Automation in Manufacturing
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Week - 12
CNC technology
Lecture - 36
Computer aided manufacturing and process planning

Hello everyone. I welcome you all to the last week of the course Automation in Manufacturing. At start of this week, we will be studying the Computer aided manufacturing and the philosophy of computer aided process planning.

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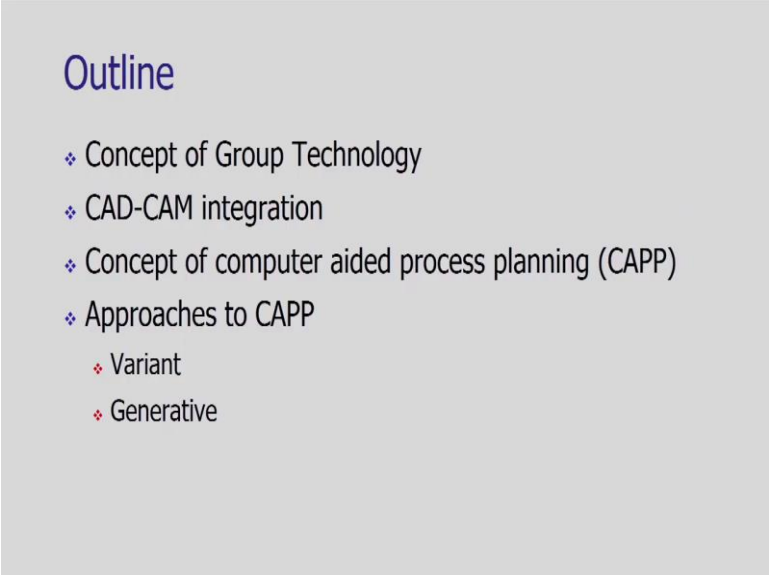

The outline of this course is there in front of us. At start of the lecture, we will see the concept of group technology; the meaning of CAD-CAM integration, why it is essential to have the integration of CAD and CAM.

We will see the concept of computer aided process planning. There are various approaches to the CAPP i.e. computer aided process planning and these approaches are variant approach and generative approach. We will go through their concepts and its certain examples.

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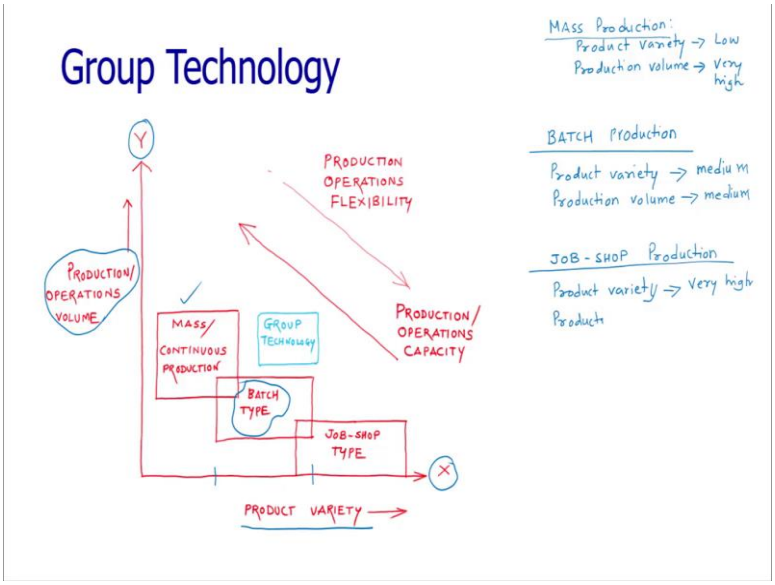

If we start looking at the variety of type of productions which are carrying out in an industry or in an enterprise, we can divide this type of productions into basically three categories or three groups. To understand this, let us take the product variety along the X axis and production operations volume along the Y axis.

When we plot this curve, if the product variety is very less; for example, the cement manufacturing company or sugar manufacturing company or any type of process manufacturing company, when the product variety is very less; but the volume of the production is tremendously high and there is a continuous production of that commodity or the product, this type of production is called as the Mass production.

The characteristic of mass production is product variety is low and production volume is very high. Consider, we need a moderate variety of the product and there may be certain example such as the tool rooms, which are manufacturing dies and molds or there are certain vendors, those who are supporting the major manufacturers.

They are also catering the needs of many industries around. They are producing the jobs which are having medium product variety and their volume is also moderate, medium volume. That kind of production type is called as the Batch type of production.

Batch production has the characteristic that product variety is moderate or medium and production volume is also medium; production volume is medium. Well, if we take the example

of a ship or if we take example of the aero plane or any bigger or very specialized machine tool which is quite heavy, which we cannot move from one work place to another work place.

When the company or enterprise or the factory is focused upon very limited variety, only one kind of job is it is producing and that is the customized job which is according to the needs and demands of the customer that kind of production is called as Job-shop type of production.

In the job shop production, the product variety is very high. As the customer is demanding, we can generate the products as per the needs. Product variety is very high and the production volume is very low. Now, if we look at the present manufacturing scenario, we will find two different cases.

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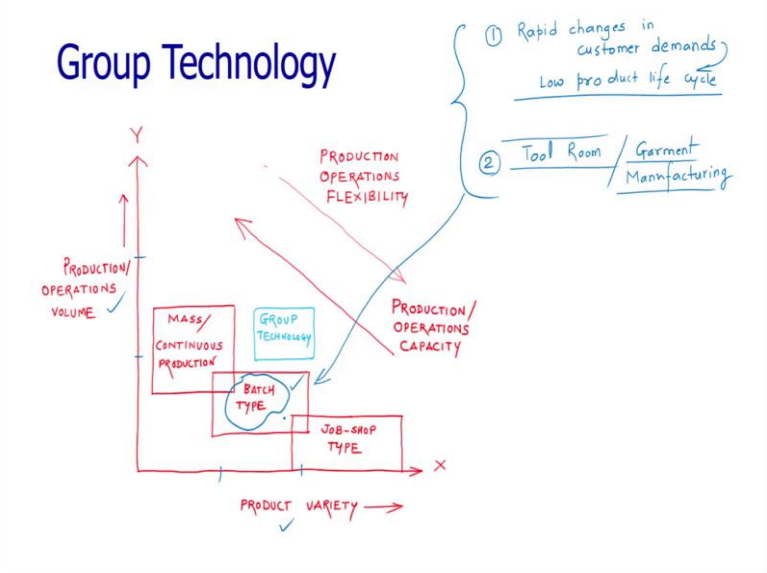

The first case is rapid changes in customer demands. It leads to low product life cycle. When the product life cycle is low, we cannot manufacture the products in bulk and just store in the warehouse because we do not know whether there would be consumption of the entire products that we manufacture. We have to take the decision based upon the demand in the market.

Accordingly, when the customer demands are rapidly changing, we have to respond to that. That is why we are studying this automation in manufacturing course or the mechatronics related course. To cater or to satisfy the change in customer demands, we need to be ready. For that purpose, most of the companies are following the batch type of production. They are

getting equipped with their factory layout for the batch type of production, so that they can cater the customer demands.

In customer demands, they are getting prepared with medium volume range and medium variety range production type. In general, today's manufacturing industry, they are following the principles of batch type of production. There is another situation where the batch type of production is important and that is the tool rooms or the companies or the enterprises, where their basic product range is having a multiple variety.

For example, the garment manufacturing company. In garments, we cannot have a same size garments in bulk; we cannot have a same shirt of in lakhs of number of pieces. There are variety of sizes, variety of colors, variety of types of the styles. All these attributes are taking into consideration.

For example, there are certain industry, such as garment manufacturing or the tool rooms. Tool rooms are generating dies and molds according to the needs, according to the requirement given by the companies. Here as well, there is need to have the batch type of production, where we are where we are manufacturing mid volume products and the variety is also at the mid-level.

For these situations, the industry is preferring to go for the batch type of production. The group technology is a philosophy which is taking care of the needs of the batch type of production. It is helping to have the efficient batch type of production. Let us look at the formal definition of the group technology in our coming slides.

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Group technology as mentioned, is a manufacturing philosophy and is employed in the industry to improve the productivity. The entire exercise objective or aim is to improve the productivity, to improve the efficiency of the enterprise. The objective of this course as well. The technology, we are trying to utilize to improve the productivity and to improve the efficiency of the enterprise.

How does the group technology is helping to improve the productivity? Here we are grouping the parts and products which are having similar characteristics. This philosophy is the manufacturing philosophy and here, we are grouping the parts or the products with similar characteristics.

What kind of similarity here we are following? We are following the similarity in terms of the geometry, geometrical attributes and the second is the manufacturing process relate. Every product is to be gone through a sequence of certain manufacturing operations.

Based upon that sequence, based upon the variety of operations which we are carrying out, we can group the parts together and afterwards, we are forming the cells. Cells of what? We are forming the cells of dissimilar machines and processes together. To cater the needs of the part family, to cater the needs of that particular group, we are grouping dissimilar machines or the equipment or manufacturing processes together, so that the operations would be easy and the operations would be efficient.

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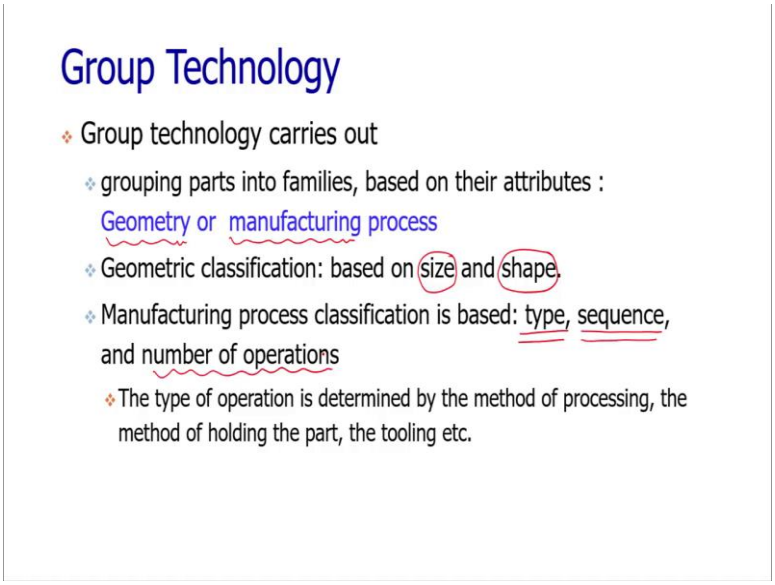

Thus, I can formally define the group technology as grouping of parts into families based on their attributes and these attributes are the geometry attributes and the manufacturing process related attributes. Geometrical classification would be done based upon the size of the product or the part and its shape.

Based on size and shape, we are classifying the products or the parts and that is the geometric classification. As per as the manufacturing classification is concerned, we are classifying the products based upon the type, the sequence and the number of operations which are needed to manufacturing a product. The type of operation basically is being determined by the method of processing.

For example, some products are being manufactured by using casting, some of them are using the sheet metals, some of them are using the welding operations, some of them are wooden products. Where we need to remove the material, that is a machining operation; then, the holding method, what kind of holding method fixtures, we are going to utilize during the manufacturing and the type of tooling being utilized to produce that particular part.

Based upon the manufacturing similarity, we are also grouping the products together and that is the group technology based upon the manufacturing attributes.

