Laser-Based Manufacturing
Prof. Shrikrishna N. Joshi
Department of Mechanical Engineering
Indian Institute of Technology - Guwahati

Module - 7
Lecture - 24
CAD for Laser-Based Manufacturing

Hello everyone. I welcome you all to the last lecture of week 7 of NPTEL MOOC course on Laser Based Manufacturing. This week, we are studying CNC technology and the application of CNC technology in laser-based manufacturing, as well as how lasers are useful in manufacturing automation. We have seen the applications of lasers in manufacturing automation in the first lecture of this week.

We have also studied various aspects of CNC in laser-based machine tools. In this class, we will be studying a little more about CAD technology, which is a computer-aided design that is an integral part of laser-based manufacturing systems. During this entire course, we have dealt with many technologies where lasers are used for a variety of operations, such as material removal, joining, additive manufacturing, and inspection.
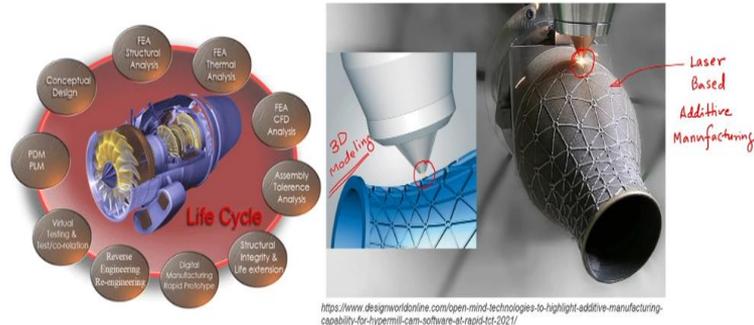
Everywhere, we are taking the help of the mechatronics-based system that is a CNC-based system. CNC is a computer numerical control system that works based on the digital input given to the system. Now, to give the digital input to the CNC system, first of all, we have to create the digital model of the product that we want to develop by using this laser-based technology.

It may be material removal that is machining or engraving, or it may be welding, or it may be additive manufacturing. Therefore, it is essential for all laser manufacturing engineers to understand CAD and learn some of its principles so that it can be effectively used during laser-based manufacturing processes.

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During our previous class, we saw the capability of laser-based additive manufacturing. You just look at a very complex shape on which the laser-based additive manufacturing technique is going. But to realize this operation, we have to first create its 3D model. 3D modeling is very much essential, and 3D modeling would be done by using CAD modeling software.

When we develop the 3D models, we can even simulate the process of deposition. In additive manufacturing, it is essential to develop the 3D models that we have seen in our previous module as well. The 3D models are sliced, generated into layers, and applied to get the deposition done. Even for machining and welding, we have to create 2D geometries to carry out all the functions. This is laser-based additive manufacturing.

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What is CAD/CAM?

- Broad term Computer aided technology : CAx
- x = design / manufacture / analysis
- CAD: computer aided design of 'y'
- Y = product or process

Well, let us study what you mean by a CAD. CAD is basically a term associated with computer-aided technology; CA of x; computer-aided of what? Computer-aided of x. Now, what can be the x over here? x can be the design, x can be the manufacture, or x can be the analysis. We can call if we replace the x with d. It comes to Computer Aided Design, Computer Aided Manufacturing, Computer Aided Analysis, or Engineering.

All these are prominent areas in the industry that contribute to achieving the objectives of the modern manufacturing industry. Well, we are focusing more on CAD in this lecture. , CAD is a computer-aided design. Now, the question comes of what? , the CAD of y; here, what could be they? The y may be a product or process. We can say that it is the computer-aided design of a product or the computer-aided design of a process.

As far as mechanical engineering or manufacturing engineering is concerned, we are working more on Computer Aided Product Design and Computer Aided System Design. As far as the chemical engineering and the process-based engineering branches are concerned, they are working more on Computer Aided Process Design.

