Engineering Graphics and Design
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Week 8
Introduction to CAD

Welcome back to Week 8. From Week 8 we will be starting the software part of the course which is on CAD. So, this week we will spend more time on introduction to the CAD, and towards the end of this week we will be using the software to create solid models. But in the next few weeks we will be going into advanced topics of developing solid models, assemblies and extracting their drawings as well as towards the end we will doing those animations for assembled devices.

So, in this lecture we will be focusing on Computer-aided Design. To know what is the evolution of this Computer-aided design and to see how it plays an important role in the development of a product or a device.

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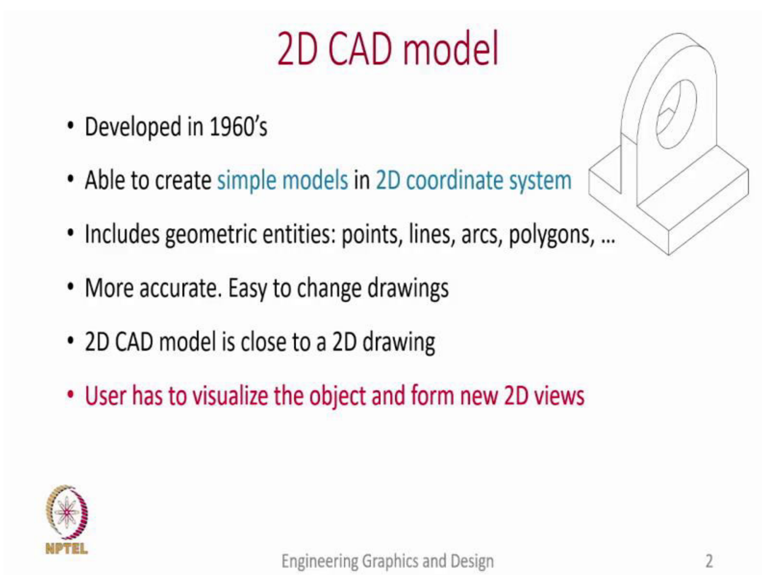

So, let us start with evolution of the CAD software because that helps us understand what are the features of these software and how they have improved over time. So, we will be talking about four different models or the modelling techniques. Initially we will start with this 2D CAD model which were developed in the 1960s. Those were the days of early times of the computers. So, the computational powers were less.

So, what were they capable of doing? They were capable to create simple models using 2D coordinates systems. So, which means if you have a point it is only represented by x and y. So, essentially it is like drawing on a paper. So, though you are depicting a solid model or an object it is almost like how we do the drawing on a paper using a pencil.

So, for every feature of the object like a straight line, curve or a surface we see what are the endpoints of the line, and then join those lines using computer graphics. So, we use different geometric entries like points, lines, arcs, polygon to depict the complete object.

So, the good thing about this is it is much easier to prepare drawings, and whatever we have prepared is more accurate. And later if we want to modify a curve it is much easier to modify a curve, because unlike when you are drawing it on a paper you need to erase and you have some markings on the paper. But here since it is all on the software it is easy to, let us say, delete a line and create a new line.

So, essentially what we are saying is the initial 2D CAD models were close to 2D drawings. There is not much difference because even the geometry of a line or a curve or a surface is represented using 2D planar curves and surfaces.

But the difficulty of this 2D CAD model is it is hard to visualize, because just by 2D sketches what we need to do is you need to first read the drawing, making a mental picture, and then if you want to make any modification to the drawing then you need to come up and make those changes. So, the visualization of the object takes a little bit of effort. You need a trained eye for someone to read these drawings and understand how the object is in the real world.