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When we got a number of products in a enterprises, let us consider an automobile manufacturing company and that automobile manufacturing company is designed an automobile, they need to manufacture it. First the management will analyze that how many parts are to be developed in-house and how many parts can be outsourced; how many parts, we can get it done from the vendors.

Still the number of parts that to be manufactured in-house would be very large. Then, the question comes how to group them together. Fundamentally the very simple process or very basic process is manual visual inspection.

A team of experts, a team of engineers, knowledgeable people in the company sit together and they will observe the components, all the components and based upon the visual inspection, they will take the decision and they group the components together that is the human intelligence they are applying.

The second process it is the production flow analysis. We will be seeing the production flow analysis and the third is classification and coding. We have to classify the components and then, code them and that coding would be done with the computers and the computers are storing the data and with the online monitoring with all sort of instrumentation, which we studied in this course can be utilized to drag the products to guide the products during the operation to pass the information at variety of places during the operation. Manual visual

inspection, production flow analysis and the classification and coding, here the part families can be formed.

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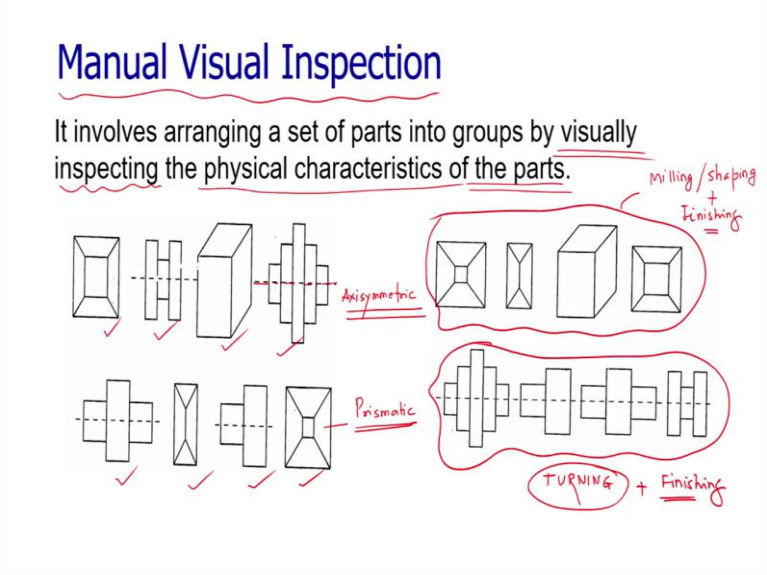

Looking at the first method that is Manual Visual Inspection method. Basically, the manual visual inspection method as I mentioned, we are making a groups, we are making sets by visually inspecting the physical characteristics of the part. Here we are making the visual inspection and the physical attributes of variety of parts. To understand the process, let us look at a number of products which are in front of you.

Here we can see there are number of products and if you just closely observe these products, you will find that some of the products are axisymmetric, this is the axis and about this axis, we can say that these products are axisymmetric products and some parts are prismatic products ok. These are the prismatic products.

I apply my knowledge, I apply my understanding about the parts based upon my knowledge of engineering, I can easily find out that we can group these components in two separate teams or the cells and these are nothing but this. Here we have grouped the parts which are the prismatic parts and these parts are the axisymmetric parts.

To manufacture this axisymmetric parts, we can suggest that like you can go for the turning operation. The basic operation is the turning operation, that need to be carried out to generate this parts.

Moreover, in addition to the turning operation, we are going for the finishing operation as well. Turning and finishing would be useful for to generate this parts and to manufacture this parts, so we can go for the milling operation or we can go for the shipping operation, which are generating the flat surfaces.

In addition to that, we have to go for the finishing operation as well. In this way, looking at the components the team will sort out the components, it will group the components based upon their physical shapes and that will help.

But this would be very difficult when number of parts in thousands. Many a times, there may be confusion; there may be ambiguity. The parts would be looking similar, but they may not be able to manufacture by using the same manufacturing sequence.

In this situation, the team will thoroughly analyze and based upon that they will take the decision. But when number of parts are more, quite large; then, there are limitations on the time, the manual visual inspection is quite accurate. But as per as the time is concerned, it takes lot of time. We need to have certain systematic methodology, where computers can help us; where the technology can help us to sort out this problem.

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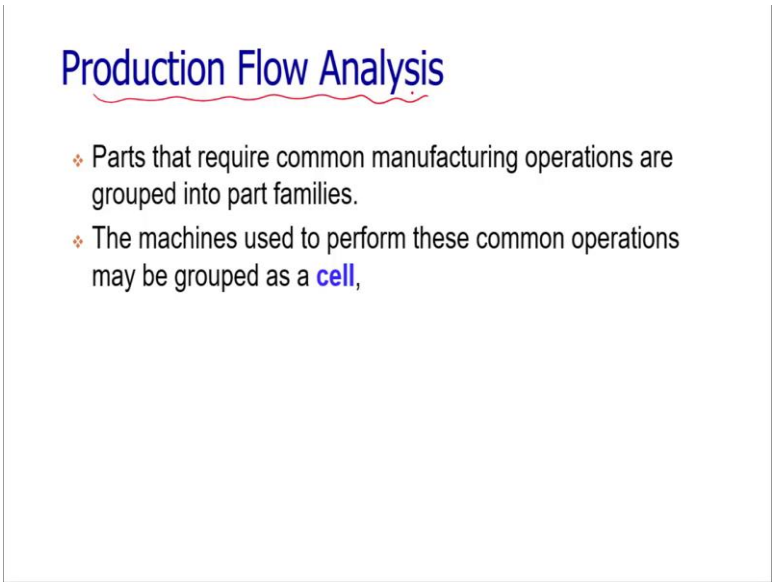

The next method to form the groups based upon the group technology philosophy is Production flow analysis. In this method, we are working on the manufacturing operations, manufacturing attributes of the products or the parts and based upon the analysis of the manufacturing

attributes and their flow during the manufacturing of this product, we are grouping the products together.

Based upon this information, we can generate the cells, we can form the cells may be the virtual cells or the physical cells. Cells are nothing but the group of machines, group of dissimilar machines. Let us see how this production flow analysis works.

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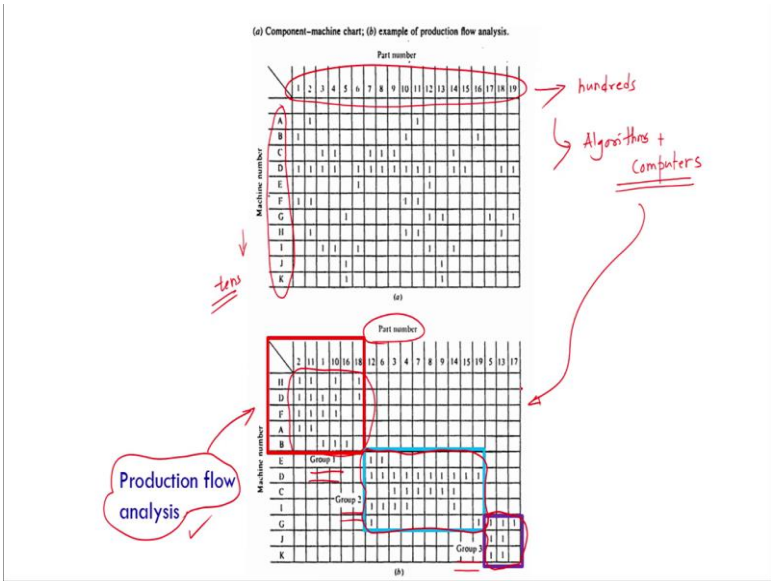

Now, the concept is consider a case, where we are having a large number of products. On your screen you can see a modest number that is 19, but in actual practice the number of parts may be in hundreds or in thousands.

There are 19 number of parts and there are a certain number of machine tools which are available in that enterprise or tool room. Now, these parts are being manufactured on these machines, they are getting processed on these machines.

It is not essential that all parts are to be manufactured on each and every machine or all the parts are being processed on each and every machine but more or less, the entire group of machines being utilized to generate these parts.

Well, the task is now in front of us to group these machines together and a part together so that we can easily handle or manage the operations. We should able to group the parts together so that we can maintain their database, we can follow their production operations very carefully

to get the required product quality and the accuracy and we can manage the number of machine tools which are dissimilar in nature.

But we by grouping them together, we can save the energy, time and resources in material handling. For that purpose, the production flow analysis kind of activity or method is helpful. After carrying out this activity, we are getting the matrix which is there in front of you.

Let us look at the matrix Here you can see the part numbers, the order is now being changed. Instead of having 1 to 19, now there is a mix number of parts which are there in a in a column and the machine numbers are also the order of the machine number is also changed.

Instead of having the chronological say from A to K, now we are having the random order of the machines and if you closely look at now, the allocation of the machines to the parts is giving us certain indication. Here you can see. There are certain clusters which are formed. If we closely look at the allocation, so we can easily detect, we can easily make out the clusters of the allocations. Based upon this clusters, we can form the groups.

These are the three groups can easily be find out by looking at this particular matrix. This is nothing but the group technology based upon the production flow analysis. But now, the question is that how to carry out this clustering; how to get this kind of clusters? Manually it is fine, but when the number of components are as I mentioned are in hundreds and the number of machines are in you know they are in tens.

The problem is quite complicated. For that purpose, we have to take help of some certain algorithms. These algorithms can be implemented with the help of the computers and the computers may give us these kind of solutions to us.

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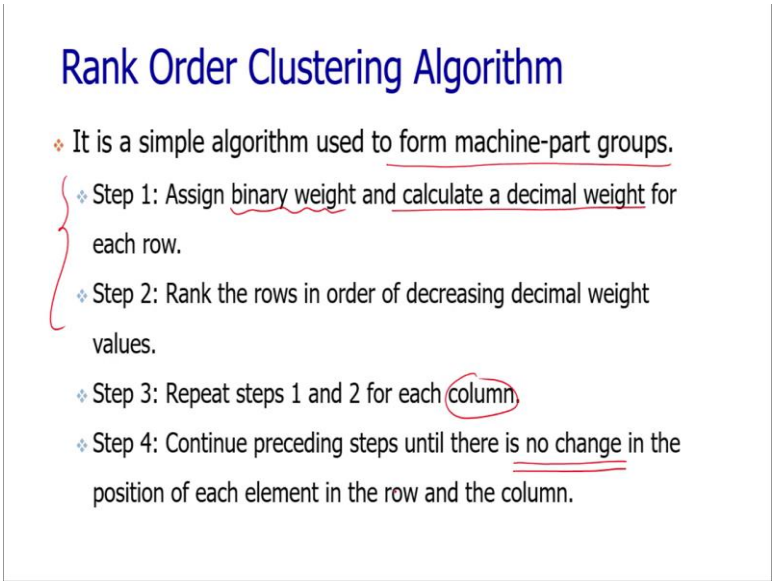

Let us look at the first algorithm that is the Rank Order Clustering Algorithm. It is very simple algorithm and it is basically used to form the machine part groups. Let us look at what are the various steps of this algorithm. The first step of algorithm is assigning the binary weight and computation of decimal weight for each row. We got various rows of allocations.

The default or the first cell or first matrix that we do have, we are assigning the binary weight to the rows and based upon that we are computing the decimal weight. We will be seeing how exactly the binary weights are assigned and how are we computing the decimal weight.

