Automation in Production Systems and Management
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Automated CAPP (Part-I)
Lecture - 55
CIM and CAPP, Process Optimization and CAPP

In the last lecture session, we will be referring to two important issues.

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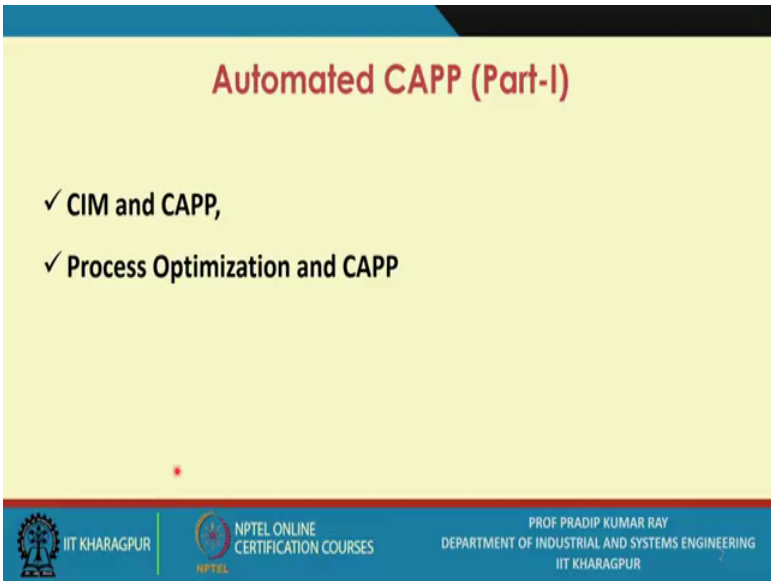

Computer aided process planning is related to the overall computer integrated manufacturing framework. The kind of the interactions you have with other elements of CIM with the CAPP must be known in explicit terms. The entire process planning is having 6 steps and these are the 6 steps you have to follow in a sequence and the last step is related to Process Optimization. This is a very important, because in a process plan for a particular product you have to specify the process conditions.

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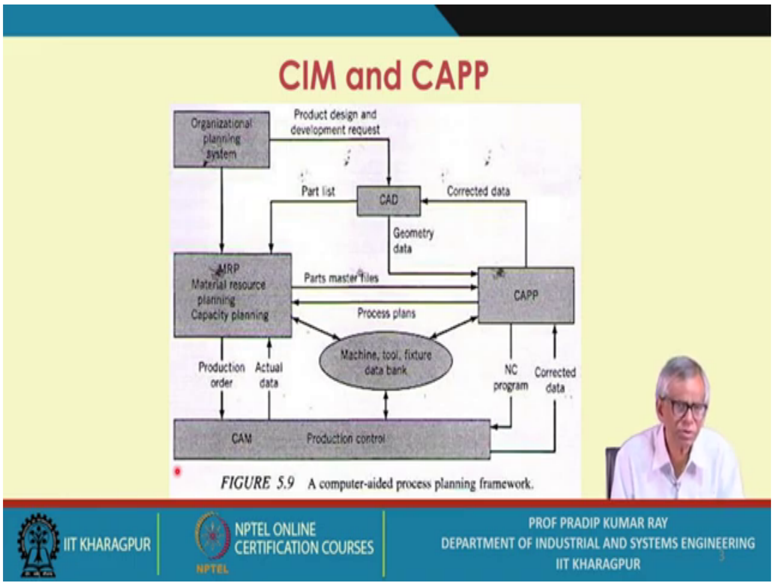

Not only you select the process, not only you select the machine tools and other elements, but you have to specify the process conditions with respect to a particular operation on a given machine tool.

The relationship between the CAPP and other elements of CIM. This is a framework where you can identify the CAPP element and how the CAPP is linked or related to other elements of CIM as well as the databases you require to the design and develop CIM focusing on CAPP or computer aided process planning.

Organization planning system. From this planning system you get the details of the product design and development. Once the product design and development aspects you focus then you start using appropriate computer aided design.