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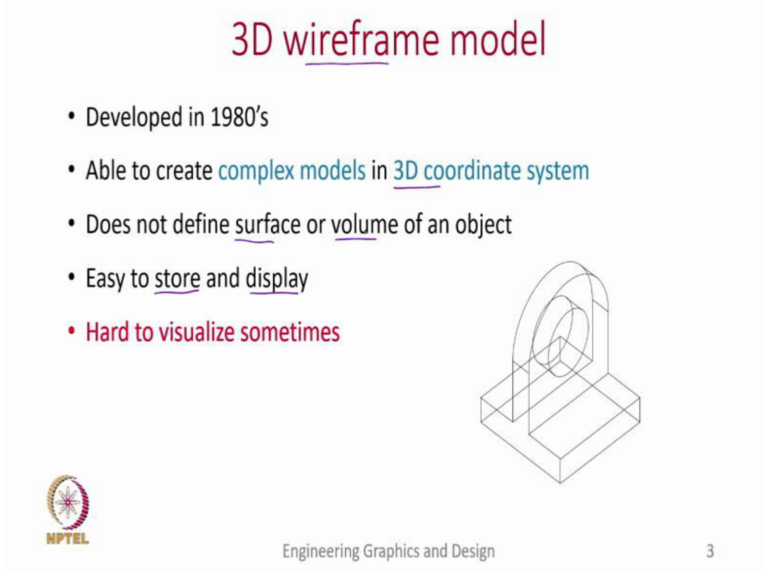

So, the next phase of the CAD softwares were developed in the 1980s which we call as the 3D wireframe models. So, here what we have the improvement is, previously all these geometric entities were defined in 2D co-ordinate system, but now, they are now defined in the 3D coordinates system. So, because you are now defining in the 3D co-ordinate system, for example if I now define a straight line I can generate different views of the straight line using geometric transformations.

So, the database what the computer saves probably is the endpoints of the straight line. Since it knows the endpoints it can give you the the front view, the top view or the isometric view. It can generate it through matrix, transformation matrices, or you can apply map essentially to get the views, different views of the same object.

It is easy to store and display. Easy to store because you have the complete details, the geometric details of the object. You can store it, and then depending on which view we want then you can process the data and visualize it. The other problem with this wireframe model is it does not define the surface or volumes. So, essential it depicts all your objects only in a series of curves and straight lines. So, there is no definition of a surface, nor a definition of a volume.

For example if you want to find the volume of this object or weight of this object, the wireframe model cannot help you because it does not have that information. The mathematical definition of surfaces and the volumes is missing. And sometimes it is hard to visualize. Probably it is not shown here but there are instances where, for two different orientations of the object the wireframe will look the same.

Now it creates a little bit of ambiguity. So, you are not sure which orientation of the object you have to look at. So, these are some of the disadvantages of using the wireframe models.

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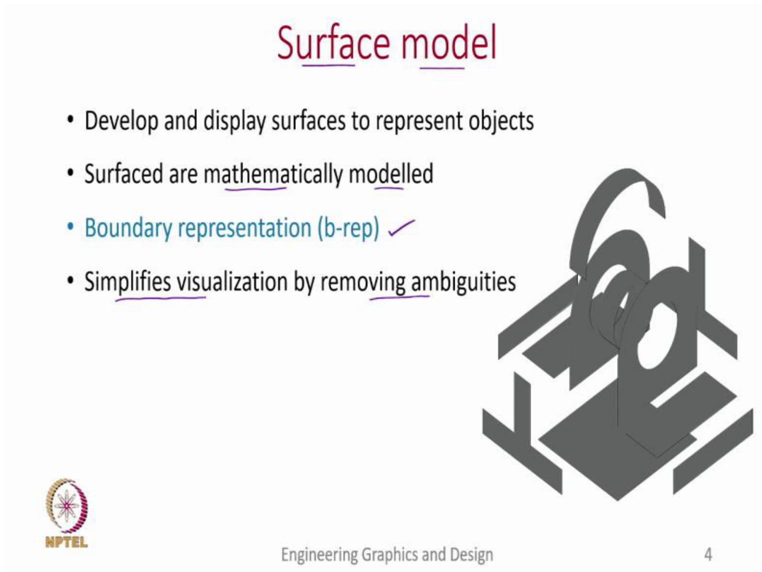

So, over the time there were improvements in the CAD software. Then people started developing these surface models. So, essentially what we do in the surface model is, if you want to show the object you first model all the surfaces of the object, and only show the outer surface of the object, because once you look at the outer surface of the object you will get an idea about how the object looks like in the real world.

So, what we are saying is we will develop and display surfaces to represent objects. Surfaces are mathematically modelled. This mathematical modelling is important because this helps you to see if a surface is rotated or translated or it is moved from one place to other, how can you show that in a different orientation? In other words you can get different views of this object once you define the mathematical model of the surfaces.