Well, the next step is rank the rows in order of decreasing decimal weight values. After getting the decimal weight values, we have to rank the rows based upon the order of decreasing decimal weight value and then, we have to reorder this rows according to their decimal weight in decreasing weight value. The step number 3 is you have to repeat the step number 1 and 2.

Now, in this case for column not for rows. We have to repeat step 1 and 2 for columns that is our step number 3 and we have to repeat the step 1 2, 3 unless and until, we come to the situation when there is no change in the position of each element in the row and the column. We need to repeat step 1, 2 and 3 continuously till we get a stand still position, no alteration position in the row and column allocations as well.

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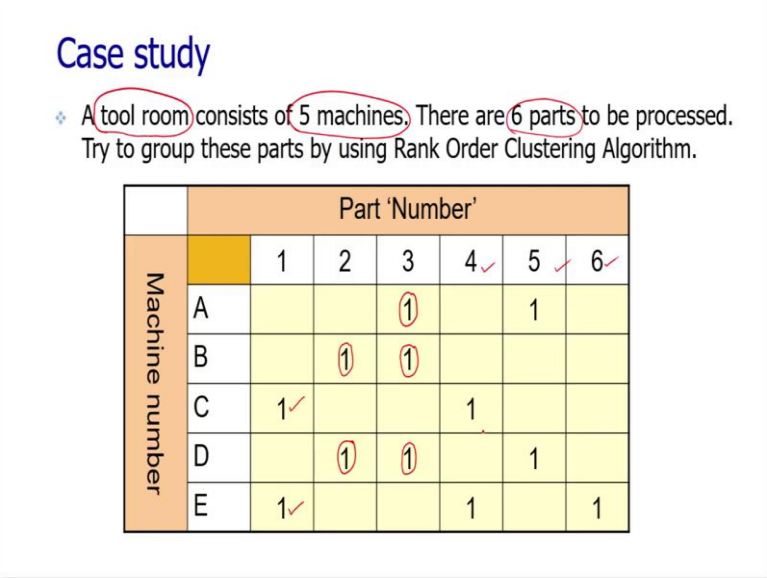

Let us take a case study to understand the rank order clustering algorithm. Here we are considering a tool room and this tool room is having 5 machines. Based upon the production planning or the process plan of we found that part number 3 is to be manufactured on machine number A, machine number B and machine number D. Similarly, the matrix is giving the information about the manufacturing of part 2 on B and D and for 1 it is C and E so on and so forth for the 4, 5 and 6.

This particular table is giving us the information that the parts are to be manufactured or to be processed on the variety of the machines and now, we need to cluster them. We need to cluster the parts together, we need to cluster the machines together so that the management of the part data would be easy and material handling in a cell would be easier for us.

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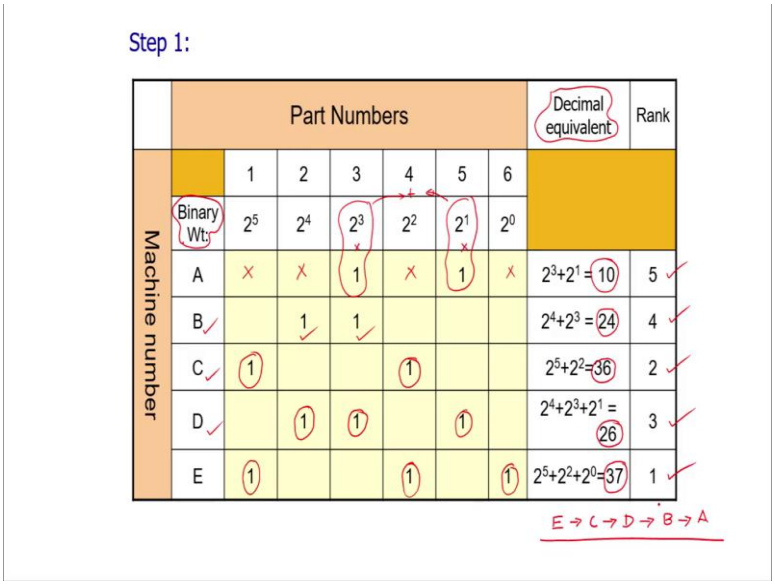

For that purpose as the rank order clustering algorithm is saying that we have to assign the binary weights; binary weights for the rows. To assign the binary weights for the rows, we have added one more row here and that is the binary weight row.

Here we have added the row and we are giving the binary weights from the right to left, from right to left the weights are to be given. Here we notice that the extreme right position is 2 raised to 0, then 2 raised to 1, 2 raised to 2, two raised to 3 so on and so forth.

Now, let us try to find out the decimal equivalent of each and every row. To find out the decimal equivalent, let us take the first row and find out the cells which are allocated which are having the value 1. As we have seen that the machine A is processing only part 3 and part 5.

We have to give the weight or we have to give the decimal equivalent based upon the binary weight of the location of that machine itself; the 3 and 5, where the machining would be done for that products, the machining would be carried out. As we can notice here that machine A is it is not processing part 1; it is not processing part 2; it is not processing part 4 and it is not processing part 6 as well.

Now, let us find out their decimal equivalent. Now, to find out the decimal equivalent, what we are doing? We are multiplying this 1 with 2 raised to 1. Here we are getting the product of 1 into 2 raised to 1 plus 1 into 2 raised to 3. This is, this we are getting the product; this is the

product and these we are just summing. This would be sum and whatever the value that we are getting that is the decimal equivalent.

2 raised to 3 plus 2 raised to 1 is 10. In a similar way, we are carrying out for the row B. Here we notice 2 raised to 4 plus 2 raised to 3 is equal to 24. For C, 2 raised to 5 plus 2 raised to 2 is equal to 36. For row D, 2 raised to 4 plus 2 raised to 3 plus 2 raised to 1 is equal to 26. For last row that is E, 2 raised to 5 plus 2 raised to 2 plus 2 raised to 0 is equal to 37.

Now, we got the decimal equivalents for all the rows. What the algorithm is saying, that you get the decimal equivalent and then, rank the rows in a in a decreasing decimal weight equivalent.

Looking at these values, we found that the row E is having rank 1; it is having the higher decimal equivalent value than row C, then row D, then row B and at last the top row is row A. In this way, the ordering would be here now is E, then C, then D, then B and then A. Let us rearrange the table by reordering the rows.

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Step 2:

		Part Number					
		1	2	3	4	5	6
Machine number	E	1			1		1
	C	1			1		
	D		1	1		1	
	B		1	1			
	A			1		1	

Here you notice we have rearranged E C D B A; the part numbers are as it is 1 2 3 4 5 and 6. Now, we have to repeat the procedure which we carried out in step 1 for the columns now. We carried out that for the rows, now let us carry out this for the columns. To carry out it, again we have to get the binary weights to the cells and then, compute the decimal equivalent.

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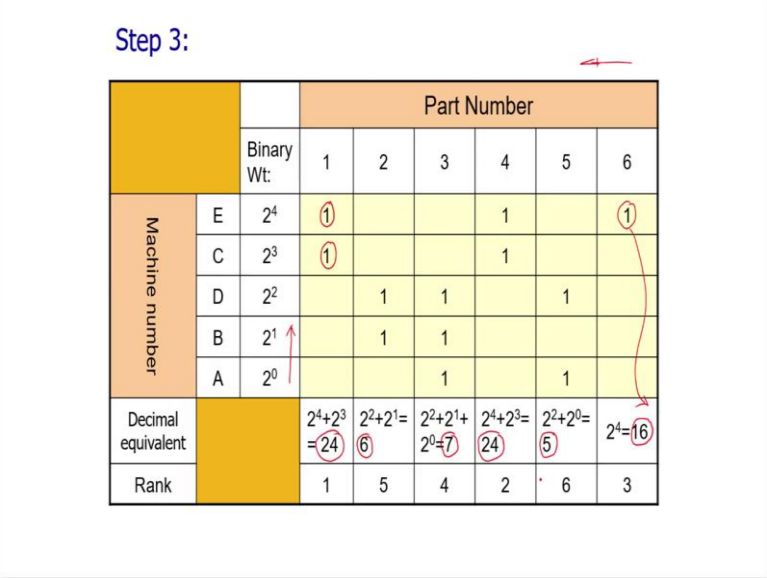

Let us look at the table once again. Now we got the allocations as you can see on your screen. 1 1, 1 1 here in this 1 1 for the part number 4 on E C. There is some sort of clustering some sort of the dynamics is going to happen here, there is rearrangements and let us see what is what is the last out, what is the outcome of this. Binary weights are arranged. Now, you notice that for the column, the binary weights we are allocating from bottom to top. We are starting from bottom to top.

For rows, we started from right to left; for rows, we have done for right to left and for the columns, we are starting from bottom to top. It is to be noted here; 2 raised to 0, 2 raised to 1, 2 raised to 2 so on and so forth, the binary weights have been given over here. We need to repeat the same process that we carried out in step 2.

For part number 1, let us compute the decimal equivalent 2 raised to 4 plus 2 raised to 3 and that is coming 24. For part number 2, we are getting 6. For part number 3, we are getting 7. For part number 4, 24. Part number 5, it is 5 and for part number 6 is 16 that is 2 raised to 4 only. This is giving a give the 16 value here.

Now, we need to again follow the same process based upon the binary weights. Now, we have to rearrange the columns. Here we are rearranging the columns from left towards the right. Higher decimal equivalent would be taken on left side and the lower decimal equivalent would be taken on the right side.

24 is the part number 4 decimal equivalent is 24 that is the part number 1. Here we are having a tie here. 24, 24 both are similar. In this case, we have to give the precedence towards the part which is on the left side. Then, 3; third position is given to the part number 6; fourth position is for the part number 3; fifth position is for part number 2 and the sixth position is for the part number 5. Now, let us rearrange these parts once again.

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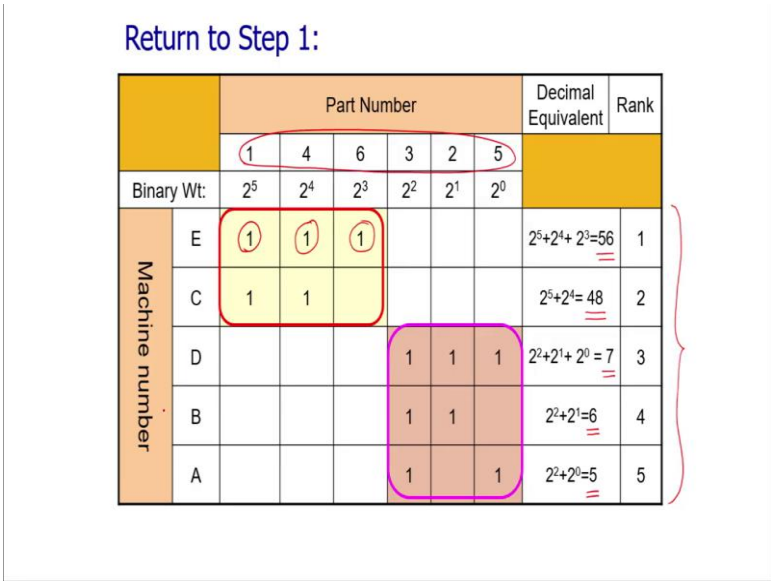

As we rearrange the parts once again from left to right, now here you can see part 1 4 6 3 2 5; 1 4 6 3 2 5 have been rearranged based upon the previous step and the machine numbers E C D B A are rearranged based upon previous to previous.