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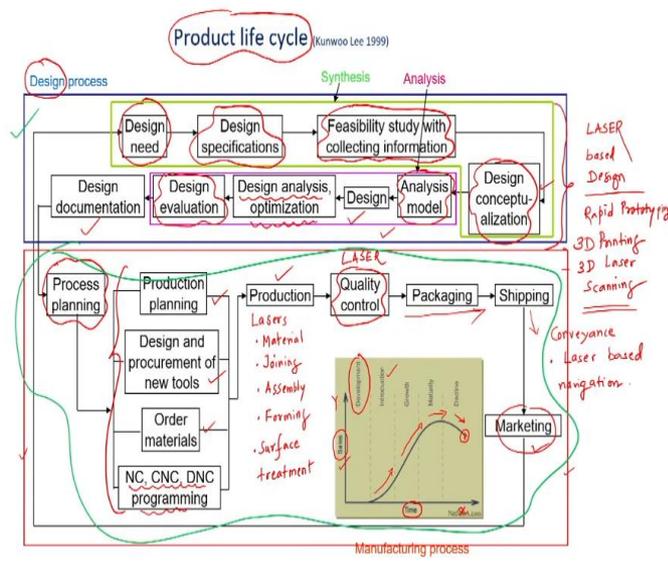
Now, let us see what various operations are being done in the industry and where the computer can be utilized to carry out these operations. If we look at the product lifecycle, then we can find that the product lifecycle starts with the development of the product. Here, we can see that we have taken time on the X-axis and sold a typical product on the Y-axis. During the product's development, sales will naturally be very low.

When we introduce the product into the market, the sales increase, it grows further, and it attains maturity. Now, the sale of that product in the market is at its peak, which is at its highest level. After that, due to many reasons such as another product which is coming into the market by the competitor or some problems associated with the product itself or the change in taste of the customer, there will be a start of declining the product into the market.

Ultimately, it comes back to the decline. Here, the marketing team of that enterprise or the industry is looking at this decline point, and based upon the feedback that the marketing team gets, it will be fed to the design team. Every industry has a design team. This design team is identifying the design needs of the product. Consider a product in the market, and the customer has given the feedback that the product is heavy; it has to be light in weight.

Here, the design needs to develop a lighter product. Now, we have to analyze, or we have to look at the specifications, what the weight of that particular product is. Can we reduce the weight of that particular product, and by what amount and by what percentage can we reduce the weight? We have to carry out the feasibility study of that particular product to reduce its weight, and then we have to come up with some concepts.

How can we reduce the weight of the product? Can we change the dimensions? Can we change the material? Can we change its shape? All these things are coming in conceptualization. That conceptualized model, then we have to analyze, and then a final design comes into the picture. At analysis, we have to apply the principles of mechanical engineering, and the final design will be delivered to you.

When we get the final design, we have to analyze the design. We have to check whether the design is up to the mark or not. We have to carry out the optimization. Whatever dimensions or sizes are suggested by the analytical model, whether they are proper or not, this is the design evaluation. Then, after testing and getting a satisfactory report, we have to send it for documentation.

All these are design-related activities. Here, rapid prototyping or laser-based additive manufacturing is helping us. Not only is laser-based additive manufacturing helping us, but laser-based cutting and laser-based joining are also rapid prototyping techniques that help to

develop the prototypes in a rapid way. We have seen that lasers are very useful for rapid production and for producing objects either individually or in batches.

After documentation, the data will be given to the process planning team. Then, all the production-related operations would be carried out, such as the production planning, design, and procurement of new tools. If the tools are not available within the industry, we have to order the newer materials if required. And generation of new CNC and NC codes, which we have seen in previous classes.

Then, actual production would be carried out. Then, we have to carry out quality control or quality assurance. Here, the lasers are helping us. , we can even find out where the lasers are helping. For inspection and quality control, lasers are useful. For laser-based in-production operations, lasers are helpful in material removal, joining, then assembly, forming, and surface treatment.

All these modules we have already seen in our previous weeks are coming into production operations. Now, the lasers are also useful at the design stage, such as laser-based design. Laser-based design is coming into the rapid prototyping stage, which is 3D printing, followed by 3D laser scanning to get the data. 3D laser scanning is also utilized to get the data or to re-engineer the products.

Well, the lasers will be used in packaging as well, and they will be shipped to the market. During this convenience process, lasers are also used, which is laser-based navigation. Right, and last is the marketing. When the product comes into the market, the sales and marketing team will interact with the customers, get feedback, and give it to the design team.

All these activities are done in a circular, cyclic way. , that is why it is called the product life cycle, which starts from the design need and ends with the design need itself. Now, when we try to club these entire activities into two groups, we can easily identify that there are activities that pertain to design that we call the design process, and there are certain activities that pertain to manufacturing.

These are all the manufacturing-related activities if we club together, and they are all the design-related activities. Now, if we look at the design activities further, we can classify them into two groups.