The part list is one kind of output from the CAD system and once you get this part type details then you are in a position to the propose materials requirement planning.

You may have MRP-I, then at succeeding stage you may go for MRP-II and you will also be considering the capacity planning issue. This is in one block and then based on this, you place the purchase order and it goes to computer aided manufacturing system.

We will be bothering about the production control. This is the CAPP module. How do you establish or how do you develop this CAPP module?

The first thing you get that is the part master files. When you create an MRP you have the product structure code plus the part master files. This will be sent to you to the CAPP module. NC part program you develop and you send it to your CAM module.

This is basically a closed loop. The collected data you also get constantly, you have to update the database related to CAPP and the main database will have the data related to the machines, then the cutting tool fixtures.

These are the 3 important components in any manufacturing systems. You have to create database for each one and then the output of the CAPP module is the process plan. Once the MRP system is established then the capacity planning aspect you considered. Whenever you get the production orders, the CAPP module will be activated.

Looking at this particular framework you will understand how this CAPP module is interacting with CAM module as well as the CAD module and other types of online real time control systems like MRP or its variants.

This is basically a particular framework where the relationship between CAM related modules and the CAPP module is established and it is a closed loop system.

The corrected data will be passed on to CAD module because there must be perfect matching between design and manufacturing through CAPP.

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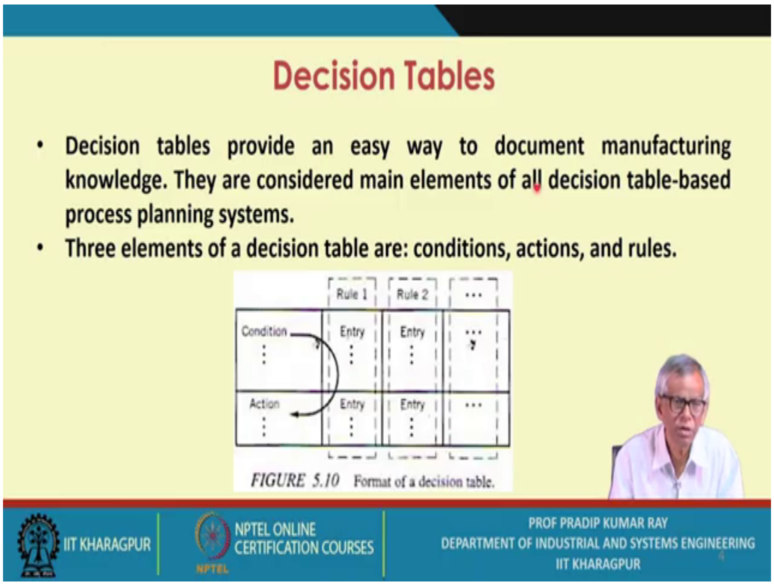

The decision tables provide an easy way to document manufacturing knowledge related to a particular part, component or a product.

They are the principal elements of all decision table-based process planning systems. The elements of a decision table are conditions, actions, and rules.

As far as rules are concerned this is a total set. When you refer to the process plan, how a particular product is getting manufactured at the different stages. This knowledge you must have and this is referred to as the manufacturing knowledge.

Once you develop the process plan it is indicative of the manufacturing knowledge.

Suppose you have to the decide on the spindle speed, you have to select some kind of one type of holding devices, all these details will be specified.