Now, the algorithm suggests that we need to repeat the step number 1 once again for the rows. Let us repeat the process for the rows; 2 raised to 5 plus 2 raised to 4 plus 2 raised to 3, we are getting 56; for the row C, we are getting 48; for row D, we are getting 7; for the next row the decimal equivalent is 6 and for the last row, it is 5.

Let us give the rank the rank is 1 2 3 4; the order need not to be changed because there the algorithm has given the rank as 1 2 3 4 5, it is suggesting that there is no need to change the order of the rows here. Once we get these kind of output, then we can say that we have to stop the algorithm and we have to get the clustering.

When we look at the allocations, immediately you can find out that the part number 1, 4, 6 can be clubbed together and the machines E and C can be clustered together. These two machines

can be clustered, they can be clubbed together either virtually or physically. What is the meaning of virtual clubbing and the physical clubbing that we will see in the next slide.

Similarly, the part number 3, 2, 5 are to be taken together and machines D, B, A are to be taken together for the part family operations. This is the rank order clustering algorithm. There are many such algorithms are available. Now, this is very simplified and the basic algorithm. There may be situation that what to be done when there are multiple number of parts are showing the same decimal equivalent. What precedence to be given in case of the tie?

For that purpose, there are advance steps are given advance solutions are given, those who are interested please refer the books related to the ordering that is a cluster clustering algorithms or computer integrated manufacturing algorithms. In this way, we are now grouping the parts; red colored parts and the pink circled or marked parts together.

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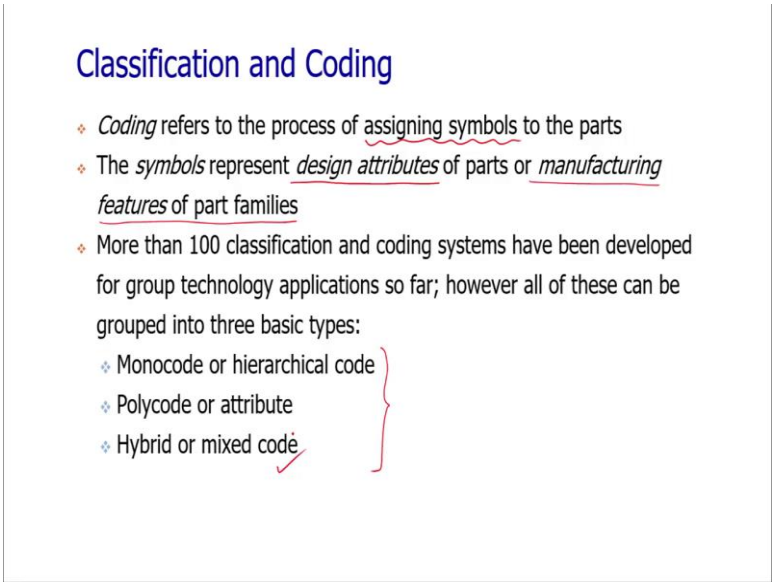

The next method of GT based classification is based upon the coding itself. The coding in general refers to the process of assigning symbols to the parts. Coding is the process of providing certain symbols to the parts and that symbols are nothing but their design attributes or they are the manufacturing attributes or manufacturing features of that part family. We have to prepare certain symbol and that symbol would be easy for the coding even that symbols would be helping just to have and efficient computer-based program efficient; computer-based algorithm as well.

If you look at the classification coding systems, you will find hundreds of the algorithms, hundreds of methods; many number of methods are available in the literature in practice in industry.

However, all of these classification and coding systems, if we try to group them together, we can classify them or cluster them into three groups and these are monocode or hierarchical code system, polycode or attribute code system and the third one is the hybrid or the mixed code system. Well, let us look at these basic types one by one.

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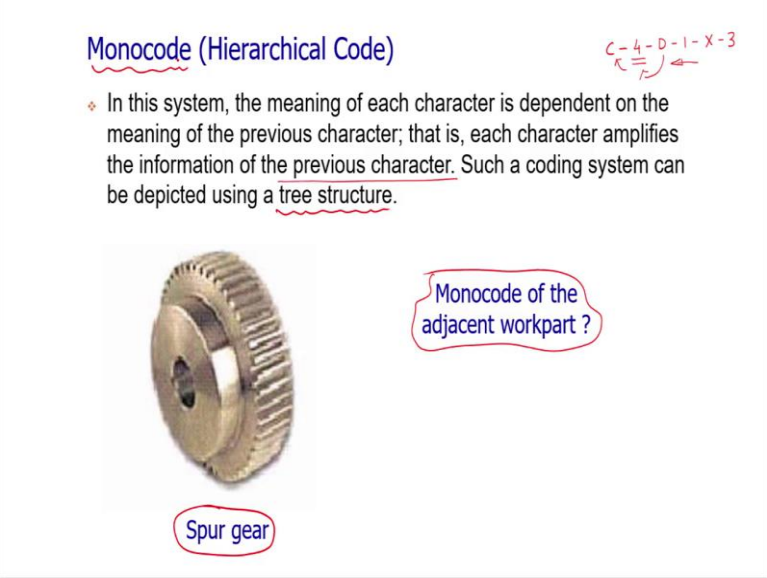

In the monocode type of system, the meaning of each character, we are giving certain codes to the product and the meaning of each character of that code is dependent upon the meaning of its previous character. Considering we are giving a certain code say C - 4 - D - 1 - X - 3. The meaning of 4 is dependent upon the C, the meaning of D is dependent upon 4 so on and so forth.

That is called as the monocode system. Thus, each character is amplifying the information about the previous character. Each character which is in succession which is coming here, it is amplifying the information, it is revealing the information of its previous character.

And basically, these type of systems are providing the information in terms of the tree you know tree structure. How this tree structure is being developed with an example we will see. To understand the monocode or hierarchical code, let us take a spur gear a component which

is there in front of you. Spur gears are generally used for power transmission or for the motion transmission.

Now, let us find out the monocode for this particular work part. Consider the company is going to manufacture variety of such spur gears and for that they have developed a certain methodology which is following the monocode type of the system. To apply the monocode type of system, the hierarchical code for the spur gear family has been developed and that is there on your screen.

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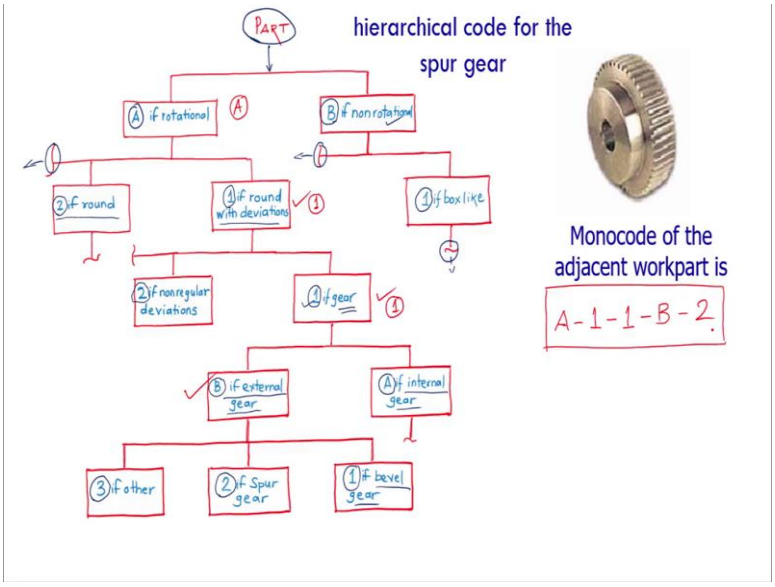

Let us consider any part, any part of that part family and once the part it is come to the decision making team, it may be team comprising of human beings or it may be a computer algorithm. The part has come. Now, we have to assign the code for that. First information would be carried out here that if the part is rotational, then we are giving the code A; if the part is not rotational, the code is B.

Now, as it is mentioned that the next character of the code or the second character of the code is revealing the information of the first character of the code. Now, if the part is rotational, then the next question comes whether it is round with deviation or it is round without deviation; if it round with deviation or it is round without deviation. If it is with deviation, the code 1 is to be given; if it is not, code 2 is to be given. Similarly, for non-rotational; if it is box like structure, 1 has to be assigned and so on and so forth.

We may have variety of additions to the tree, variety of branches to the tree along this direction or along this direction as well. Similarly, after this, you may have few more branches based upon the requirement. For example, I have I have shown the limited number of branches for this hierarchical code.

Now, let us consider if the product is round with deviation, the next question would be whether if it is gear, we have to assign 1 and if the deviations are non-regular, then certainly it is not gear, it is for some other kind of machining feature. 2 would we assigned if the deviations are completely not regular and the component is not gear. If the component is gear, then the next question comes whether it is an external gear or it is an internal gear.

If it is internal, give the code A; if it external, give the code B. If the external gear is chosen, in our case, it is it is the external gear. Again, the next questions would be whether it is bevel gear; if it is bevel gear, I give 1. If it is spur gear, assign 2 or if it is something else, some other type of gear then you assign 3. These are the indication that the branches can be extended.

We can have add more branches to this kind of hierarchical tree. For the spur gear purpose, let us solve the coding problem. This is part is there in front you, the part is rotational. The part is rotational. We are choosing A; part is starting with A. First character is A. As it is A, then we have to ask the next question whether it is round with deviations or if it is round without deviations.

The part is having deviations. Let us have A 1. If the part is gear or it is having non-linear deviations, certainly the spur gear is a gear. One more character that is 1 has been put; A-1-1; A-1-1.

Then, the next question what is whether it is internal gear or the external gear. Certainly, it is the external gear. We are adding the letter B as a next code and now, the external gear of which type whether it is bevel gear or the spur gear. It is spur gear 2. A-1-1-B-2 is the monocode for the work part which there in front you.

This is just an example. As you are having the complicated parts, the tree would be large; then, you have to take help of the computers to take the decision, you have to take help of the CAD software's to find out the features of the work part and based on that, generate the codes that code would be put on the work part and then, they will be processed inside the factory.

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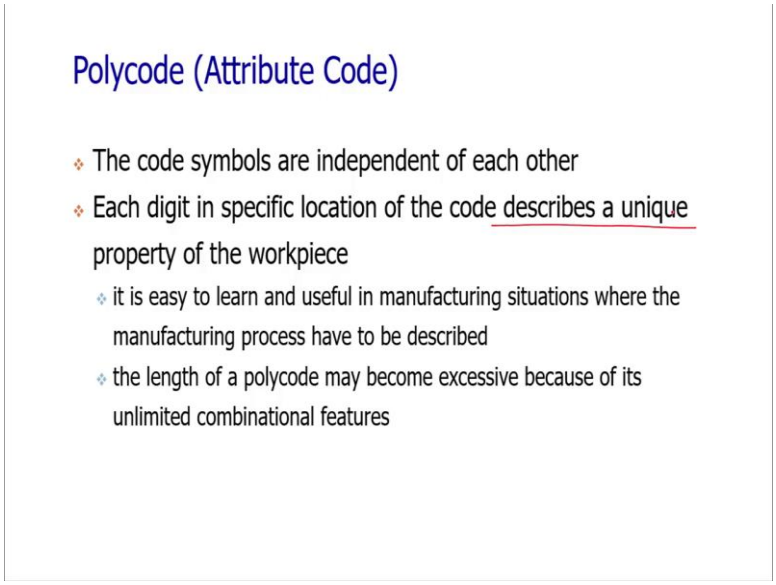

In polycode or attribute code type of system, the code symbols are independent of each other. In monocode, we have seen that the code symbols are dependent on each other, the second digit is revealing the information of its previous digit; but in this case, each and every symbol is independent, it is not dependent upon its previous code or the digit.