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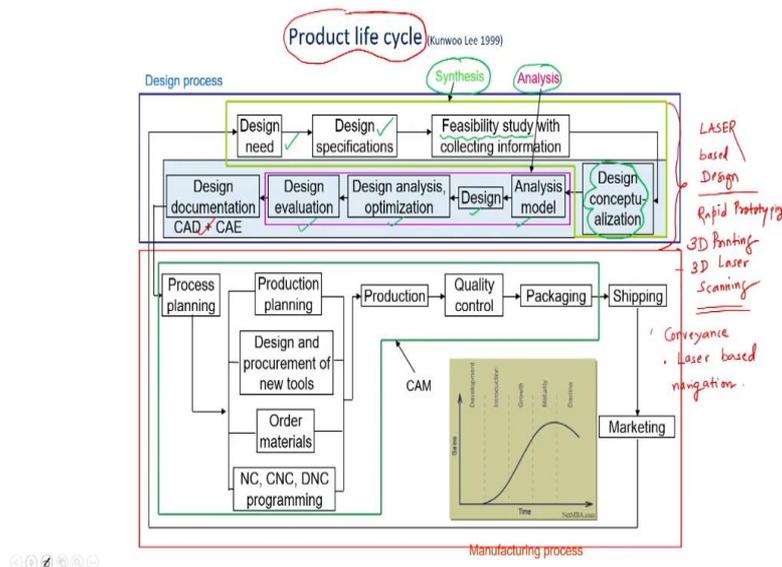
The first one is the synthesis group. Here, you can see the identification of design needs, then convert the design needs into design specifications, carry out the feasibility study, and come up with the design conceptualized model. , all these activities are termed synthesis of the design. Well, if we consider the analysis of the model, then converting the conceptualized model into reality, we have to test it, and we have to convert that into an engineering model.

So, the conceptualized model may be artistic; it may not even be possible to manufacture as per the design team. , the engineering team will look at the manufacturing aspects as well. We may need to modify the design provided by the design team based on the manufacturing capability of that particular enterprise or company. , the designing would be done.

Analysis of the design, optimization of the design, and evaluation are termed analysis. , analysis includes design analysis, optimization, and evaluation. If you look at all these activities in a broader sense, you will find that so many activities are to be carried out either in a sequential way or in a parallel way in the industry. Carrying out these activities manually is an uphill task; it is very difficult.

So, here the computers are helping us to automate the process. For example, the conceptualization of design. , to conceptualize the design, we have to develop the clay model.

Earlier, people used to have clay modeling, or they may go for wooden models, and then they carried out all the analysis over that. That used to take a lot of time. But now, with computer-aided drafting or computer-aided 3D modeling, we can have a digital model of our idea.

It will come for the realization or for visualization immediately on your screen. Then you can discuss, you can have all sorts of analysis and deliberations over that design, and then you can finalize it, which has reduced the time of conceptualization from months, weeks to days, or in a few hours. Also, you can have the conceptualized model with you.

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Computer aided design

- Synthesis = philosophy, functionality and uniqueness
- Analysis = conversion of conceptual design into model (engineering science based)

So, the same has been summarised here. The synthesis deals with the philosophy of design, functionality, and uniqueness, the features of that particular design, which is at the initial stage itself when the concept of the product comes into the picture. We have to develop a certain philosophy. Accordingly, we have to incorporate various functions and look for the uniqueness of the product so that it can be sold in the market easily.

Then, the analysis has to be carried out by converting the conceptual design into the model. Here, we are applying all the engineering science-based principles to get the required conversion.

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Scope of CAD CAM
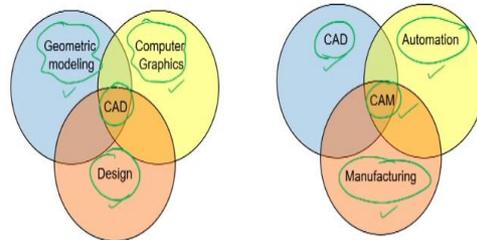
Now, what is the scope of CAD and CAM?

CAD is, you can say, the intersection of 3 disciplines: geometric modeling, computer graphics, and the design that is mechanical design. To develop or to have expertise in CAD, we must have knowledge of computer graphics, knowledge of design that is mechanical design, and modeling. As far as Computer Aided Manufacturing is concerned, it is the intersection of Computer Aided Design, automation, and manufacturing operations or manufacturing processes.

