Automation in Manufacturing
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Week – 03
Selection and fabrication
Lecture – 03
Computer aided design of components

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We are studying how to select or fabricate the required components to develop an automated equipment or a system.

In previous lectures we have seen how to select electrical and electronics components, what are the selection criteria, what are the technical terms which one should understand before taking the final decision about the selection and purchase of electrical and electronics components.

In today's lecture we will be studying the use of computer aided design philosophy in the designing of the mechanical components.

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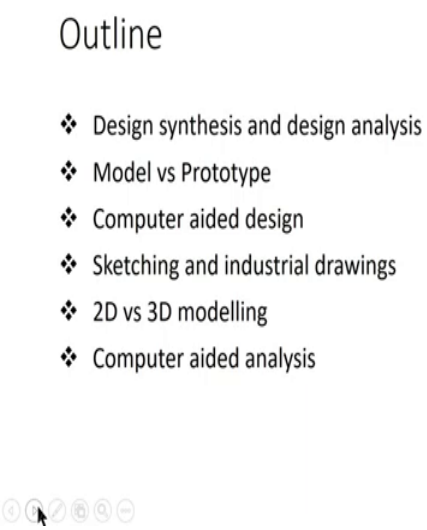

The outline of this lecture is as follows, at the start we will study the design synthesis and design analysis, then we will see what is the difference between modeling and prototyping.

We often use these words. I have to develop a model or prototype. What exactly is the difference as far as the engineering point of view is concerned. Next we will see how computers are helping in designing the models or the prototypes.

We will see what is the difference between sketching and industrial drawings. The industrial drawings are represented in either 2 dimensional mode or the 3 dimensional mode, the pros and cons of 2D and 3D modeling will be studied. And at last we will see what is the meaning of computer aided analysis, the preliminary discussion would be carried out.

The detail analysis is out of the scope of this course. But as far as the use of computers in the product lifecycle, it is essential for the budding mechatronics engineers to know how the computers are helping in designing of the products.

We need electrical and electronics components for the desired automated system.

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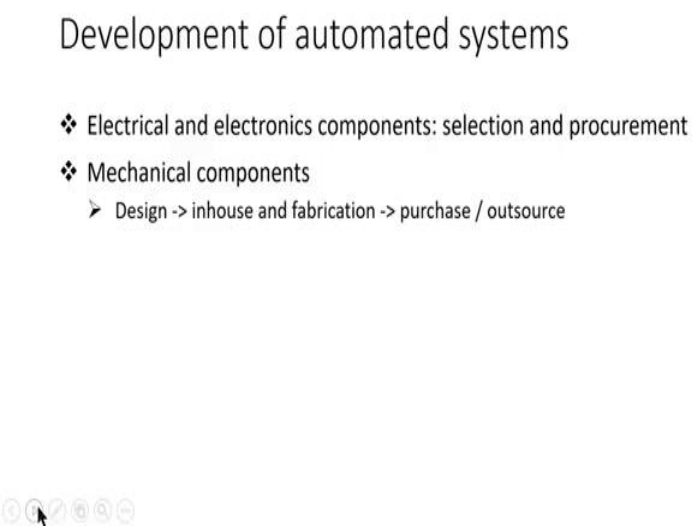

These selected components are based upon the thorough knowledge of the working principle and construction of these components and then these components are procured from the market.

The mechanical components are also needed to build an automated system. The mechanical components may be variety of the links mechanisms structure of the automated system; it is scheme or the body of the automated system. All these mechanical components are to be designed and then decided whether these components are to be manufactured in house or they are to be procured from the outside.

Basically there are two aspects, the first is the designing of the mechanical elements and the second aspect is the decision about fabrication or the procurement. The first option may be designing the components in house, but purchasing the components from the market. The second scenario is design and fabricate the components in house.

This decision is altogether dependent upon many factors. These factors may be the cost associated with the components that is the primary factor, second the availability of the components in the market. A simple example is the fasteners, the standard fasteners such as screws or nuts or the rivets that are available in the market.

There is no point in manufacturing these fasteners in house, they can be manufacturedby procuring an equipment. But if the good quality components are available in the market

it would be wiser to purchase the components from the market and use them for our intended purpose that is the assembly or the product development.