Each digit in its specific location of the code is describing the unique property of the work piece that unique property may be the geometric attribute of the work part or it may be the manufacturing attribute of the work part.

Polycodes are now finding them quite useful, when we want to reveal, when we want to provide the manufacturing information, manufacturing process related information to the user; but the polycodes are having a drawback that the length of the polycode may be excessively long. When more information or more type of attributes are to be incorporated in the code, then in that case the length of the polycode may be excessively long and handling such a long codes would be difficult.

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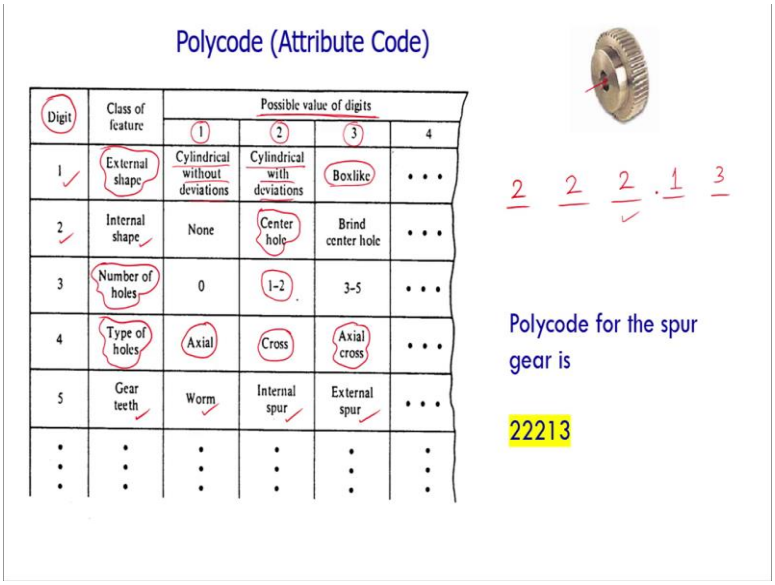

Let us find out how to define a polycode of a typical product. To understand the concept, let us take the example of the same spur gear that we have seen for the monocode.

A typical chart for the polycode or the attribute code for such facility can be seen on your screen. Here we are making a table and that table is having a variety of information and that information is written against the digits. Here you notice the first column is the digit column and each and every digit is having its specific meaning.

The digit 1 is providing or it is explaining the class of feature as the external shape; 2 is providing the internal shape, the information about the internal shape; 3 is about the number of holes; 4 is the type of hole so on and so forth and a gear teeth and then, there are possible values of the digit.

For first what are the possible values of the digit if it is cylindrical without deviation, then digit number 1; cylindrical with deviation, then digit number 2 and the box like is the digit number 3.

When we are giving the value of 2 at first digit; that means, the part is cylindrical with deviation. The second digit of the code, we have to assign a number say 1, 2, 3, 4, 5, 6. If nothing is there in the internal shape, then 1; if the center hole is there, then the possible value of 2; the blind center hole is there, then possible value of 3. Each and every digit is

independently giving the information. It is not dependent upon its previous thing. Consider we are having certain digit here that to be processed for this polycode of the spur gear.

We have seen that the spur gear is cylindrical with deviation. The code is 2. The spur gear is cylindrical with deviation, so the first digit the value of first digit, we are putting 2. Then, we have to choose the possible value for the second digit. It is none whether any feature is there internal, yes there is a center hole.

This is center hole. The value of the center hole is 2. Second digit is 2. Then, we have to examine how many number of holes are there? There are the holes which are ranging in between 1 to 2. The spur gear is having only 1 number of hole. This third digit is also 2.

Then, the type of hole; what kind of hole it is, whether it is a axial hole or it is a cross or it is a cross axial hole? This is a axial hole; it is not cross means not cross to the axis it is the axial hole. That the next digit is 1. Now, the last digit that is the gear teeth, what type of the gear teeth are there; whether it is a worm or internal spur or external spur? Certainly it is the external spur.

The attribute value is 3. The code for the spur gear as per the polycode or attribute code methodology is 2 2 2 1 3. It is 2 2 2 1 3. It is more compact than the monocode and it is very easy to understand the meaning of each and every code because the digits are not dependent on it is previously.

If somebody wants to ask the question that what the meaning of the fifth digit is a fifth; what type of the gravity tar? It is a certainly 3 means external spur; it is external spur type of gear and how many number of holes are there? The third digit is giving the information that the number of holes are in between 1 to 2.

In this way, we can retrieve the information from the polycode or the attribute code comparatively easy. But when the number of attributes are more, when more information it is to be incorporated, then the length of the code would be excessive that will consume lot of space inside the computers and that will slow down the processing of the data.

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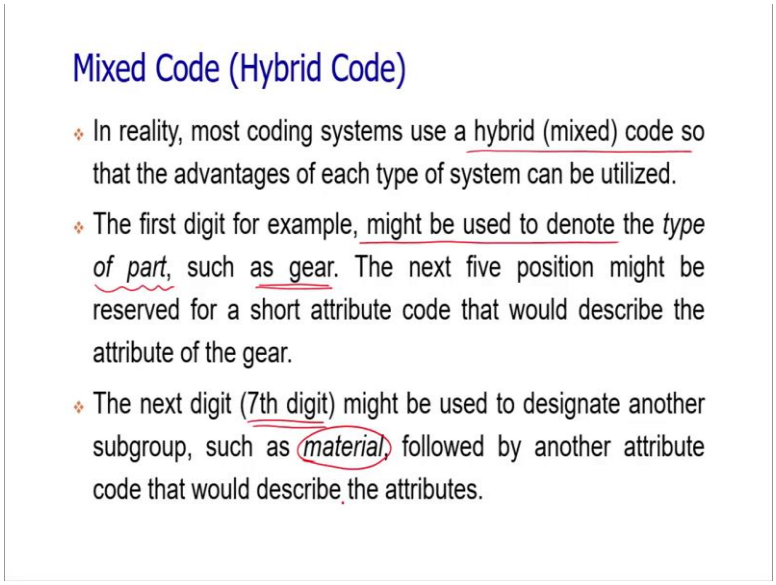

In reality, in the industry, the most coding systems, they are based upon the hybrid code. They are getting the benefits, they are utilizing the advantages of the monocode and the polycode methodology and a hybrid code methodology, the industry is using. In the first digit of the code, it is might be denoting the type of the part.

How the hybridization can be done? The first digit is denoting the type of the part such as it is a gear and the next 5 positions might be reserved for the short attribute code, that would describe the attribute of the gear; its geometric shape and the its geometric features basically.

The next digit that is a digit number 7 can be dedicated to the another subgroup say, material, a material of the spur gear followed by a set of digits which are giving the information about the type of material its alloying elements and the other material properties if required.

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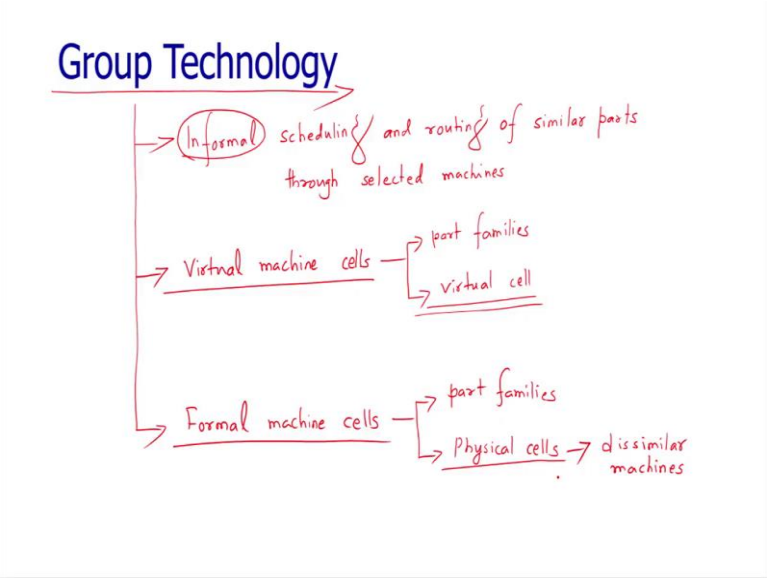

Now, how these group technology principles can be applied in the manufacturing; how we are applying the GT in the manufacturing? We got a cluster of products, we got cluster of machines and now how to move ahead. For that purpose, there are basically three modes or three prominent application. The first application is informal scheduling and routing of similar parts through selected machine.

It is informal scheduling and routing of similar parts through selected machines. We got the cluster, now we have to schedule. Here the scheduling of the operation, here the scheduling of the work operations would be carried out in an informal way and we are routing the similar parts through the selected machines in informal way.

We are not making any part family. We are getting the similar parts and then, informally we are scheduling them for the operations. So, there is no formal way, we are making any part family and there are no formal physical cells that will be done ok. In the next process, we are using virtual machine cells.

This approach is basically consisting of creation of part families and dedication of equipment to the manufacture of this part families. We are creating the part families and we are dedicating the equipment or machine tools for manufacture of these part families.

But we are not physically rearranging this equipment or the instrument together. They are in a in a virtual mode only. So, we are creating the part families here. Part families would be made and we are virtually making the cells.

We got the machine tools, but we are not physically changing this machine tools or the equipment, we are just saying that these four equipment which are scattered on the shop floor and the part would be routed in that the virtual cell; accordingly, the material transfer plan material transport plan would be made and a operations would be carried out.

This application is having the advantage that there is no need to physically rearrange that will save lots of cost, but when the when we are trying to move the parts inside the shop floor or the tool room, that material transport time and the cost would be high. If the shop floor size is quite large, then the transport would be sometimes would be very difficult that will consume lot of time and may hamper the production schedule.

In third way, we can go for the formal machine cells; formal machine cells. Group technology is providing us the cluster of products and cluster of machines and then, we are making the part families and we are creating the physical cells. We are rearranging the existing equipment which are there inside the factory and we are making a formal cells of dissimilar machines.

Physical cells which are comprising of dissimilar machines, we are grouping this dissimilar machines together in the physical cell and then, that cell would be dedicated to that part family and we can even say we can save lot of time of the material handling and we can enhance the production capacity.

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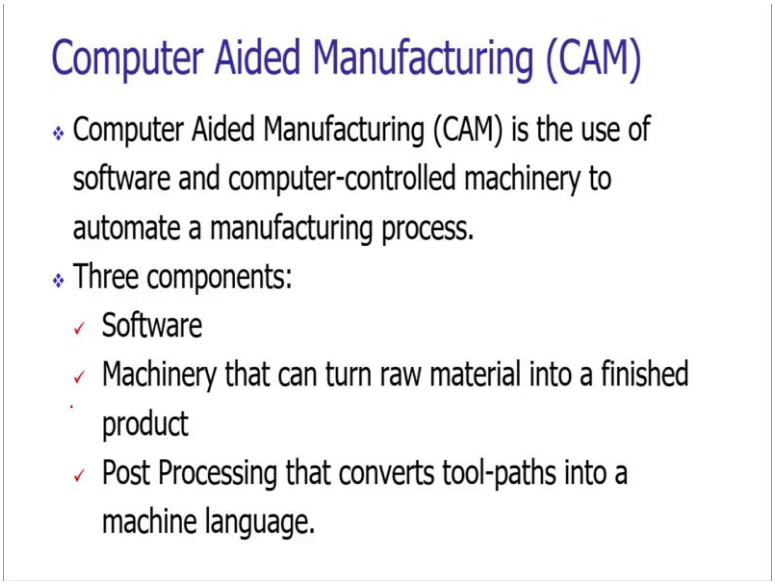

After developing the part families, after using the group technology during the manufacturing, then when we are actually starting the manufacturing operation and when we carry out the manufacturing operation, we are taking help of the computers and that is called as the Computer aided manufacturing.