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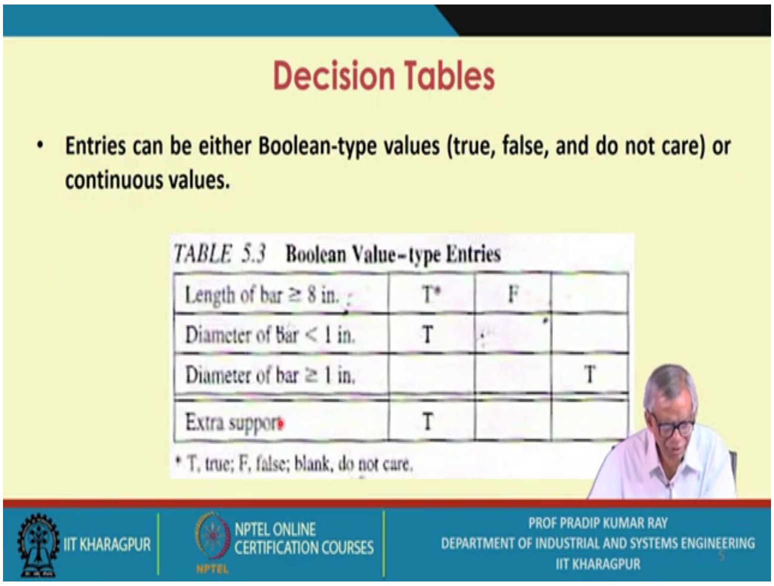

This values which you specify could be Boolean type and true or false or 0-1 like that. What are the conditions? For a given part, the length of the part, if it is 8 inches, it is true.

Similarly, diameter of the bar is less than 1 inch if it is true. The diameter of bar is greater than equals to 1 inch.

If it is true, whatever the actions you take, these actions are dependent on certain conditions, either could be one condition or multiple conditions and each condition you specify the rule, and accordingly you take action.

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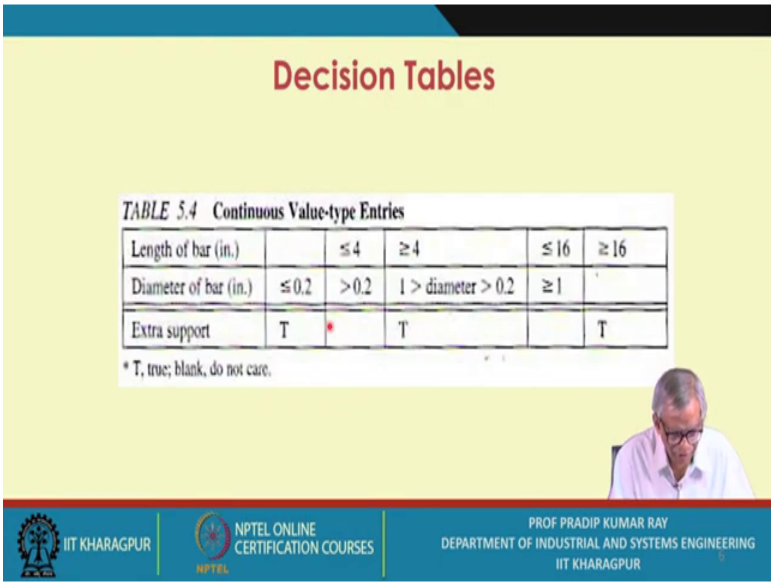

Another example is when you deal with the continuous value type entries, like the length of the bar is less than equals to 4, greater than equals to 4. These are the possibilities, less than equals to 16 or greater than equals to 16. These are the 4 rules you specify. These are the conditions then.

If it is the true, the diameter of the bar is less than equals to 0.2, then whether you need extra support that knowledge-base you have. Similarly, if these two conditions hold; that means, the length is greater than equals to 4 and the diameter is between 1 and less than 1 and but greater between point 0.2 and 1, then, obviously, extra support is required.

If the length of the bar is greater than or equals to 16, definitely you must have one extra support. So, length is the main determining factor.