So, there is a representation called as the boundary representation which is very commonly used for these surface models. So, what does boundary representation mean? You define the object by boundary of it. So, for example just let us talk about a simple rectangular area. Then you say you will define this rectangular area by the edges of this rectangle.

Similarly when you move to the 3D and, let us say, it is a cuboid you define the cuboid by the six faces it has. So, once you define the six faces and you say these six faces are closed then the software understands that it is an object and it can help you represent that on your monitor screen.

So, the good thing is it simplifies visualization. So, if you compare it with the previous two, the 2D CAD models or the 3D wireframe models, here the visualization is simplified because those ambiguities we were talking with the wireframe model are no more there.

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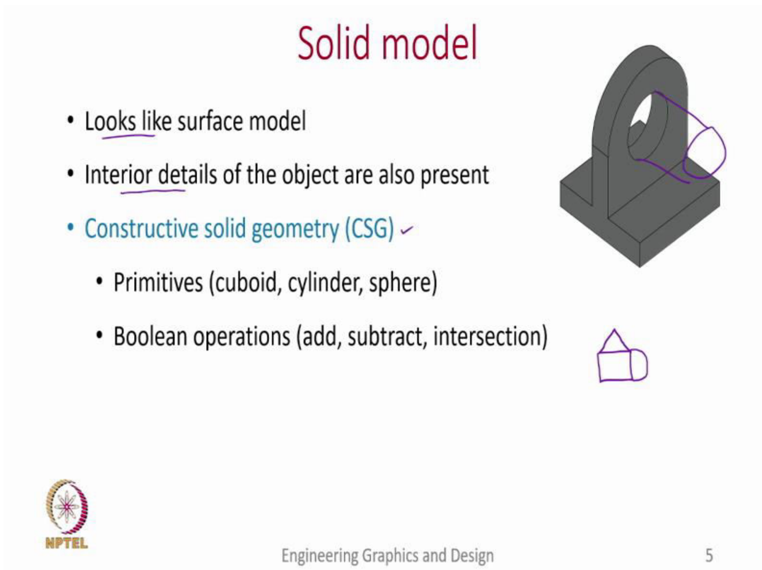

But in the recent times solid modelling is more popular because it has some other advantages which we will be discussing now. So, solid modelling looks very close to a surface model. So, if you look at the monitor, the object, it looks exactly like the surface model. But the difference is the interior details of the object are also defined.

So, for example, let us say if you are looking at this object which is shown on the slide. Can we answer whether the inside of the object is empty or is it a solid block? So, both are possible. So, if I modelled it just by using the surface model I cannot answer whether it is a solid object or a hollow object.

But now if I model it with solid modelling now I can answer this question whether it is a solid or a hollow object, hollow meaning let us say, it is made up of some thin sheets so that inside it is encompassing a volume. So, a very powerful and a common way to represent these solids is the constructive solid geometry. Here we start with primitives like some basic 3D objects.

What are some of the basic 3D objects we can think of? A cuboid, a cylinder, or a sphere, and maybe a few more based on the requirement. So, what we do is we do Boolean operations, Boolean operations with these primitives. What are Boolean operations? These are things like add, subtract and intersect. So, far example I can say, just to make it simplified I am showing in 2D. Let us say we have a square, and then a triangle.

If you add them together, now you slightly increase the complexity of object you are depicting, and maybe you can add a semi-sphere to depict a further more complexity. So, if you look at real world objects most of the real world objects can be modelled by doing these Boolean operations of addition, subtraction and intersection of some primitive objects or solids. So, sometimes, for example in this object how did we create this hole?

So, before creating the hole probably it is a solid, and then we say it is intersection or subtraction of the solid object with a cylinder. So, let us say, there is a cylinder lying here. Then if we subtract the cylinder from the object that's when we get an object with a hole. So, these are the kind of operations one can make to make slightly complex objects and which are close to the real world objects which we are designing.

