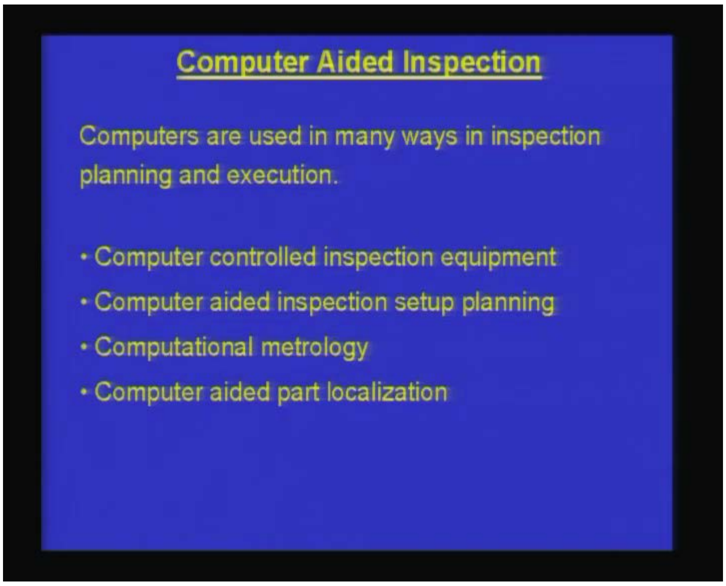

Inspection is one area where computers are found to be extremely useful. Now I have put a few examples of usage of computer in let's say an inspection process. We are aware of computer controlled inspection equipment like one of the commonly used inspection tool is a coordinate measuring machine which is basically a computer control machine or I can have let's say a profile projector which also has an interface with the computer and it basically takes the image of the lets say the image or geometry of the component which you are trying to inspect and compare with the original geometry to know what are the deviations. So, lot of you can say metrology equipment these days have a computer interface or they have a computer control or I may be looking at computer aided inspection setup planning.

One of the important decisions in inspection is if I have let’s say a component which has to be inspected for certain tolerances and other features then how to setup this particular component for inspection process itself? Either it may be an in process inspection or it may be an inspection after the manufacturing. So this planning can also be done using computers and computers are used in metrology like what you call as a computational metrology. For example I am trying to measure let’s say a geometric tolerance like flatness and as a part of this measurement, I take number of points on the surface feature for which you are trying to measure a flatness.

Now what you do with these points like you have setup of points which have been let’s say recorded by a coordinate measuring machine. Now you have to process them in order to basically evaluate what the flatness values are. And as a part of this like suppose if I am trying to measure a flatness and if I take let’s say about 30 points on a surface feature then what do you do with these 30 points to arrive at the flatness value. So you have to basically process them and may be carry out some kind of a computation. For example I may fit for example a plane which is like a least square plane passing through these points and use that as a basis to carry out my flatness values. So most of the features which have to be inspected whether they are geometric tolerances or dimensional tolerances or associated with a computation which is carried out by a computer which is attached to a coordinate measuring machine which is the part of a CMM or it can also be done in an offline manner if I do not have system to do that. So, this aspect is basically a computational metrology software which is where you have application of computer. There are also situations where computers are used for like a part localization.

Now when I say part localization in all manufacturing, in all inspections scenarios what you are trying to assess is that whether the manufactured geometry and form meets the requirements, like in order to assess this you have a reference form or reference geometry which is a design geometry. So we are trying to compare a manufactured geometry with the design geometry. So whenever I have two geometries which they have to be compared, first they have to be localized. One has to be placed with reference to other for actual comparison process. Now this is usually called as a part localization. So I have a design geometry which has some reference, I have a manufactured geometry which comes from CMM. Now I have to compare these two. Now when they have two different references, how do you compare them? You try to place one with reference to other as a part of a localization process and a computer can help you to decide what the localization points are and then you can carry out the process in order to do that. So these are like a few examples of using computers in an inspection process.

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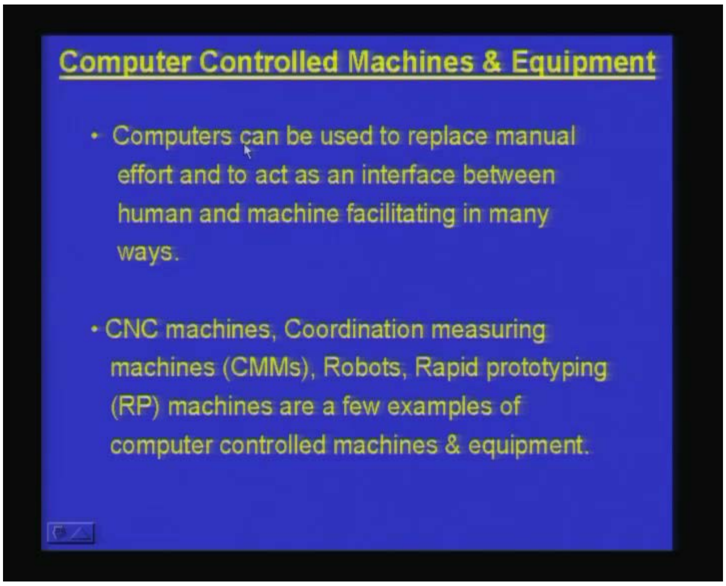