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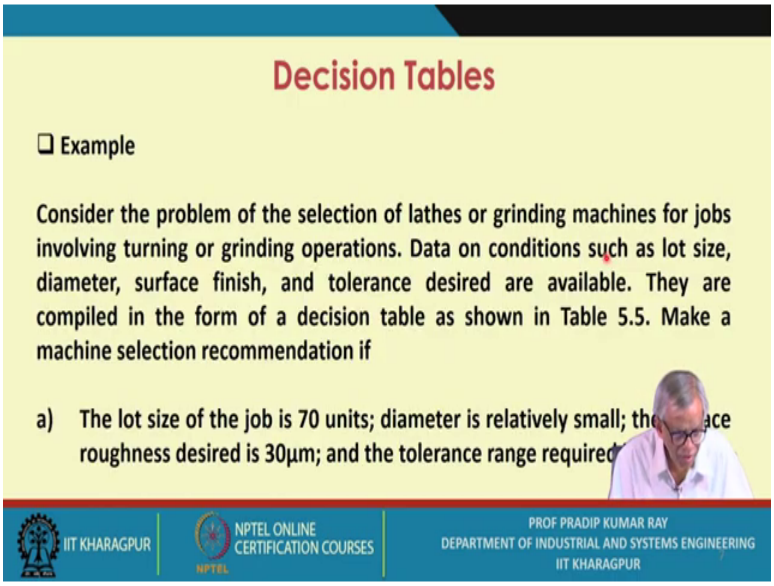

I will highlight one particular example. Consider the problem of the selection of lathes or the grinding machines for jobs involving turning or grinding operations. Data on conditions such as lot size, diameter, surface finish and the tolerance desired are available. They are compiled in the form of a decision table as shown in table. So, this table will be shown. Make a machine selection recommendation if

a) The lot size of the job is 70 units; diameter is relatively small; the surface roughness desired is 30μm; and the tolerance range required is ±0.003 in

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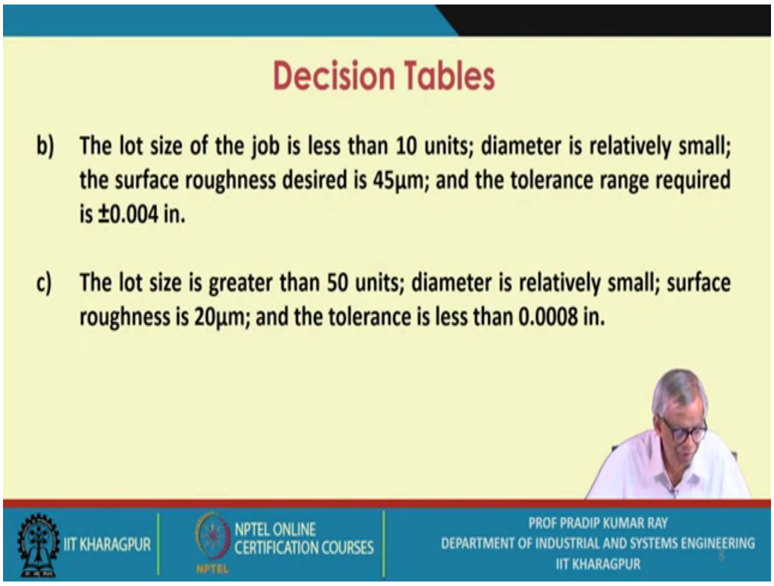

b) The lot size of the job is less than 10 units; diameter is relatively small; the surface roughness desired is 45µm; and the tolerance range required is ±0.004 in.

c) The lot size is greater than 50 units; diameter is relatively small; surface roughness is 20µm; and the tolerance is less than 0.0008 in.

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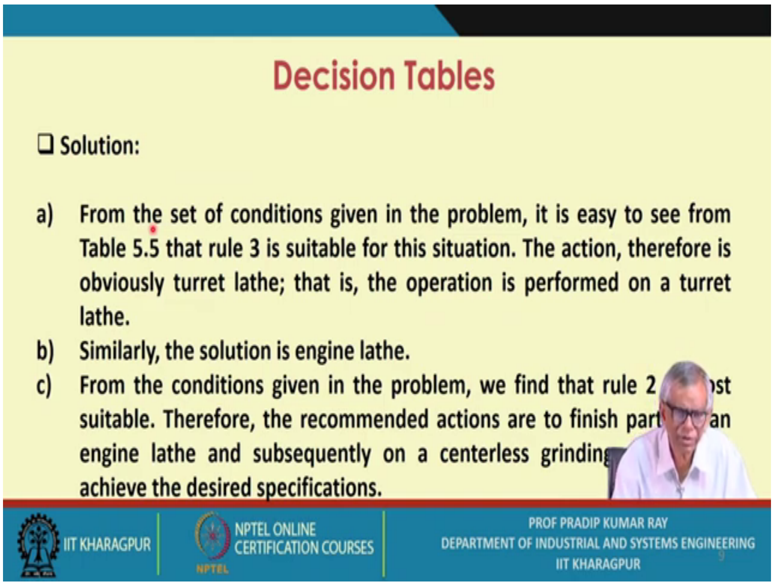