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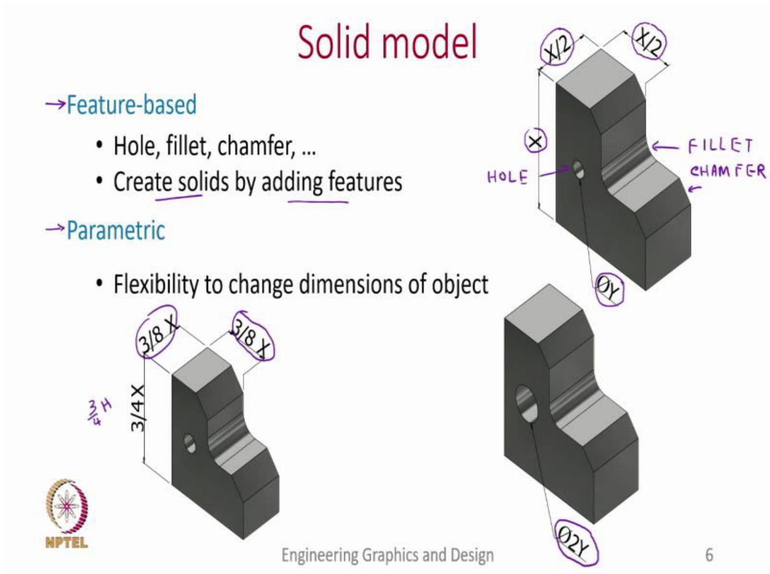

So, there are other features of solid modelling which made it more popular and which helps us in designing real-world objects such as feature-based. So, if you look at this subject what are the kind of features we see. So, we see that there is a hole here, there is a fillet here, and we also notice that there is a chamfer here. So, these are the features which define the object.

So, if you keep on adding these features, gradually the primitive objects you started with, they will approach close to the real world objects what we wanted to design. So, you can create complex solids by adding or subtracting, essentially doing the Boolean operation with these features. So, this is what is called as feature-based modelling. In addition to feature based modelling there is another aspect to it which makes it more powerful, which is parametric.

So, most of these CAD softwares are parametric. What it means is it gives you the flexibility to change dimensions of the object. What do you mean by changing the dimensions? So, let us say for this object we have on the slide we define the dimensions, like let us say, the height is defined as X. The depth is defined as half of X, and this dimension is given as half of X. Similarly we say that the diameter of the hole here is by some other variable Y.

So, using this if we have developed a solid model, later you can come back and change the dimensions of this object. So, let us say, now I say I increase the height by three fourth, so three fourth of the initial height H. So, once I change the height it will automatically change the depth as well as this dimension. But if you notice carefully the size of the hole remains the same as in the original object so, because that is defined by a different variable Y.

Now let us say, instead of changing height, I only change the diameter of the hole. So, in this, let us say this is the second model. I only change the diameter to be twice the initial diameter, two times Y. But the height remains the same. So, you see that the overall shape or the size of the block remains the same. The only difference is we are now able to change the size of this hole.

So, this is what we meant by parametric, saying that you can make changes to the object very easily and once you make these changes it automatically makes adjustments to the object or the solid you are preparing. So, just to summarize, sorry, so to summarize what we have discussed till now is we have looked at four different ways the CAD models has evolved starting with 2D CAD software where we are only working with 2D coordinate system. It had limitations like, if you need to have a new view you need to restart because you cannot use the same.

Over the time the next improvement was the 3D wireframe models where the geometry is represented in 3D coordinates system. So, at least it is better than the previous 2D CAD software. By creating new views you need not start from scratch again. But it had some problems with the visualization. To overcome this visualization problem it evolved into these surface modelling techniques.

So, surface modelling was visually very good. It was easy to visualize. But the few disadvantages it had are like, you do not know what is the interior details of this model. So, for example like finding the volume, weight or let us say if we do an intersection it is hard to find out how to manipulate these operations.

So, lastly we discussed about the solid modelling technique where it overcomes all these disadvantages, as well as it had a few features which made it powerful. We have discussed about the feature-based modelling and the parametric modelling which makes the job of creating more complex objects easier, as well as it helps you to make modifications to the existing or the already created solid modelling.

So, next let us see how these solid models are used in the industry. So, in the industry there is a lot of design activities happening as well as the manufacturing activities which happen to realize the product and bring it to the market. So, let us see what are the ways in which this solid model is used.