So, to become a CAM engineer, he or she must know about CAD-related software or CAD-related technologies, various manufacturing processes that are being used in the industry, and automation technologies.

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CAD

- Integrating computer science techniques for engineering design
- Use of hardware and software
- Hardware
  - Input devices
  - Output devices
- Modeling Software
- Numerical methods
  - Matrices
  - Differential equations
  - Optimization methods

Well, there is another definition of CAD. Here, we define CAD as the integration of computer science techniques pertaining to computer graphics and optimization for engineering design to design parts by applying engineering principles. But to realize them and visualize them on the screen, we should also know computer graphics.

There has to be an integration of computer science techniques into engineering design. The CAD requires hardware and software. , hardware in general that we know that we require a lot of input devices, and there is a need for output devices as well; without that, the CAD system is helpless. It is not only the hardware; there is a strict requirement to have modeling software as well.

Modeling software is an integral part of the CAD-CAM system. The software is a group of programs that is helping us to carry out the modeling and analysis of the 3D models. Then there are a lot of techniques or methods which are being used, which are mathematical techniques such as matrices, differential equations, and various optimization methods.

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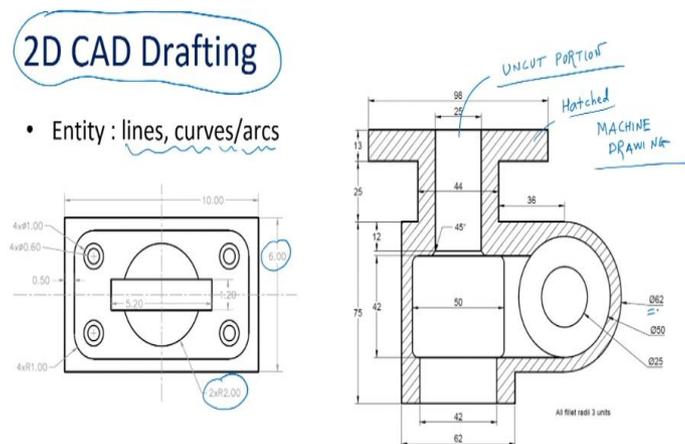
Now, let us see what is the meaning of 2D CAD drafting. In 2D CAD drafting, we are generating various 2D shapes, two-dimensional shapes which are made up of lines, curves, and arcs. We are arranging these lines, curves and arcs in a very logical way. And by looking at this 2D drawing, one should understand or it is a way of communication, it is a language of interpretation, it is a language of communication with your subordinate or with your boss or with your team members.

In 2D CAD drafting, we are generating 2D drawings which are made up of lines, curves and arcs, and these 2D drawings are giving us certain information. The information is about the shape and size of the product, but it is in a 2D format, two-dimensional format. To give all sort of information about the product, we may need to have more than 2 views of a particular product. We have to go for the orthographic projection.

There are simpler 2D modelling techniques that is the orthographic projections are being used in the industry. Computationally, these 2D drafting is inexpensive; it is cheap; it is not time consuming as well. However, the 2D models or 2D drafting entities are not giving the realistic view of the product. On your screen, you can see a 2D drawing. Here the dimensions are provided.

So, here you can see a drawing which is made up by the straight lines and the circles and certain dimensions are given here. based upon the dimensions, one can easily interpret or understand the shape and size of the object. And based on that, the intended operation can be carried out. In 2D drafting and modelling, even we can reveal the internal shapes, internal features by following certain conventions and that is called as the machine drawing.

In machine drawing, there are lot of conventions and by applying these conventions, we can easily communicate about the internal shape. Now, here you can see, this is the hatch lines and these hatch lines are designating that some portion has been removed. And after removing the portion, this is the shape that we are getting. Wherever the hatch lines are not there, that portion is uncut portion. This is the uncut portion or it was void.

There was nothing over here; that is why there is no hatch lines are given. There are lot of other conventions we are using such as the dimensions. This is the indication of the diameter; that is a phi. Well, by applying all these conventions and by using the geometric entities such as lines, curves and arcs, we can create the 2D drawings.