From the set of conditions given in the problem, it is easy to see from Table 5.5 that rule 3 is suitable for this situation. The action, therefore is obviously turret lathe; that is, the operation is performed on a turret lathe. Similarly, the solution is engine lathe. From the conditions given in the problem, we find that rule 2 is most suitable. Therefore, the recommended actions are to finish parts on an engine lathe and subsequently on a centerless grinding machine to achieve the desired specifications.

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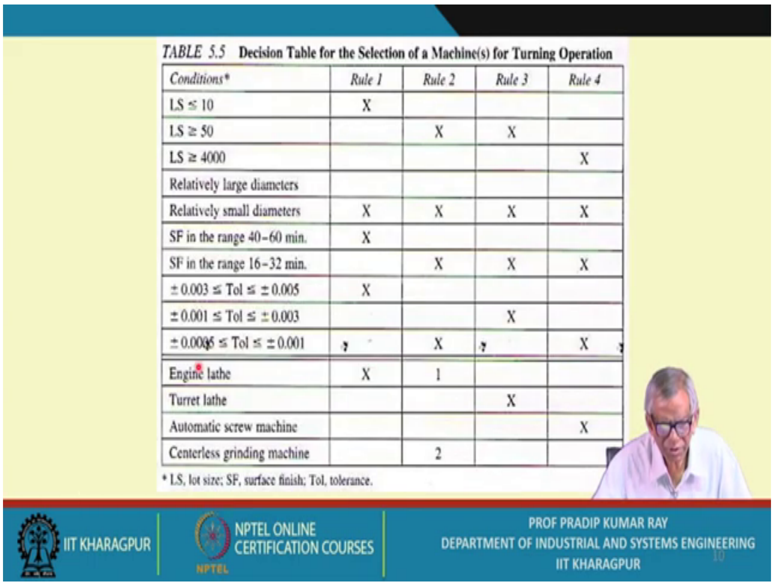
TABLE 5.5 Decision Table for the Selection of a Machine(s) for Turning Operation

*Conditions**	*Rule 1*	*Rule 2*	*Rule 3*	*Rule 4*
LS ≤ 10	X			
LS ≥ 50		X	X	
LS ≥ 4000				X
Relatively large diameters				
Relatively small diameters	X	X	X	X
SF in the range 40–60 min.	X			
SF in the range 16–32 min.		X	X	X
±0.003 ≤ Tol ≤ ±0.005	X			
±0.001 ≤ Tol ≤ ±0.003			X	
±0.0005 ≤ Tol ≤ ±0.001		X		X
Engine lathe	X	1		
Turret lathe			X	
Automatic screw machine				X
Centerless grinding machine		2		

* LS, lot size; SF, surface finish; Tol, tolerance.

This is the decision table for the selection of machines for turning operation.

LS < 10, LS > 50, LS > 4000. These are the possibilities. Relatively large diameters relatively small diameters and the surface finish in the range of 16 to 30 mm. These are the possible tolerance ranges.

There are 4 specific rules. The 4 conditions you have to meet simultaneously. Your choice is engine lathe.

Your first priority will be the engine lathe and the second priority will be centerless grinding machine. Similarly, you apply rule 2 and rule 3.