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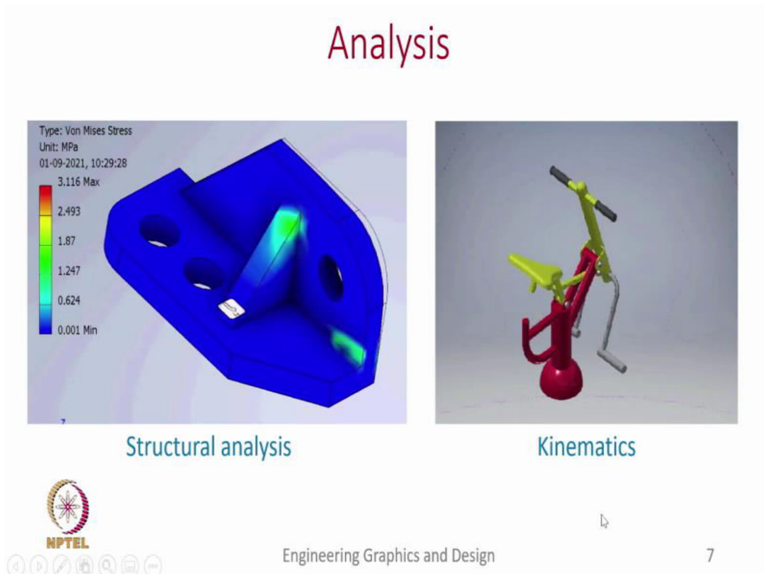

First let us start with analysis. There are many analysis engineers do in an industry or at a workplace. They include structural analysis. Like for example this is a, what I show here is a bracket and once you apply a load it deflects. So, when it deflates, it induces stresses in this object. And as a designer one may need to know whether these stresses are within the allowable limit or not. So, that can be done using the same solid models.

So, once you develop a solid model in the CAD software you bring that CAD model in to this analysis softwares. You apply the loads, the properties of this object and then find out how it responds to the loads. So, the next thing you can do is kinematics. Let us say we have a gym equipment like this.

One may be interested to know what are the kinematics of it, which means if you apply a movement at the handle how does the leg move, or how does the person who is sitting on it is moving? So, those kind of analysis can also be made using softwares. For that what you need is you will start with a solid model. And since here it is a device you need multiple objects, bring them together and then see how they relate with each other, so if you move one how fast or slow the other moves?

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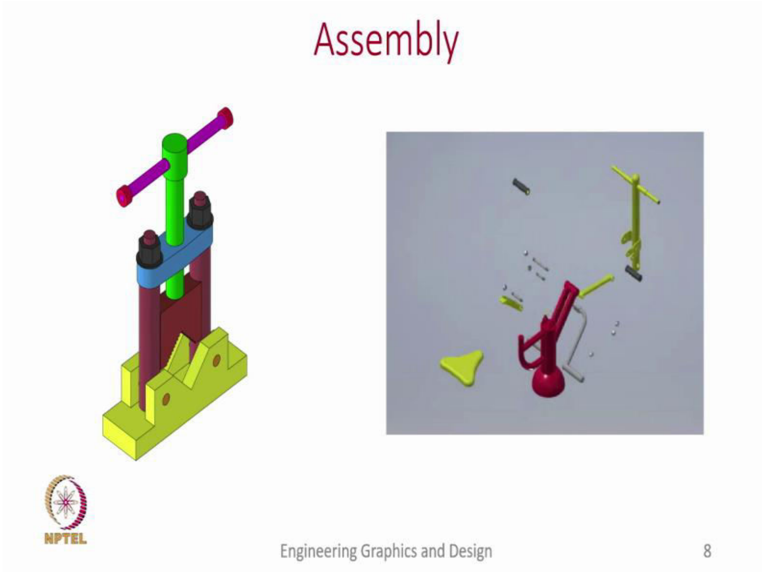

So, similarly we can also do assemblies, because at the end of the day most of the times we are looking at devices. Devices usually have more than a single component. So, then if you have multiple components you need to make sure not just the component design is perfect but they come and fit together in a required manner or the intended manner.

So, how do we check that? We can use an assembly software. Usually a CAD software has this assembly feature where you bring multiple components, bring them together and see how they are relative placed. This gives the designer a feedback of, if any further changes need to be done at the component level to accommodate this perfect assembly.