Some of the components may not be available in the market. These components need to be designed in house and we have to select proper manufacturing process and go for the actual production of that component.

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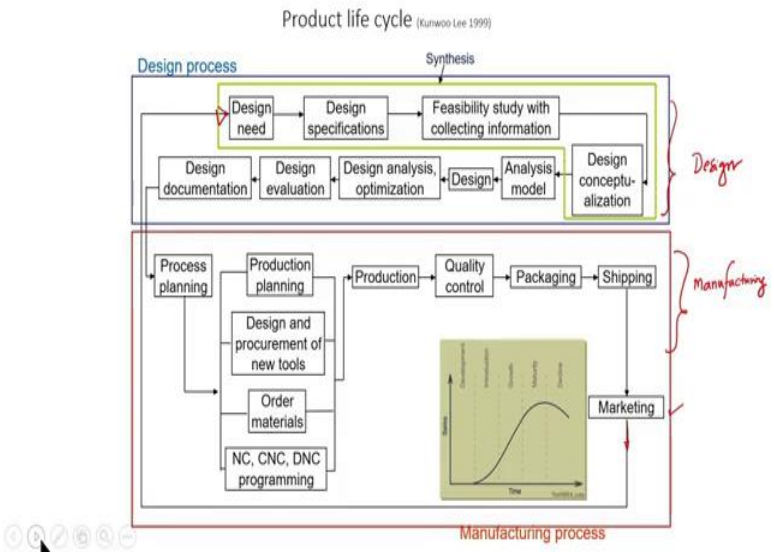

On the screen we can see the various functions and operations that need to be carried out during a typical product life cycle. The product life cycle is starting with the marketing, the marketing people will provide the inputs to the design team.

Based on that inputs design activities will be carried out and after that the manufacturing activities will be performed. All these activities are grouped for the identification of design need, deriving the design specifications, feasibility study of the design and the design conceptualization.

These 4 activities are combined together and the design is synthesized. We are getting the design need from marketing team and from the customers, we are specifying that requirements into the numbers or we are finding out the specifications based on the inputs that is the need of the customer.

And after that the feasibility study is carried out, whether it is possible to manufacture the product or whether it is possible to modify the existing design of the product as per

the need of the customer. After that the design is revised or modified and the revised concept is generated, which is called the design conceptualization.

These 4 activities are clubbed together and this process is called design synthesis. After conceptualization of the product design, we are analyzing the design and applying the mechanical engineering principles and afterwards we are finding out the optimal design parameters.

We are finding out the size shape material and the dimensions of the product by applying the mechanical engineering principle. Then the testing or the evaluation of the design is done and then the design is documented, the documents and production drawings are made and these drawings will be sent to the manufacturing department or the production department for actual manufacturing.

The analysis of the model, the designing of the product, optimization design, evaluation and design documentation; these are grouped together and this process is called analysis of the design.

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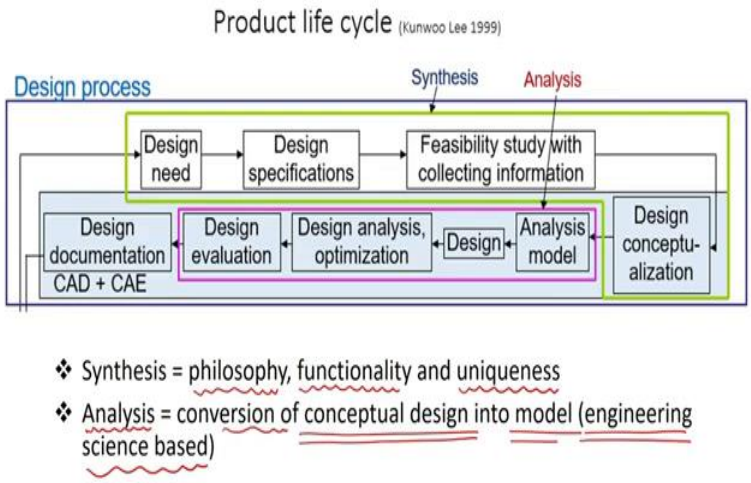

The design synthesis module or the design synthesis activities are analyzing the philosophy of the product development. The objectives of the product development or the motive behind development of the product, then in this operation the intended functionalities are analyzed and the uniqueness of that product is defined.