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3D modeling

- An aid to visualization ✓
- Curves > surfaces > solids
- Define of an object
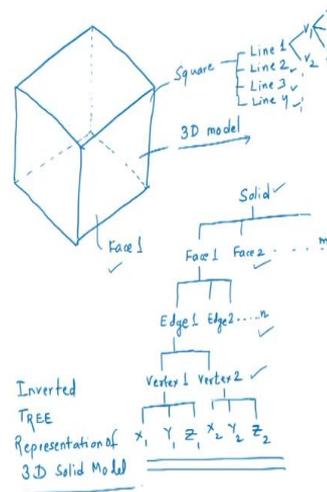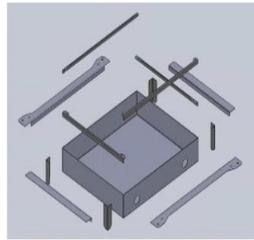
But as I mentioned you, the visualisation is difficult in 2D modelling; , that is why we have to go for the 3D modelling. , in 3D modelling, there is better visualisation. , we are generating the solids as we know that solids are having surfaces. , consider we are having a cube. , this is a 3D model and it gives the realistic view. So, if we consider the 3D model, , it is made up of the surfaces. The cube is having 6 surfaces.

Consider this is the face 1. The face 1 is nothing but an area bounded by certain curves. Here the lines are there. By using the lines, we are getting a certain shape and that is the face 1; it is a square. Now, this square is made up of lines, line 1, line 2, line 3 and line 4. Now, these all lines are having 2 vertices. The vertices are V1, V2. In a similar way, we are also having vertices for line 2, 3 and 4. And each vertex is having X, Y and Z coordinate.

If I try to develop an inverted tree, then I can say that we are getting a solid. The solid is having faces, face 1, face 2, on and forth. The faces are having boundaries or curves or lines. The most appropriate word is edge, edge 1, edge 2 and whatever the number of edges it has, say n; number of faces are m. Now, each edge is having endpoints. Endpoint I can call vertex 1 and vertex 2.

And each vertex is having 3D coordinates, X, Y and Z coordinates. This is X 1, Y 1, Z 1. Similarly, we are having X2, Y2, Z2. This is the inverted tree representation of a 3D solid model. To define an object, we should have the information about the solid. And solid can be manufactured or can be developed by giving the information of faces. Faces can be developed by giving information in terms of its edges.

Edges are defined by giving the information in terms of the vertices. And vertices are defined by its coordinates. To develop a solid model, we should have all this information ready with us and then we can go for the utilisation of 3D CAD modelling software.

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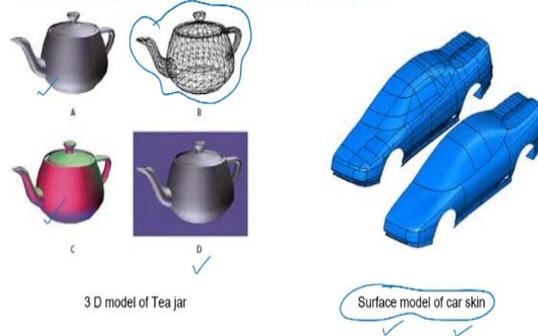
Well, the solid modelling is again having various other paradigms where we can represent a 3D solid model. We can have the wireframe model. So, here in the wireframe model, we are not providing any volume or we are not providing any surface; it is just the vertices and these vertices are connected by the edges. The wireframe models are light in weight as far as the membranes are concerned, but they are difficult to interpret, difficult to visualise.

Simple wireframe models are useful for analytical computations only. But for visualisation, we have to go for the 3D solid models. This is a 3D solid model. To this 3D solid model, we can attach various materials, we can render them by attaching various materials; we can apply texture on these models as well. We can apply the lighting systems, illumination to give more realistic view to that. Surface models also can be developed. These are the surface models of the car skin. Modelling, it is having 2 paradigms; that is the 3D solid modelling and the surface modelling.