Sometimes what happens is you may want to, you have designed a device but you need to market, or you need to communicate your idea to others. So, usually just by, instead of showing a static image, you can also animate and show how this device is assembled. So, these are presentation features which few CAD softwares have. Most of the recent CAD softwares have these features which help you to present your device in a more elegant fashion such that the working of the device or the components which are used in the device can be communicated more effectively.

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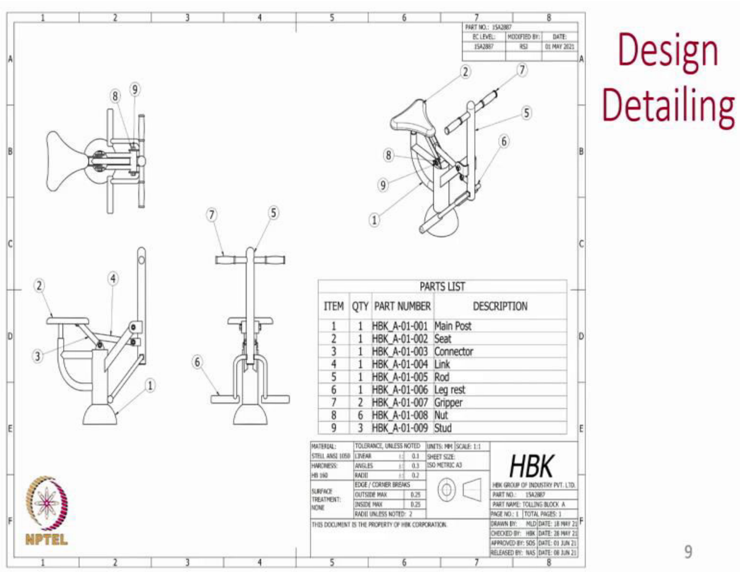

So, let us say we are done with the design process and then one needs to fabricate your device or an instrument. Then you need to approach a third person who fabricates these devices. Usually that third person takes engineering drawing which are more precise. So, for example you can use the same solid model and with a click of a button the CAD software will help you get the design drawings.

Of course you need to specify what kind of drawings you need, do you need it at an assembly level, component level and which views you are interested to communicate your design. But the good thing is, once you develop a solid model you can use the same model to develop these design details. You need not again start from scratch, like what we do it on a paper.

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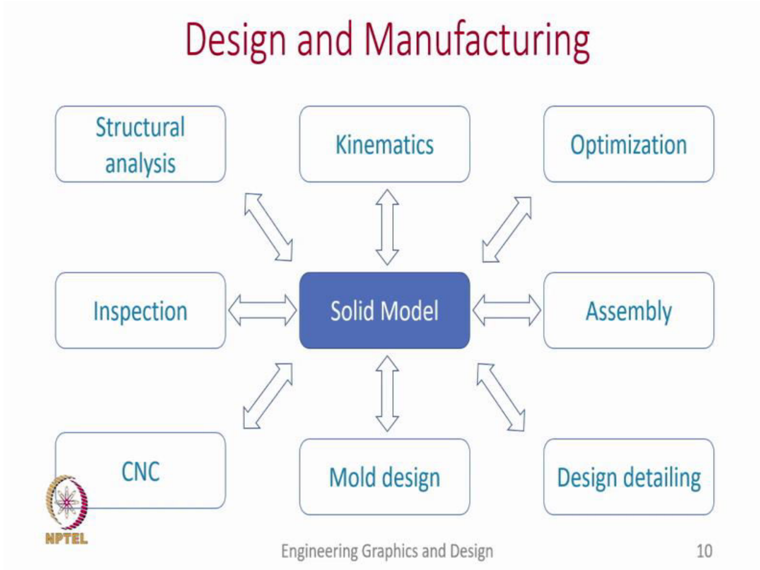

So, to summarize, the solid models help us both in the design aspect as well as the manufacturing aspect of these idea of building devices. So, let us see a few components. So, we talked about structural analysis, kinematics. These are the kinds of analysis we do. We also can do optimization of a product design.