The second group of activities that is carried out are the analysis activities. Analysis activities are dependent upon the engineering analysis, application of the mechanical engineering principles and the conceptual design is converted into the engineering based model or the prototype. After testing of this model or the prototype we can directly go for its production.

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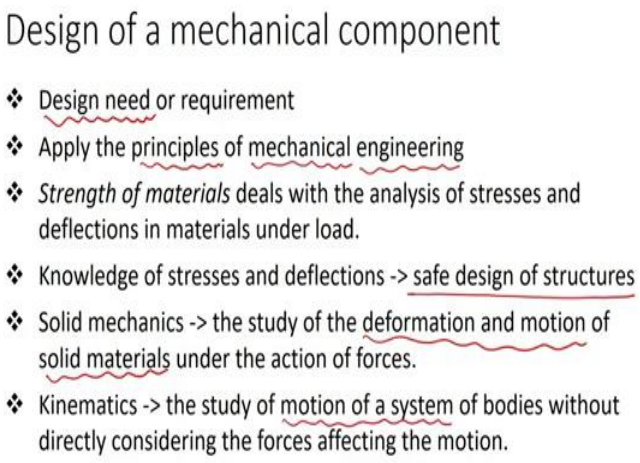

In general what are the various steps to design a mechanical component? The first step in designing a mechanical component is to identify the design need. We have to clearly specify the design need, as far as the mechanical components are concerned and we have to identify the size, shape of the mechanical component.

We have to apply the knowledge of mechanical engineering. Fundamental knowledge is required of the strength of the materials, which deals with the analysis of stresses and deflections in the materials which are under load.

To manufacture any physical product we need the materials and we must know how the materials are behaving under the application of the load. The simple example may be the forks of a forklift truck, which are made up of the steel material. But what kind of steel material is required what should be its strength. It is very essential to understand and to specify the strength of the material when we are suggesting certain material for the operation.

We cannot have the plastic forks for the forklift truck which is used in the industry application. Certainly we have to go for the steel which is having very good strength, secondly the knowledge that we acquired during the analysis of stresses and deflections will certainly make the design safe.

The objective is to study the strength of the material and find out the stresses and deflections, so that the design of the product would be safe and we can easily go for the manufacturing of that product. The next important aspect in mechanical design is the application of solid mechanics principle.

Solid mechanics comprises of the study of the deformation and motion of solid materials which are used in a product or a system. The solid materials will be under the action of various forces. When the materials or the components are under the action of forces, as well as the components are moving, the application of forces are also there.

Study of the deformation under the action of forces and motion will help in developing a robust product and a robust automated system. The third aspect as far as mechanical engineering is concerned is the kinematics of the automated systems. Various mechanisms are clubbed and the automated system is developed that is called the automated machinery as well.

These mechanisms are having various links and they are connected with each other through joints. When these links are moving with respect to each other then what is the transmission of motion and forces. The principle of mechanical engineering which deals with the study of motion of a system of bodies without directly considering the forces affecting the motion is called as the kinematics.

The kinematics basically deals with the motion of a particular system or without considering the effect of forces on the motion. By applying these principles of mechanical engineering the design engineers are getting the final dimensions of the product, afterwards the design is tested.

To test the design, a model or a prototype of that desired product is created. What is the difference between the model and a prototype term, which are used in the product design.

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Modeling and Prototyping

A Model	A Prototype
A Model shows the appearance of the desired product. It does not work.	It is a working model of the product.
Used for visualization of the product in early stage of the development. Display and demonstration of product.	Used for performance evaluation and further improvement of the product before the start of the production
Scaling can be applied.	True scale.
May consist of only the exterior (skin) of the product.	Comprises of exterior (skin) as well as the interior parts/components/mechanisms.
Relatively cheap to manufacture	Relatively expensive to manufacture.
Rapid prototyping with 3D modeling	Conventional manufacturing or 3D printing, purchase and assembly.

The first difference between a model and a prototype is a model shows the appearance of the desired product, so it does not work.