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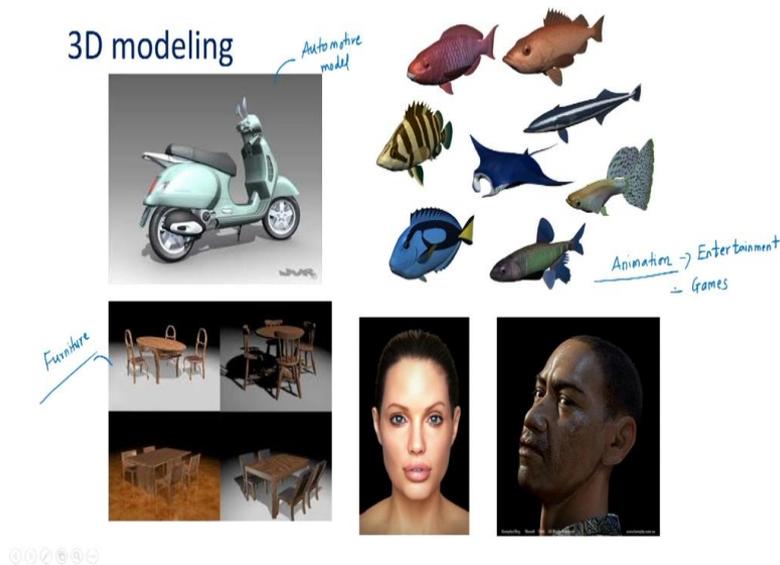
Few more examples are there on your screen. Here you can see, this is automotive model. Then we are having the furniture, and these are the 3D models, and these are for the animation industry, animation or the entertainment. Here the games are also part of this.
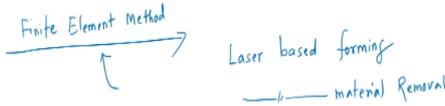
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Fine! So, to have the proper visualisation or the display, we have to display the objects on the 3D screens. And when we put the models on the 3D screen, we have to map them properly, that we call mapping of the developed model on the screen coordinates. We can apply shading; we can even remove the hidden surface that is coming into the surface modelling or surface geometric modelling.

Then by applying various projection techniques such as the orthographic projection and the perspective projection. Perspective projection is giving us more realistic view of the object. It

is a bird eye view, basically being used in the architectural drawings, which is giving more realistic view. The orthographic views are the 2D views and to provide the knowledge or to give the information about the part model. In orthographic projection, we have to use multiple number of views and that is a drawback or the limitation of orthographic views; it is difficult to understand or visualise.

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What are the application of CAD and CAM? , the CAD and CAM techniques are useful in mechanical, electrical, civil and architectural engineering. As far as analysis is concerned, we can carry out the stress analysis. , for that purpose, we are using a technique and that is called as the Finite Element Method technique. , to carry out the deformation analysis or the temperature analysis to solve the heat conduction problems, we are using this Finite Element Method, but the basic input to the Finite Element Method is CAD drawing itself.

Consider you have to find out the stresses which are developed in the laser-based forming or consider you have to find out these residual stresses which are generated during laser-based material removal. To sort out these problems, we are taking help of the finite element; but to have the proper finite element analysis, the 3D model has to be generated. The deflection; then, the numerical simulation and the animation:

Consider if you want to carry out the animation of the movement of various linkages inside a mechanism, there also the CAD drawings are very much useful to even find out the optimal levels of the parameters, particularly the sizes or the thicknesses of the various elements of a product, the CAD modelling is essential.

Now, let us see or have a look at various input-output devices which are being used in the CAD. We are using the mouse which is very basic element, we are also often being used when we are dealing with the computers. The earlier mouse technology was based upon the potentiometer or sensible variable registers, but nowadays we are using optical mouse and the wireless technology.
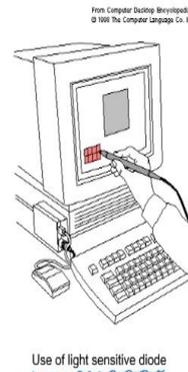
Even in CAD industry or in animation industry, the track balls; track balls are here; by manoeuvring these sorts of balls, we can even change the location of pointer on the screen. Or we can use the joysticks. Again, joysticks are being used to change the pointer location on the screen.

Digital devices

- Light Pen

Then, light pens: these are the digital pens which are working based upon the infrared technology and even we can select or pinpoint a particular location on the display. By using light sensitive diodes, we can pinpoint a point on the screen. And based on that, we can carry out variety of CAD related operations.

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Tablet and Pen

Pen emits signals of certain radio frequency.
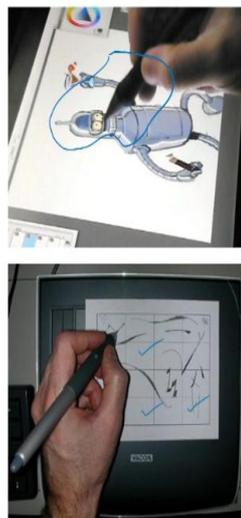
In addition to this, we are using tablet and pen. And these tablets are having the pens which are emitting signals of certain radio frequency, and the tablet is having circuitry beneath the screen. And when the pen is touching to a certain point, at that point the frequency will get sensed and that location will be recorded by the microprocessor system. These are some of the applications, particularly the tablets and pens are used in animations. You just notice, these are the applications of developing various animated characters.