And of course one of the major applications of computers is in manufacturing is that lot of manufacturing machines and equipment are computer controlled where computers basically are used to replace a manual effort in some way or the other which facilitates in many ways. Now the examples are like I have a CNC machines where I have a computer numerically controlled process or it can be a coordinate measuring machine or I have a robot which is computer controlled or it can be a rapid prototyping machine where computer is an integral part of the machine itself. So all these are examples where the role of the computer is to basically a control, control some process or some aspect of the machine.

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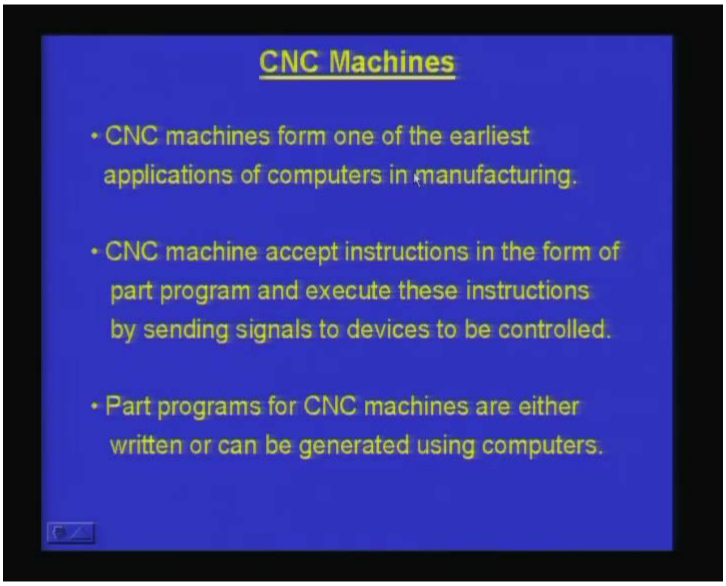

We are all aware of CNC machines where you have, they are used extensively in industries small and medium, even large industries. So what CNC machines do is you have a computer control, computer reads the instructions in the form of a part program and processes these and whatever is the intended action suggested by these part programs, so it basically initiates action in the sense it sense the signals to the various devices of let's say CNC machine in order to control the process. And again computers can be used to generate these power programs etc, either a program for a CNC machine can be written or it can be using a piece of software, so computers are useful there in terms of generating these software.

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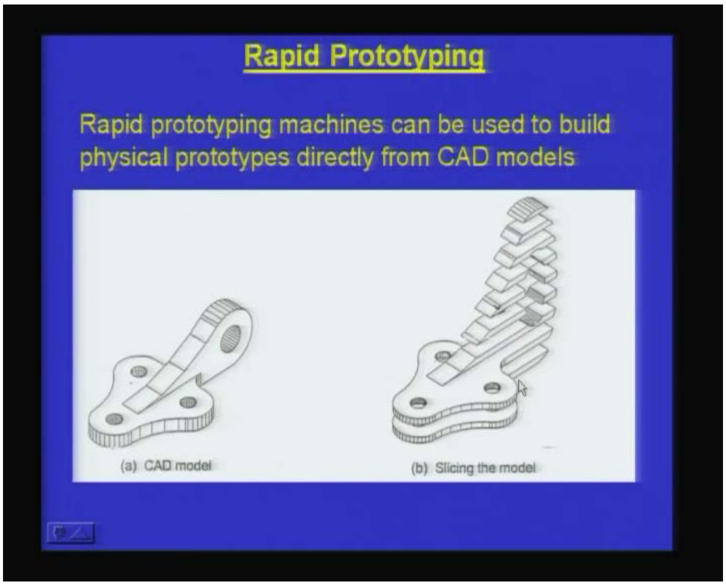

Rapid prototyping is another example of a computer controlled machines. So in a rapid prototyping what you do, they are based on the concept of what is called as a layered manufacturing. If I have let's say a geometry which has to be realized and if I have a CAD model then in a layered manufacturing, you try to basically slice this particular component in terms of layers. So once I have the layer geometries, I can build layer by layer in order to arrive at let's say a manufacturing in order to realize this particular product. So there are many rapid prototyping machines which are available in the market for example, you may have heard of a stereo lithography or selective laser sintering or laminated object manufacturing or you have fused deposition modeling.