A model will just show the physical appearance of the product and the exterior of the product. How the product will look like after its development is called the modeling. However, a prototype is the working prototype that is why it will have all the functionalities and the features which are incorporated in the product.

It is a working model of the product that is called the prototype. The second difference between the model and the prototype is in general the models are used for the visualization. To visualize the size, shape or the appearance of the product after its development and in general the model is used for the display or the demonstration purpose.

On the other hand the prototype is used for the performance evaluation and analysis of the product.Based upon the performance evaluation or the analysis, the product can be further improved before the actual start of the production. During the development of the model scaling can be applied, the scaling means the size of the product can be reduced. For example, if we are trying to develop an automated guided vehicle the size of the automated guided vehicle is in meters.

However the final shape of the automated guided vehicle can be visualized by scaling it down. By using 3D printer, a smaller model of the automated guided vehicle can be developed which will help in visualizing its appearance after the development.

But in the case of prototype it is to be the true scale, it should have the exact dimensions as the final product would have. The model will consist of the exterior or the skin of the product, the prototype will have the exterior that is the skin as well as it will have the interior parts or the components and the mechanism.

Obviously, as we are developing only skin or the exterior portion of the product, the cost associated with development of a model is less in comparison with the development of the prototype. The development of the prototype is having designing and development of its components and assembly as well.

Moreover the development of prototype will take longer time. So now a days the 3D printing is used comprehensively and the 3D printing is coming under the philosophy of the rapid prototyping. The 3D model have to be first developed and afterwards the 3D model can be utilized to develop the RP based models.

The 3D printing is also used to develop the various components of the prototype. If it is not possible by using the 3D printing then the conventional manufacturing is adopted. If we do not have the metallic 3D printer, but the certain components are to be manufactured by using the steel or the metals.

In this scenario the components which are made up of the steel, we have to go for conventional manufacturing like casting, we have to go for the machining of that casting. Therefore, the time required to develop a prototype is quite long. With the use of the 3D printing technology now, it is a matter of few minutes or a few hours to develop the skin of a typical product in its scale down mode.

Now, there are other 2 modes as well which are used in modeling, these are the virtual mode of modeling and the physical mode of modeling. In virtual mode of modeling, computers are used which help in visualizing the model in the digital format.The digital modeling and the 3D printers are helping us to develop the physical models of the product.

Of course the 3D modeling or the digital modeling is convenient for less time, but the skills required to develop the 2D or the 3D models of the product must be acquired. For that purpose it is essential to have the knowledge of application of computers to develop the 2 dimensional models or the 3 dimensional models of the product.

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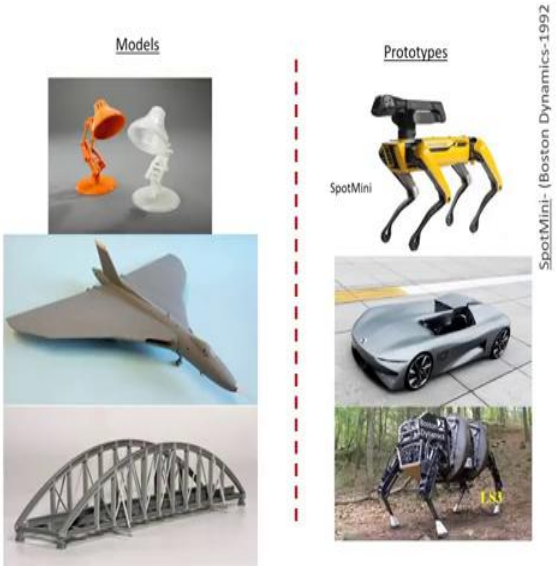

These pictures will give us a better idea about the concept of the model and the prototype. We can see the model of a lamp, these lamps are 3D printed and have a lot of linkages which are connected to each other.

But they are not functional, they are rigid and not moving. Moreover these lamps do not have the electrical connections. These models simply giveus the idea of how the cover of the model or how the lamp would be after the production.

Same concept is there for a military aircraft which we can see on our screen, this is the clay model of the military aircraft which is developed to know how exactly its physical appearance would be after its development. The third example is a simple bridge i.e the civil structure.