So, let us say, a product, you start with a crude design. We can also improve the design using some analysis methods. But there are some CAD softwares which can help you automate this process of improving the design. So, there are some optimization softwares like Optistruct which can do this process of structural optimization.

Later, once we are done like designing at the component level then we come with the assembly level where we being bring multiple components, assemble and see if there any further design changes required. And let us say, once the design looks good and you are ready to manufacture you need to have this design detailing, which means you need to get the assembly and the component level drawings in standard views. We have been discussing in this course.

But once you give it to the manufacturer even he will use the same CAD models or the solid models you prepare to help him in his process. So, he can use it to design molds. So, let us say if you can think of any plastic bottle, right, usually you need an injection molding technique to prepare these plastic bottles. So, further one needs to prepare a mould and once you prepare the solid mold of your component then you can use these CAD softwares to design the mold to prepare this object what we are intending.

And sometimes you can also use the same model which will help you to do the CNC machining. What is CNC? Control, Computer Numeric Control which automates the process of steps needed to machine this product to the final product.

Initially you start with the block of either metal or a material and from this block you do a series of machining operations to reach a final product. So, this also can be automated through machines what we call it as CNC machines. So, once you give a component to it you need to generate a code for the steps needed to achieve the final product. This can be done by CNC softwares.

Finally, let us say you have prepared the product and you want to inspect before you send it to the market. Even for that you can use the CAD software because let us say, you have a laser scanner to scan the final product. Once you have the laser scanner it will collect all the data points and recreate the model.

Once you recreate the model then you can compare this recreated model with the initial design and see whether it matches with the dimensions of the shape. So, if it is out of the acceptable tolerances then you may reject the component, and if it is within the allowable limits you accept the component for going to the market.

So, what is central with all the activities of design and manufacturing is the solid model. So, which in this course we will be helping you to develop enough skills where you can use a software and develop a good solid model.

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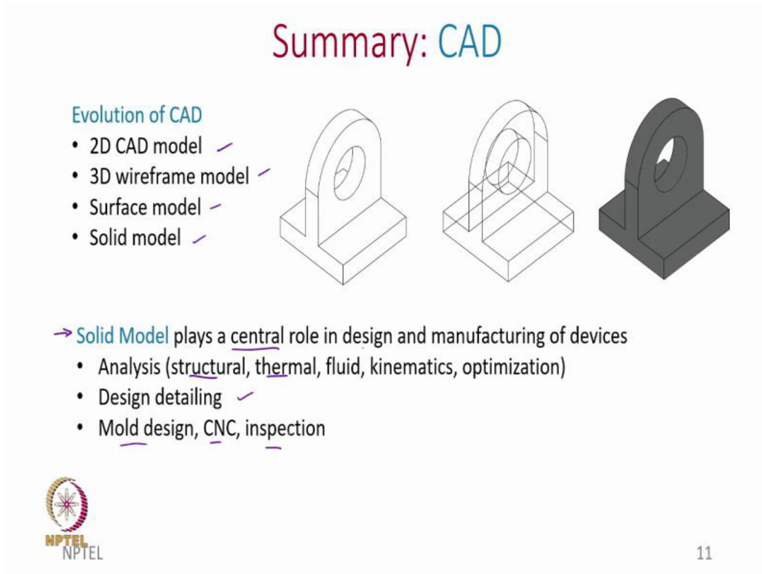

So, let me summarize this lecture. So, we started by looking at the evolution of CAD models where we started with a 2D CAD model, then the 3D wireframe models, surface model and finally the solid model. We said, currently in the industry the solid modelling is a more powerful technique and very commonly used. This solid model is used both in the design and manufacturing. It plays a central role in the design and manufacturing of devices.

So, how does it help us? It helps us with analysis techniques like the structural, thermal, fluid, kinematics and optimization. That we have just discussed in the previous slide. In addition to that we also can do the design detailing and it also helps in the manufacturing activities like designing of molds, CNC programs, to develop those CNC programs, as well as in the inspection of the final product.

So, what we have discussed in this lecture is to say how CAD plays an important role in our idea of designing or developing these devices or machines? So, in the next few lectures what we will be looking at? We will pick one CAD software and then see how to use that CAD software to develop these parts as well as assemblies. We will meet again in the next lecture. Thank you for your attention.