So these are all like examples of rapid prototyping machines which actually build an object slice by slice and they usually use a raw materials which are either polymeric monomers or they use either polymer or metallic powders to carry out this particular sinter process. In fact a smaller version of rapid prototyping is also available as what is called as a concept modeler where I can attach a concept modeler to a computer. And once let's say I have a design which is finalized, if I want to basically have let's say a physical prototype of the design so then I can just say build the component and the design is sent to rapid prototyping machine or a concept modeler and I have a physical prototype which is coming out after let's say a few hours or a few minutes depending on the size of components and one can visualize. So it can also be used as a visualization tool. And we know that the all rapid prototyping machines are computerized machines because all the process planning for rapid prototyping that is taking a CAD model, deciding the slice geometries and then controlling the actual you can say a slice manufacturing process or slice realization process are all completely computer controlled which is basically an example, a good example of computer aided manufacturing.

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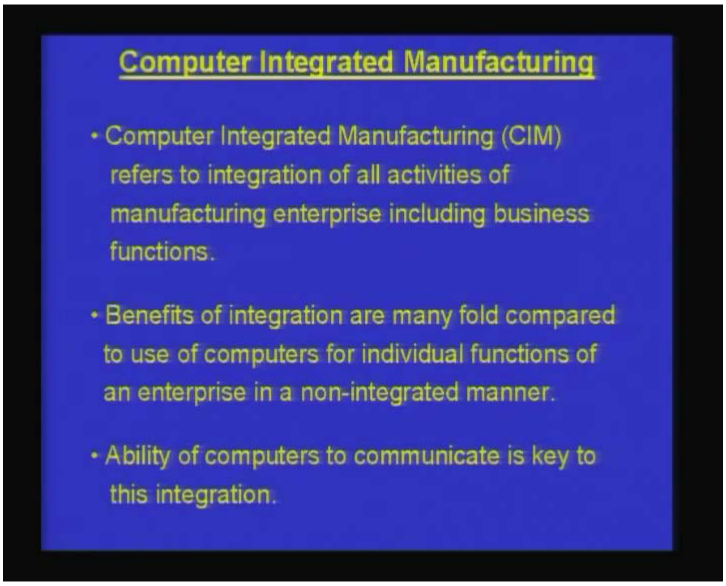

Now coming back to a little more broader picture of a computer aided manufacturing, in a computer integrated manufacturing what you are trying to do is like we have looked at various you can say stages of manufacturing that is inspection, assembly, manufacturing process or DFM design for manufacturing where the computers can be used separately but if I can combine all these activities through let's say in an integrated manner that means you are not looking at assembly or inspection or manufacturing process or let's say process planning activity separately but they are all integrated in one framework. And not only the manufacturing activities, you are also trying to bring let's say a business functions like manufacturing has a very close relation with sales, marketing or finance or many other for example let's say a material department. So if I am trying to integrate my core manufacturing activity with all the other, you can say functions of an enterprise and put in an integrated manner then it basically belongs to bigger domain which is usually called as a computer integrated manufacturing.

And it is seen again and again that if I am using computers for an individual activities of a manufacturing, I have certain benefits but if I use it in an integrated manner then the benefits are manifold. It's like for example I have a design and manufacturing integration which is a very common. So what happens is whenever there is a for example I have a problem either with a design or a manufacturing, since you have a close integration between design and manufacturing, I can communicate fast and if necessary a design can be changed or if necessary a material can be changed.

If it is not available in the market, so a many things can be done if you work in an integrated fashion. So ultimate realization or you can say an ultimate benefit of computer aided manufacturing is if I can go for let's say environment like a computer integrated manufacturing. In a scenario like CIM computer integrated manufacturing, you are not only using the computational and visual you can say capabilities of a computer, you are also trying to use a communication aspect. Computers can communicate or I may have a system where there are human beings, computers and machines communicating with one another in a scenario. If I have such a framework then many of the decisions can be taken faster and lead times in new product design and manufacturing can be considerably reduced.

So this is you can say that a broader picture of computer aided manufacturing. So what I try to do is basically in this lecture is to take you through basically an introduction to computer aided manufacturing taking a few examples. So we have looked at starting with design for manufacturing which is first aspect then we looked at computer aided process planning then we looked at using computers for predictive models and we also looked at computer aided assembly planning, virtual manufacturing, computer aided inspection and computer controlled machines and combining all of them with let's say other functions of enterprise in the form a computer integrated manufacturing. So that's a brief introduction to computer aided manufacturing. If you have any questions, please. So is that clear or as a part of lecture, you may have some doubts or you. [Student: that whether we are considering that also the manufacture with other location as an integrated (Refer Slide Time: 00:41:09 min)].