As far as prototypes are concerned, we can see a robot that is very famous called SpotMini. This is the prototype of the desired final product which is having all the functions and doing all the activities of the final product.

To develop the virtual models or to have the virtual modeling, it is very much essential to understand the principles of CAD.

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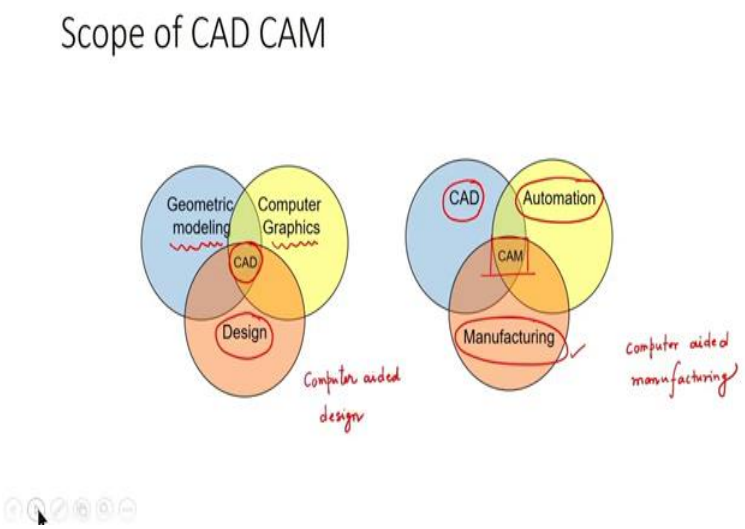

The CAD is nothing but application of the knowledge of geometrical modeling and computer graphics to solve the design problems, the principles of geometrical modeling are applied and computer graphics are used to visualize the part digitally on the screen virtually. This activity is helping us to design the components in virtual mode. This is called the computer aided design.

In a similar way the computers are helping us to automate the manufacturing operation as well. But idea of operations of manufacturing can easily be automated with the use of computers.

A simple example is generation of the part programming code GNM code, which is used in the CNC machining operations. But to generate these codes or to use the computers in manufacturing, the CAD based drawings and the required automation are necessary.

The application of CAD and automation to solve the manufacturing problem is nothing but the CAM. CAM is nothing but computer aided manufacturing and CAD is computer aided design.

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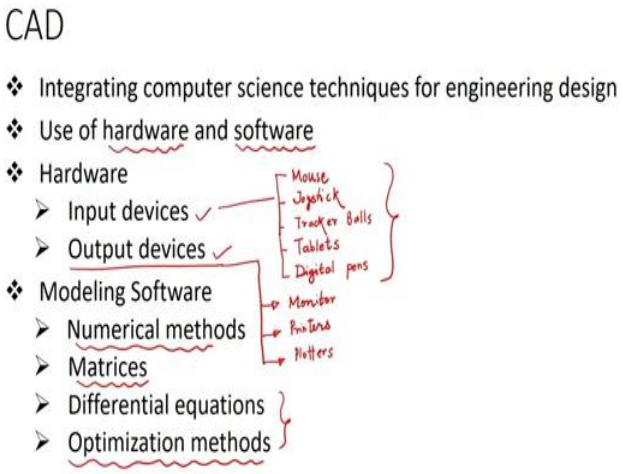

CAD can be defined as the integration of computer science techniques for the engineering design. The CAD systems require certain hardware and specialized software. What are the hardware elements required to have the CAD system? The input devices and the output devices are required. The input devices are a typical mouse or joystick, tracker balls, tablets, digi pens or digital pens.

With these input devices, the required information is entered to carry out the design operation. And what are the various output devices or variety of type of displays like the LCD displays, LED displays, plasma based displays, printers and plotters.

The industrial plotters are of huge size, in meters and they are used to develop the blueprint of the product. With these input devices and output devices the digital models of the product are generated. After generating the digital models of the product, various numerical methods and the knowledge of matrix matrices are applied. .

And with the help of basic mathematics such as differential equations, the dimensions of the product are finalized. To finalize the dimensions of the product, variety of optimization methods are being utilized nowadays. These are the classical methods of optimization or the evolutionary optimization methods, such as genetic algorithm.