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Display devices ✓   Monitor
• CRT (cathode ray tube)
 • Refresh CRTs
  • Persistence 10 to 60 micro seconds
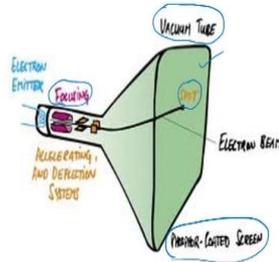
As far as the output devices are concerned, the prominent output device is the display device, that is the monitor, the display monitor. And based upon the pictures or the images that we are getting on the monitor, we are visualising them. It is very essential for us to select a proper monitor. Nowadays, we are getting all the advanced monitors or advanced display devices which are based upon the liquid crystal display, that is LCD, or light emitting diode display, that is LED.

But earlier, people used the CRT that is the refresh CRTs basically; This is a particular arrangement of the CRT. Here the CRT screen is having the phosphor coating and we are using an electron beam. This electron beam is focused on this coated screen, and wherever it is getting strike, that much portion is getting eliminated. Then, by manoeuvring the electron beam on the screen, we can create variety of images on the screen.

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Raster scan display

- Picture memory : refresh buffer
- Refreshing speed : 60 to 80 times per second
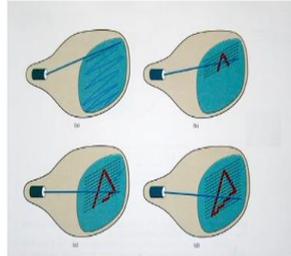
Now, to create that image on the screen, we have to use a huge picture memory and refresh buffer. And the refreshing speed should be at least 60 to 80 times per second. Here you notice that the electron beam is moving over the screen in a raster way. It is starting from the top left corner and then it is moving in a zig-zag manner. Wherever it is applying the intensity, that much portion is getting eliminated. In this way, the pictures or the images are created on the CRT screen.

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Color CRT

- Based on random scan display method
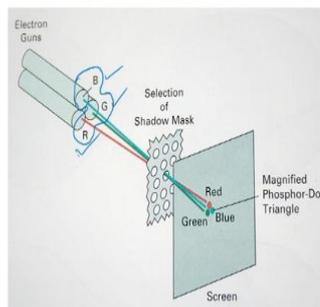
Now, when we are having 3 different electron beams of 3 different colours that is the RGB, red, green and blue, then we can create the coloured images as well.

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Flat Panel Displays

- Reduced volume, weight and power requirements
- Emissive displays
    - Light emitting diodes
    - Plasma displays
- Non-emissive displays
    - Optical effect to convert light from other source into graphics pattern
    - Liquid crystal display (LCD)

Then, recently we are using the flat panel displays. These flat panel displays are having reduced volume; their weight is also reduced; and certainly it is saving lot of power. Instead of handling a very big device that is a CRT device, we are using very thinner display devices. And these displays are emissive displays, that is the plasma displays and LED displays. There are certain non-emissive displays also being used and these are the LCD, that is the liquid crystal display. **(Refer Slide Time: 36:33)**

Output devices

- Printers and plotters

Now, what are the various output devices being used in the CAD industry? Particularly, the output device is printer or the plotter. , printer, the size is comparatively very small, but the plotters are having a very huge size. And by using these printers and plotters, we are communicating the developed design, developed models with the team. And then we are acting upon the drawings further for its production or the manufacturing. With this brief note about the CAD and its utilisation or its importance in the perspective of laser-based manufacturing;

Summary

- CAD/CAM : vital role
- 2D and 3D modeling
- Hardware requirements for CAD

. Applications of CAD in general

in Laser based manufacturing.

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We have seen, the CAD and CAM systems are playing a vital role in development of a laser-based manufacturing system because all the systems are CNC based and CAD technology is very much essential to know about. Then, what are the various 2D and 3D modelling techniques being used? What are the various input output devices being used? We have seen them in a very introductory level.

, the details about these are out of scope of this course. We have also seen the hardware requirements for the CAD; even we have seen the applications of CAD and CAM in detail during our discussions. Applications of CAD in general; that we have seen; and in laser-based manufacturing particularly. In laser-based manufacturing as well, we have seen the applications of CAD. Well, with this, I would like to stop for today's class and this week as well. Thank you for watching this video. Goodbye. Thank you.