Actually your question is basically are you looking at using a computers for a manufacturing process for a enterprise or you go beyond enterprise. It's true, even I think can classify that also as a manufacturing. We know that if in a manufacturing enterprise, you have a close relation with customers and you also have a close relation with suppliers. So if I can make them also a part of my entire manufacturing activity then it is usually called as a extended enterprises. They are called as an extended enterprise.

So a computer manufacturing is not necessarily restricted to basically a manufacturing activity which happens within the enterprise you go beyond enterprise, like when it comes to a customer like a relationship, you have what is called as a CRM or customer relationship management. When it comes to let's say supplier etc you have what is called as a supply chain management. So if I have let's say my whatever manufacturing activity which goes on in my enterprise, combine with let's say CRM and let's say a supply chain management SCM then you are actually looking at a complete extended enterprise and it's happening. For example if suppose I generate a design as a part of this thing and trying to let's say design a process plan for that, I can throw away this information that means others can also access it, customer can access and critic on the design.

The supplier can access the same information and see whether they are able to supply the required raw material for this particular process or not. So you are involving others also and in fact you can say a computer integrated manufacturing also includes in a broader sense where you are trying to bring people who are not only within the enterprise but people who are, who influence the entire activity who are outside the enterprise so that's a part of this. And this is happening in a big way because more and more subcontracting is happening particularly with the big enterprises, like for example I am let's say an automobile manufacture I only manufacture only a certain key components or subassemblies of this particular product in house. Most of it is bought or supplied by other vendor. So unless I have a close communication link, particularly using computers it would be difficult to reduce a lead time or to do it in an efficient manner. That's definitely happening in terms of this. So that can also be classified in a broader sense as a computer aided manufacturing.

I have not actually put together the exact rapid prototyping process here like I can give an example. For example let's say I want to build let's say a solid object which has a very complex geometry. Now one thing which I can do is let's say this has certain geometry. First I prepare the slice geometries, deciding what are the slice geometries is purely a geometric computation problem. Once I have a slice geometries, these geometries can be stored. Imagine that the raw material which I am going to use is a paper. So I can cut down these slices and put together, glue the slices to realize let's say solid object.

A process which is somewhat similar to this is used in one of the rapid prototyping process called as a laminated object manufacturing. LOM is a process which basically uses laser to cut a slice and then glue them together to realize a product but that I can be done in many other ways like in a process like a selective laser sintering, you are actually laying down a slice of a powder and wherever the laser strike, the powder get sintered. So you have a slice which is formed. So then I have a next slice which is formed over an existing slice and the un sintered powder. So the process can be carried out in a typical (Refer Slide time: 00:45:33 min)). So there are different RP technologies, rapid prototyping technologies use different ways to basically realize these slices. So that's why you have a variety of rapid prototyping machines in the market. So any other questions?

In fact you can call your question is whether FMS and CIM are they different or one is a subset of the other. I would put it FMS as the subset of a CIM because in a flexible manufacturing system, you are actually looking at the manufacturing process and also the manufacturing system aspects and trying to integrate them but CIM is a broader this thing, you are also trying to bring the business functions which is not a part of any FMS system. So you can say FMS is a subset of a computer integrated manufacturing function because in FMS, you usually do not have a business functions which are integrated whereas in a CIM you have this kind of integration. [Student: sir, one more question like is CIM also flexible for sake of the variation of product or something suppose company wants to change a product model like from one model to another (Refer Slide Time: 00:47:02 min)].

So what you are trying to, your question is whether computer aided computer integrated manufacturing is a product specific. Not necessarily, in fact the whole idea of computer integrated manufacturing is to be able to cope with this flexibility. The idea is whenever there is a product changes or at least you can say product variation happens, I should be able to basically have a computer integrated manufacturing with minimum changes. Now if I have a scenario where I have a very rigid kind of a situation then you are not actually getting a many benefits of computer integrated manufacturing. So one should be like, you can say flexibility is part of any computer integrated manufacturing system. Not only flexibility, in fact it goes one step beyond like what you call as a agility. You may encounter some unforeseen changes in terms of products or processes and a CIM should be able to basically take care of agile aspect also. That means ability to cope up with the change is what you call as agility and sometimes you use a word called as a agile manufacturing to basically take care of this particular (Refer Slide Time: 00:48:27 min).

So CIM is a more broader concept which includes the agile manufacturing concept to. So any other questions? So if there are no questions then I will stop it here. And what we are going to do next is basically we look at more from the computer aided design and manufacturing from the integration perspective. We have already seen some of these integration in these two lectures but let's say in a more tighter way and like you have certain benefits of computer aided design, when it is used for the only the design process. You have certain benefits when you do it only for manufacturing but if you have a CAD/CAM as an integrated environment you can say benefits are manifold. That's what would be basically a subject of our next lecture. So that's what we will do when we meet next. Thank you.