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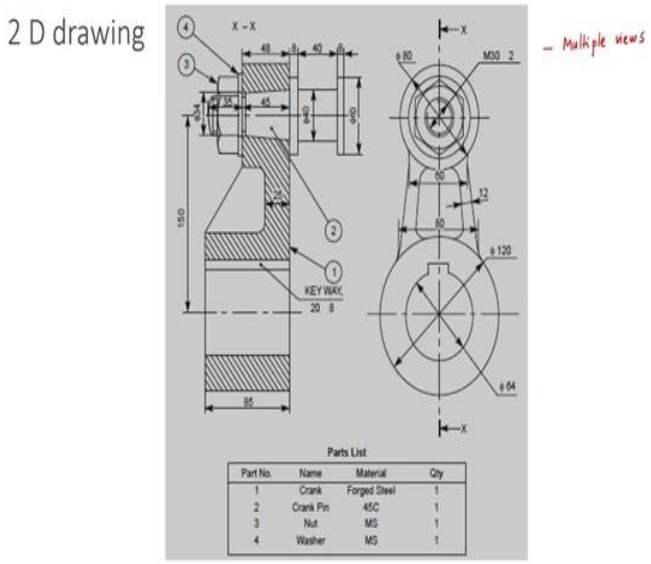

Let us look at what are the modes to visualize the product in the digital environment. The first mode of visualization is in a 2 dimensional mode, on our screen we can see a crank assembly. this crank assembly is being shown by using 2 different views. For 2D modeling, multiple views are needed, more than 1 view is required to communicate the information about the product.

It is not possible to communicate all the geometric information about the product by just giving only 1 view. For manufacturing and the use of the drawing, multiple number of views are required and that is the characteristic of the 2D mode of modeling.

On our screen,we can see a typical product and it also shows the sectional view of the product. The dimensions are provided and the production engineer will understand the meaning of these dimensions.To manufacture a component, its not only the product dimensions that are required.

The design engineer should also provide the information about the surface roughness, the tolerances on the dimensions as well as on the features. It is essential for the design engineer to provide all these information and once this information is provided, a simple 2D drawing will be converted into the production drawing.

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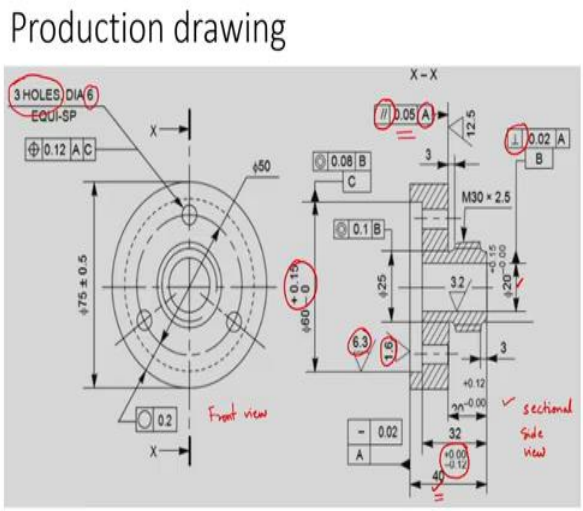

On the screen wecan see a typical production drawing which has 2 views. We can see a sectional side view and the front view. This is the front view of the wheel and this is the sectional side view. In addition to the dimensions, the tolerance values are also provided.

Tolerances are nothing but the permissible deviations on the basic dimension of the feature. This is the 40 if the basic dimension positive side there is no tolerance and no division is permitted, on the negative side minus 0.12 is allowed. In addition to this the roughness values are also provided where also it is required to generate the surface finish of the required quality.

The production drawings also have the information about various features such as the number of holes and their respective diameters. When such detail information is provided as far as the manufacturing of the component is concerned then it is called a production right.