The computer aided manufacturing basically has a software application or employment of a software and there are computer-controlled machineries CNC machine tools, CNC machines, automated product or part handling equipment such as robots, various electromechanical conveyers, trucks, automated guided vehicles, the computer-controlled machinery equipment instrumentation, we are taking help of all these things to convert or to transform the raw material into the semi-finished product or the finished product.

Basically the CAM, it is a computer aided manufacturing; it is having the software, it is having the machinery and the post processing which is converting the tool paths into the machine language.

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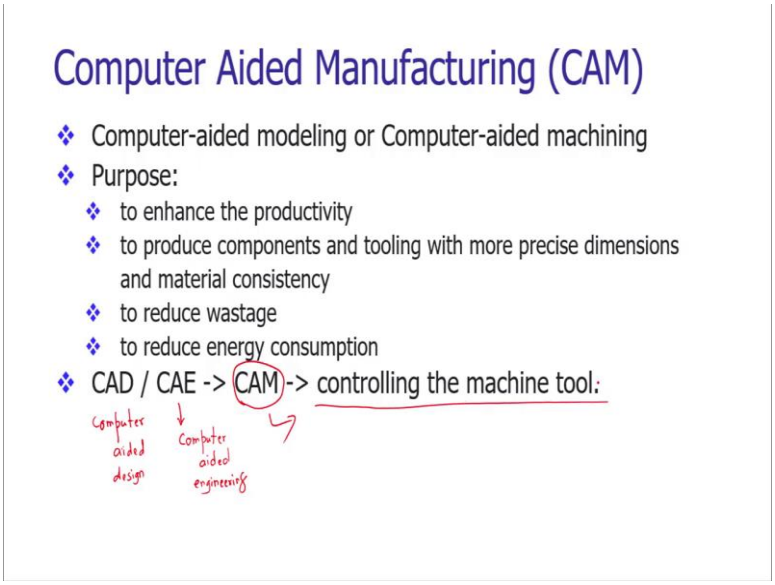

The computer aided manufacturing is very widely used in the industry and the very popular abbreviation or the short form is CAM. But many a times, the C A M that is a CAM is also used for computer aided modeling or computer aided machining as well. However, the basic purpose of the computer aided manufacturing is to enhance the productivity.

We are using the computers and that computers are helping us to enhance the productivity, to reduce the errors, to make the components precise, the dimension should be precise, to have to required surface quality or the superior surface quality to reduce the wastage, to avoid the undue utilization of the materials or the auxiliary things such as coolant and to reduce the energy consumption.

With this objective, with this purpose, it is very essential for an automation engineer to look at how can we implement the computer aided manufacturing in in the factory. Till now, we have seen a variety of technological advancements as far as the censors, actuators, equipment, the drives, variety of power drives, their utilization, their capabilities.

Now, we need to also look at how can we use the computers for process planning, for making the thing things workable at the shop floor. For that purpose, we are taking help of the computer for the designing. So, that CAD, we have seen in our previous lectures. CAE that is a computer aided engineering, it is analyzing the part geometry, it is applying the forces, it is applying the boundary conditions, it is applying the engineering principles and trying to get the required

outcome from that CAD drawing whether it is visible to produce this kind of products by using existing facility or not.

Whether this product will sustain in the market, whether the product we carry out its designated operations or the desired operation. That would be carried out by the CAE. After the designing and after the engineering analysis that is a computer aided engineering analysis, the next stage is coming that is a CAM.

CAD is computer aided design; CAE is computer aided engineering, computer aided engineering analysis and the CAM will certainly take you to the actual transformation or the CAM will certainly take you the transformation of raw material into its physical state it is a desired physical state. CAM software's or the CAM systems are controlling the machine tools.

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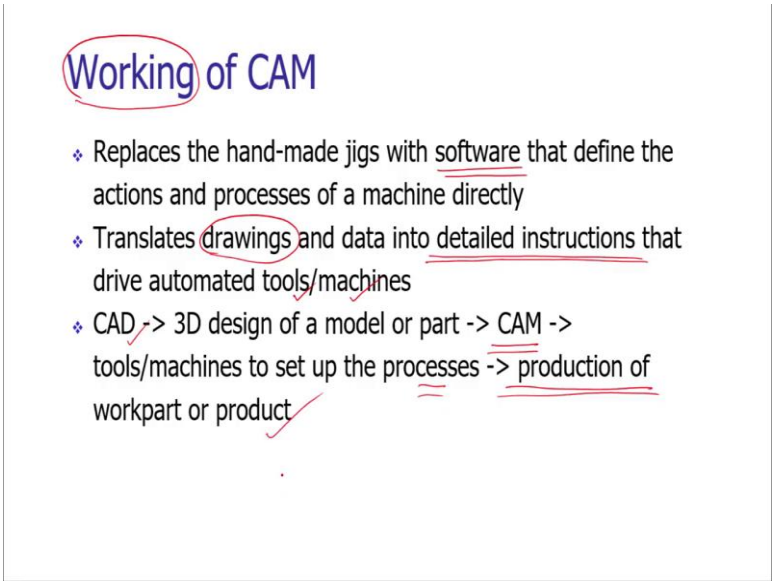

What exactly the CAM systems are doing? They do basically replace the handmade jigs with the software. Software's are being utilized which are defining the actions and the processes of the machine that to directly carryout. The CAM systems are converting the drawings.

CAD systems are providing the drawings or 3D models, but there has to be a system which should convert or translate the drawings into the required form and that form or that data would be utilized to generate the codes or the programs which are controlling the operations of the CNC machine tools and that we call the CNC programs G A M code program, to get the data

or to translate the data from the drawings into the detailed instructions, that to be given to the tools and the automated machines.

CAD is generating the 3D design of a part or a model and the CAM is controlling the tools and machines to set up the processes and it is actually carrying out the production operation and finally, it is generating the product as per the desired design.

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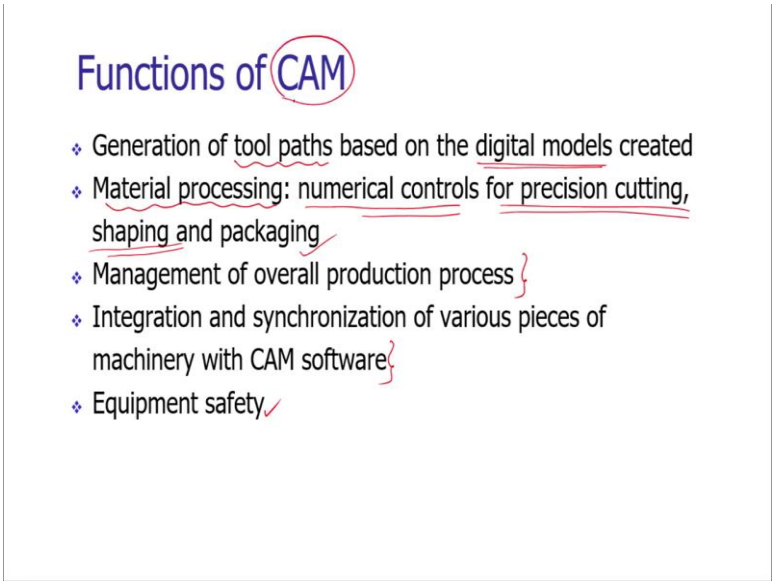

We can list out the functions of a CAM. It is basically used to generate the tool paths as per as the CNC machine tools or the subtractive type of machining operations is concerned, to generate the tool paths based upon the digital models which are created; based upon the 3D CAD models which are created. We need to generate the tool path according to the drawing or the design made by the modular.

Then, actually carrying out the material processing operation; material processing by using the numerical control machine tools, it may involve precision cutting or it may involve the shaping or it may involve the packaging, painting, inspection. Material processing and allied operations that would be carried out by the CAM systems.

The CAM systems are needed or they should have the capability to manage the overall production processes; the entire production processes need to be combined together and that to be efficiently handled, efficiently managed by a CAM system, integration and synchronization of various pieces of machinery with CAM software.

Whatever the software being utilized in the in the company or at the shop floor, we need to integrate that CAM software, we need to synchronize that CAM software with the machine tools or the equipment and that will be done by the CAM systems. To take care of the safety, the equipment safety that is also part of the function of a the CAM system.

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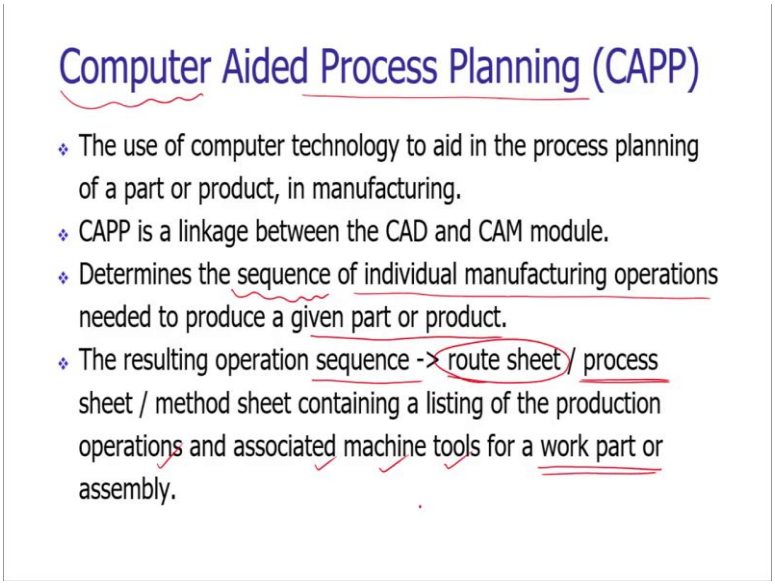

Computer aided process planning is a very vital; it is very important aspect of CAD-CAM. We are using computers for designing and we are using computers for manufacturing; both of things we have seen.

But there has to be a bridge, there has to be some sort of linkage between the CAD and CAM and that would be done by the process planning with the help of computers. That is called as the computer aided process planning. Thus, planning is very essential.

We have to get the we have to extract the features from the CAD drawing, we have to apply the logic, we have to apply the experience, knowledge on that data and then, we have to reason out we have to made a process plan and that process plan will be just utilized by the CAM systems to execute that process plan. Who will do this process planning?

In traditional way, a group of experienced engineers in the industry, they are developing this process plans, they are applying their knowledge, they are applying their experience, they are coming up with a process plan and that process plan would be further given to the production planning department and they are taking the that plan for the execution.

As I mentioned, when the number of parts are in very high number, product sizes are very high, there are many assemblies, there are many sub-assemblies. To handle the number of parts, it is difficult for a small team. For that purpose we have to take help of the computers to automate the mechanism of the process planning and that is nothing but the computer aided process planning.