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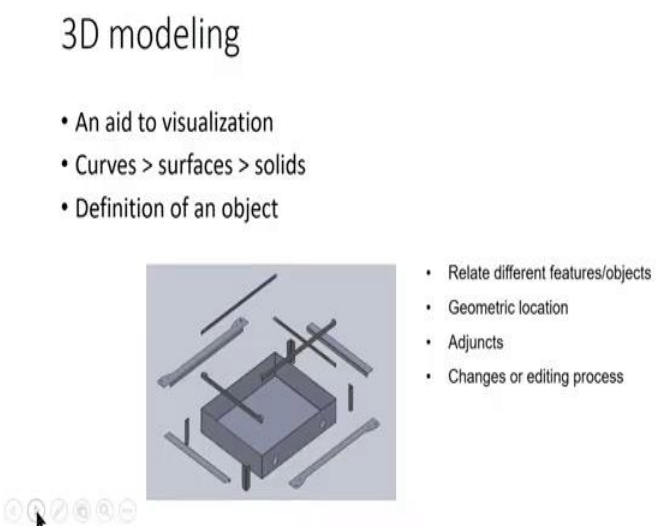

The next mode of visualization is 3D modeling. In 3D modeling solids are used to visualize the objects, solids are having surfaces which are made up of curves. The curves are connected to each other which make a surface and the surfaces are stitched together to develop the solids.

On the screen we can see the exploded view of a typical 3D model. This 3D model has various features or objects which are joinedtogether with certain geometrical location. These features are having relation with the other adjacent features adjuncts. In 3D modeling the 3D objects are represented on the 2D plane.

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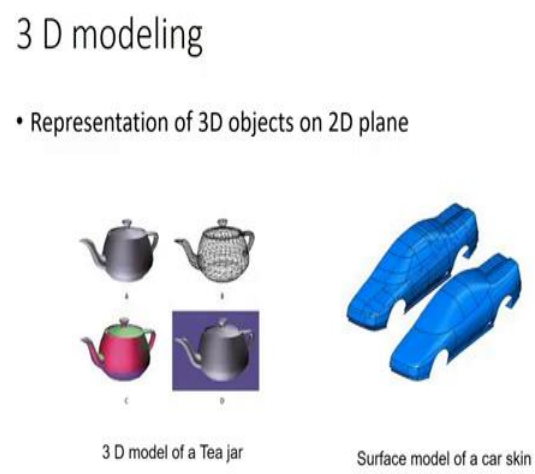

On the screen we can see the variety of ways to visualize the object. This is the wireframe model and this is the surface model or the solid model. We can attach colors to the scheme of the solid model and even we can attach the materials. In 3D modeling we can render the objects we can have the effects of lighting.A typical surface model of a car skin is shown on the screen.

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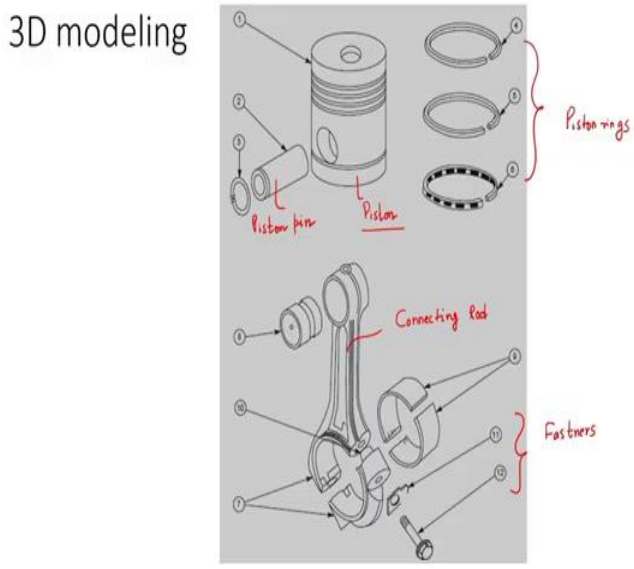

As far as the industrial components are concerned the 3D models are more effective; they are less ambiguous, easy to understand and it is a better way of communication. On

the screen we can see a piston connecting rod arrangement. This is the piston of an engine, piston ring, connecting rod, piston pin which is helping to connect the connecting rod with the piston, there are various fasteners which are used.

With the 3D model it is very easy for us to visualize the components and develop the assembly drawings, the exploded views or the maintenance related drawings. All these type of drawings are based upon the 3D modeling and which makes the life of the designer and the production engineer easy.

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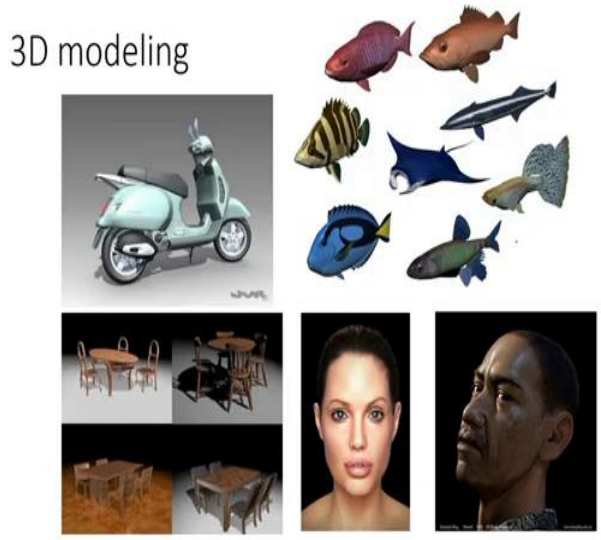

In addition to the production drawings or the typical mechanical drawings, the 3D modeling's are very much used nowadays for the entertainment purpose. We can see the variety of the 3D models, which are also used to develop the realistic views of the various products. 3D modeling is also used to design and develop the furniture's and architectural drawings.

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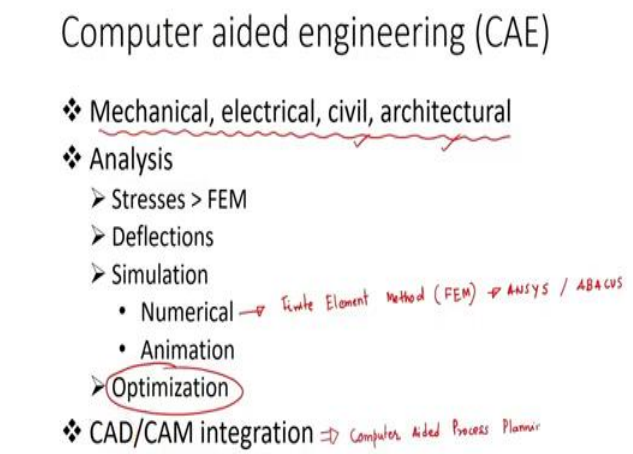

After the development of these digital models, the mechanical engineering principle is applied to test them. The material is attached, the forces are applied and then the deformation is found in this mechanical component. For this purpose, the numerical techniques such as finite element method and various FEM based softwares are used which are available in the market nowadays.

These are the ANSYS or the ABACUS. In addition to this if the product or the system is having the fluid then there are a lot of fluid analysis based software which are also available, such as the fluent or the gambit. When the analysis of the products is carried out by using the software, that is called the computer aided engineering or the computer aided analysis.

This analysis is very much important to find out the optimal values of the parameters for the intended purpose. It may be the mechanical product or the civil product or the architectural product, so we have to come up with the final values of the parameters. Moreover the CAD are helping us to develop the process plans or the production plans.

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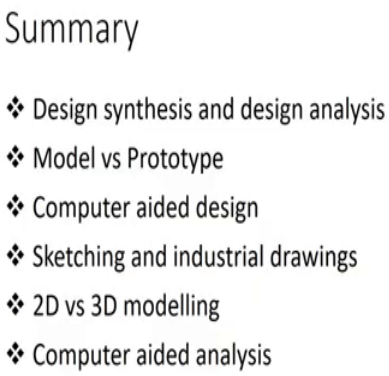

In this lecture we have seen the difference between the design synthesis and design analysis in the context of the product lifecycle. We have seen the difference between the modeling and a prototyping phenomena that is used in the product development. We have seen the utilization of computers in designing and development of the prototypes.

Then we have seen the difference between the 2 dimensional modeling and 3 dimensional modeling methodologies and at the end we have also seen the computer aided analysis and utilization of the numerical methods to solve the mechanical design problems.

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In the next lecture we will look at various fabrication processes, which are used in the manufacture of the automated system. There are many manufacturing processes we will be studying, the important manufacturing processes such as casting, forming, joining, machining and the next generation manufacturing that is the additive manufacturing.