The process plans basically they are determining the sequence of individual manufacturing operations which are needed to produce a part of the product. And the resulting operation sequence is generating the route sheets or process planning sheets which is having the information about what kind of production operation need to be carried out, what are the association machine tools that to be utilized to convert the raw material into the semi-finished or finished product for that particular work part or the assembly.

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In general, it is envisage that it is expected that the CAD should be integrated with the CAM. Instead of using the CAD or the CAM software's in a standalone phase. These will not work certainly. There has to be certain mechanism which will integrate the CAD and CAM and that is nothing but the CAPP. It is basically the bridge, as I mentioned between the design and manufacturing and that is translating the design specifications into the manufacturing process details.

There are indeed certain translator which is converting the information, the design information into the manufacturing process details. The process plans are important and they should answer

the questions regarding the various information, which is needed at the shop floor about the process, about the tooling, about the process parameters, their values and the sequence. There are various steps of process planning.

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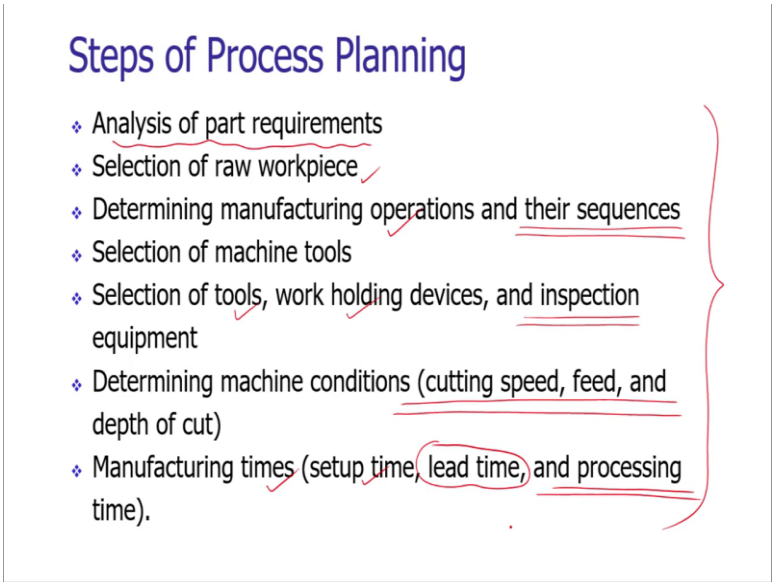

The first step is to analyze the part requirements and then, select the raw material, raw work piece is to be selected. After that, we need to determine the manufacturing operations and their sequences. Here the actual skill or the knowledge is required, the team has to certainly put their efforts, they have to put all their experience to select the proper manufacturing operation.

A same product or part may be carried out by variety of manufacturing operations and the team has to certainly look at the variety of options and they have to choose the best one. For that purpose, they might have to carry out certain optimization as well. Selection of raw material, raw work piece and determining manufacturing operations and their sequence; in which sequence, the operations need to be carried out.

The manufacturing operation selection is also dependent upon the capacity of that enterprise, the capacity of the tool room as well. Whatever the machine tools whatever the equipment the tool room or the enterprise are having, based on that the team may or the computer may take the decision to choose the suitable manufacturing operation.

If it is not possible with the existing facility, then we have to procure it. In that case, can we change the design and can we get the alternate design which can be manufactured by using the

existing facility. Such decisions are critical decisions are suggesting by this process planning team and they are helping in collaboration with the CAD and CAM team to get the right process plan which is workable and in the desired time limits. Selection of tools, work holding devices and inspection equipment.

All these information need to be finalized by the process planning team and there is a part of the process planning itself. In addition to that, the details, the technical details regarding the cutting speed, feed and depth of cut, the setup time, the estimation of the setup time, estimation of the lead time that is a preparation time and the actual process time.

Recording of the same monitoring of these times and based on that avoiding the bottle making. All this things would be done by the process planning in step wise manner, in a phase wise manner.

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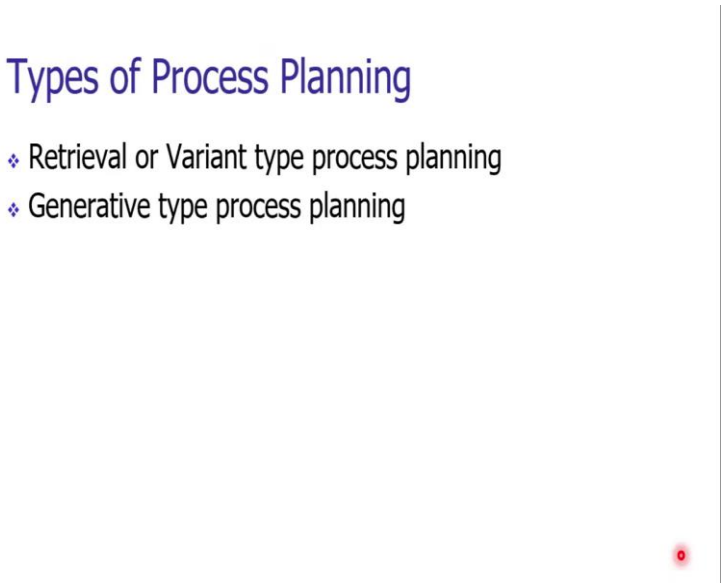

In the industry basically two types of process planning systems are employed or utilized. These are retrieval or variant type of process planning and the next one is generative type of process planning. Now, let us look at the details of these two process planning systems one by one.

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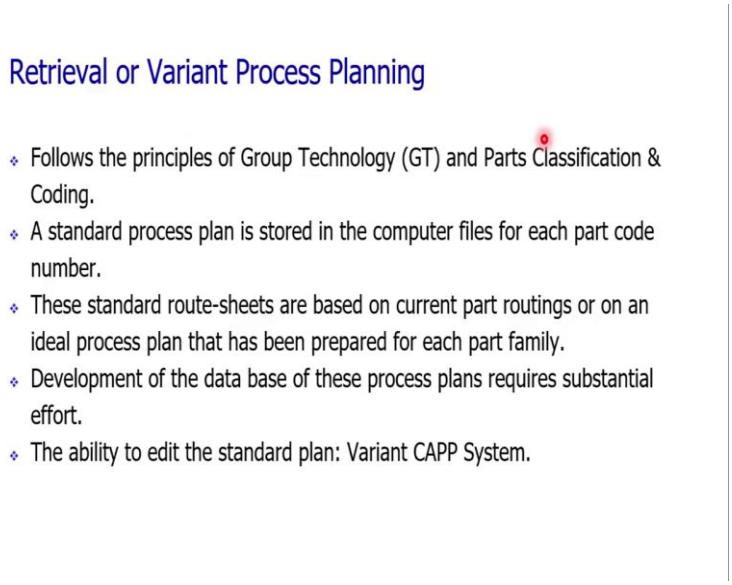

The first one is retrieval or variant type of process planning system. This process planning system basically follows the principles of the group technology. We have seen that in group technology is generating the part families based upon the design attributes and the manufacturing attributes.

In this process planning system, a standard process plan is created for each part code number and these standard route sheets, the route sheets which are having information of the manufacturing or the sequence of manufacturing operations, the tools, the jigs required, the fixtures required, the production information, the process parameters and all manufacturing related information and the sequence is documented.

Such documented file in the stepwise manner would be stored. There may be an ideal process plan for that part family as well. Because we have seen that the part families are made up of either based on the geometrical attributes, although the part sizes may be different; but their process plan maybe the same. For example, in garment manufacturing the sizes of the garments are different.

From small to medium, medium to the large, large to the extra-large, the sizes are different; but the manufacturing process sequence is same, material is same, only the size is the matter. In that case, the process plan is exactly the similar, only the machining related attributes or the dimensions are different.

That ideal process plan will be prepared for the each part family and when new item or new part is coming into the part family based upon its geometrical similarity or the manufacturing similarity, this existing process plan will be utilized to create the process plan for that part.

It is retrieval based, the existing database, existing knowledge in terms of the ideal plan will be taken out, will be retrieved and that would be edited. Then, as it is being edited, it is called as the variant process plan. The retrieval or variant process plan do have the capability of editing the standard plans.

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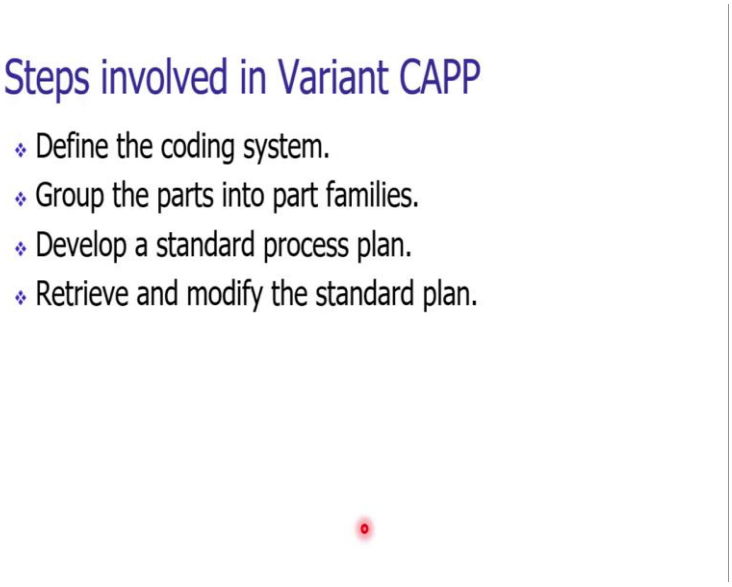

What are the various steps involved in the variant plan? We have to define the coding system, then we have to group the parts into part families, then we have to develop a standard process plan. Here either a team or physically will carry out the process planning, operation or there maybe the software which are generating the process plans and then, we have to retrieve and modify the standard plans which are available with us.

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This kind of systems, are offering the shorter development time because we are just retrieving the existing plan. The plan is ready with us and there is man power consumption is very low.

The system, we have to just search through based upon the similarity, the way we are searching in our regular computers; in a similar way based upon the geometrical attributes, the system will search a best plan available with a system and that would be given to you. And based on that, we can regenerate, we can we can develop the new plan based upon the existing plan itself.

However, to have that efficient variant CAPP, the basic process plan or the fundamental process plan must be of very good quality. It must be very robust; it must all-inclusive; it should able to inclusive the variation inside that. Therefore, the fundamental process plan or the original process plan for that part family has to be developed with at most care with all possible the probabilities to include more number of parts of changes in the size and the shapes.

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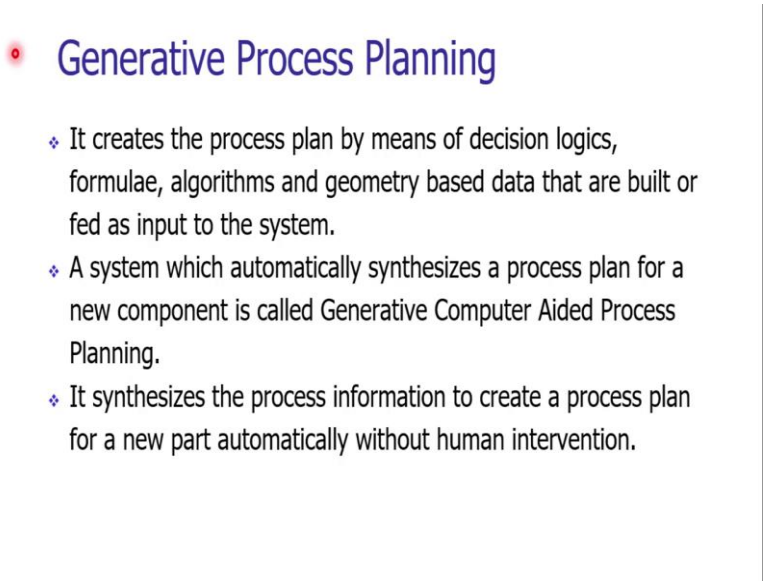

But in many of the cases this may not be true. The new product or new part which is coming inside or which we need to manufacture would be entirely different. There may not be any part family matching to that particular product. In that case, we have to start from the scratch to develop that process plan.

When we are creating the process plan from the scratch from the 0 that is called as the generative process planning. When we do this activity, so we are taking help of the various engineering formulae, engineering principles, algorithms, geometry-based data and based upon that, we are generating a fresh process plan a original process plan for each and every part that will be added.

For that purpose, the system is automatically synthesizing process plan for the new component and since, we are generating a fresh, we are creating a fresh; it is called as the generative type of the computer aided process planning.

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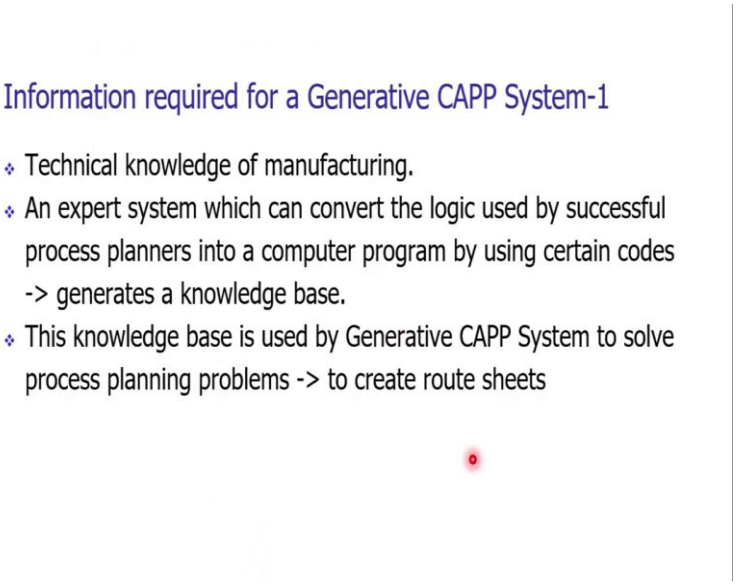

What are the information required to generate a process plan in generative type of process planning? We need to have the technical knowledge about the manufacturing and we need to develop an expert system which will convert the logic used by successful process planners into computer programs.

Here we are trying to replace the human beings with the computer systems. But who will train the computer systems? The computer systems are being trained by the software's or the programs and the programs are nothing but a set of rules, set of rules are based upon the experience or knowledge of knowledge gained by the experienced people of the shop floor.

We need a expert system which will convert the logic used by successful process planners into computer program and based on that codes, based on that rules, we have to generate a new process plan.

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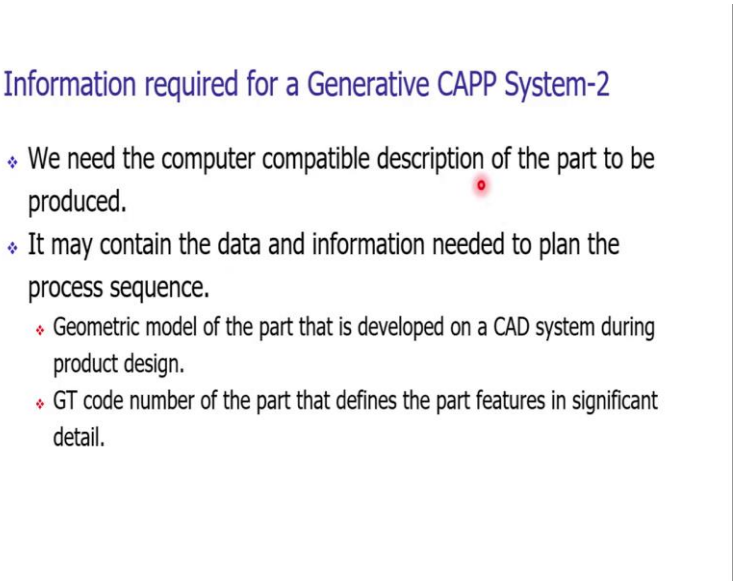

The second information needed as far as the generative process planning is the description of the part in compatible way with the computers. We are having lot of alpha numeric data, maybe in the format which may not be directly useful for the computers.

We have to convert the raw data in terms of the process plan into the format which is compatible with the computers. For that purpose, there has to be a convergent system, there has to be a standard way of converting the raw data into computer format. For that purpose, we need to write certain programs as well. The data may be related to the process plan sequencing, the data may be related to the geometric modeling that is at the CAD system, the feature extraction system.

The CAD systems are given to the CAPP system and that CAPP systems are extracting the features, the machining features such as the threads, screw threads are to be manufactured. All this features are to be extracted from the CAD system that is needed for generation of the process sequence, manufacturing process sequence.

Then, we need the GT code number, the numbering or the coding of the system which is signifying its description, the product description, the part features with significant details. In general, as I have as we have seen that either polycode or the hybrid code type of systems are utilized to designate the various parts in the industry. This GT code is also very essential to generate the CAPP system.

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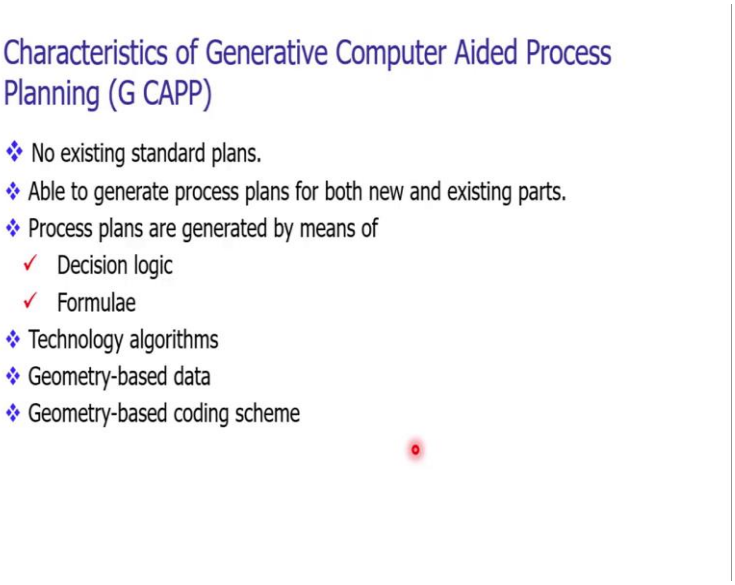

Various characteristics of the generative computer aided process planning systems are listed. The first characteristic is that there is no existing standard plans being utilized to generate a process plan in this methodology. These type of systems are able to generate process plans for both new and existing parts.

This process planning system is based upon the knowledge gained by having an expert system and there is a decision-making system. This system is nothing but a software. It will ask many questions to the end user, the process planner and based upon the information given, based upon the CAD model which is given to the CAPP system, the process planning system will generate a new process plan, that is the generative process plan.

This kind of systems are very much useful for creating entirely new plan for the fresh products or fresh parts, which are entering into the part family or they are defining the process planning route sheets for the existing parts as well. These plans are generated or developed based upon the decision logic and the formulae, the engineering analysis formulae, lot of technological algorithms are needed.

It also needed to have the geometry-based data and the geometry-based coding scheme as well. With all this information, with all this characteristics, the generative based CAPP systems are utilizing.

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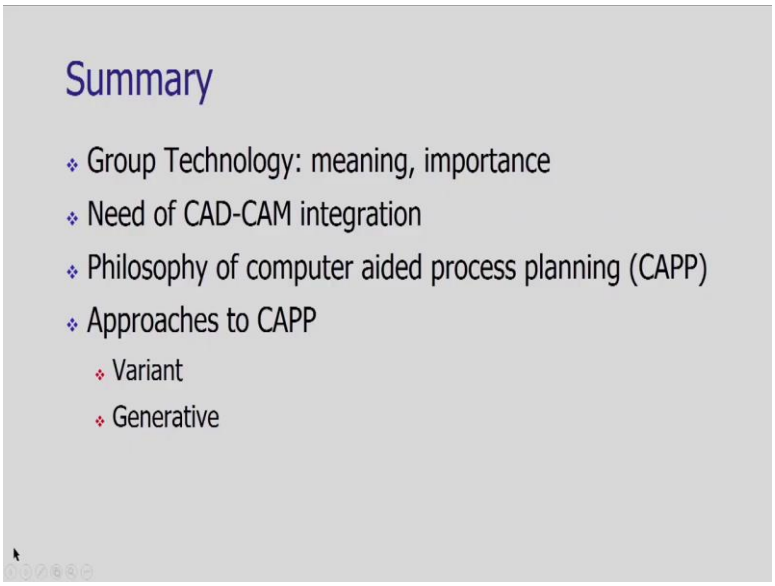

Let me summarize lecture 1 of week 12. In this lecture, we have studied the meaning of group technology. We have seen the importance of group technology in the perspective of product lifecycle. We have seen the need to go for the CAD-CAM integration and how to integrate the CAD and CAM; how to bridge the gap between CAD and CAM.

There is a philosophy of computer aided process planning that we studied. There are various approaches for the CAPP. So, these approaches are the variant approach and the generative approach. These approaches, we learnt during this lecture.

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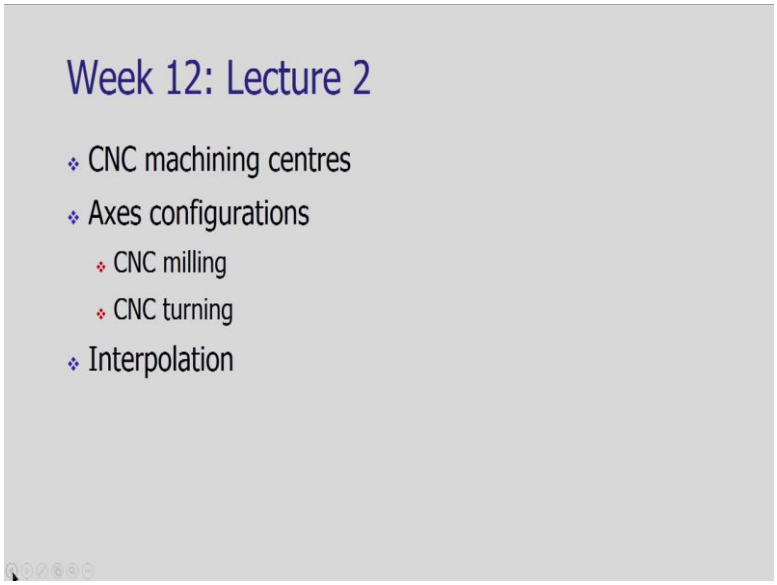

In the next lecture that is lecture 2 of week 12, we will be studying the CNC machining centers; what are the constructional details of the CNC machining centers; what are the various axes configurations of CNC milling and CNC turning center.

There is a important concept or technology that is a interpolation which is integral part of a CNC control unit. We will see the meaning of interpolation and how to carry out simple interpolation by using certain algorithms.