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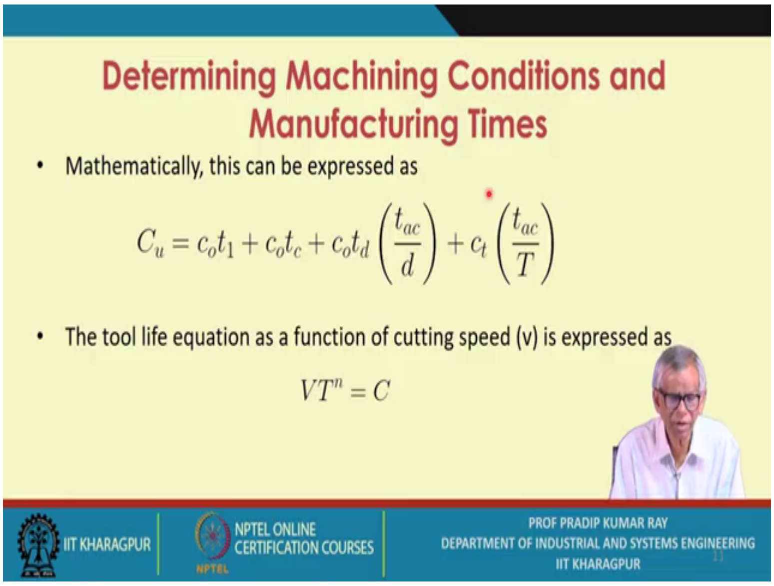

If you want to have a generative type CAPP, it is fully automated. Obviously, you have to create such decision tables.

You start with the manual experience-based process planning.

There are 6 specific steps you have to follow in a sequence to get the process plan and the process plan structure is also known and the elements in a typical the process plans the document.

Now, the sixth step is essentially related to determining machining conditions and manufacturing times.

The performance of the manufacturing system will be affected or will be influenced by the kind of process plan you use or you adopt. Now, how do you say that among the many processes plans which one is the best? You have to determine the processing conditions or the parameter values.

You have to determine the parameter values related to a particular process in such a way that the production rate is at the highest level. That is one condition you have to fulfill and if the production in the rate reaches the maximum level, your process plan is the best one at this point in time.

Another condition you have to fulfill that is the total manufacturing time. It should be as minimum as possible. The optimal process conditions you must know.

Mathematically, this can be expressed as

$$C_u = c_o t_1 + c_o t_c + c_o t_d \left(\frac{t_{ac}}{d}\right) + c_t \left(\frac{t_{ac}}{T}\right)$$

The tool life equation as a function of cutting speed (v) is expressed as

$$VT^n = C$$

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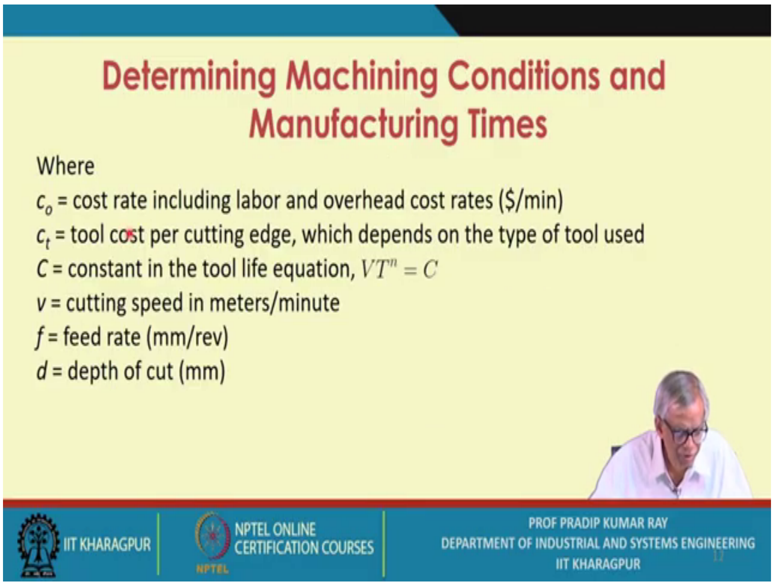

Where

c_o = cost rate including labor and overhead cost rates ($/min)

c_t = tool cost per cutting edge, which depends on the type of tool used

C = constant in the tool life equation,

v = cutting speed in meters/minute

f = feed rate (mm/rev)

d = depth of cut (mm)

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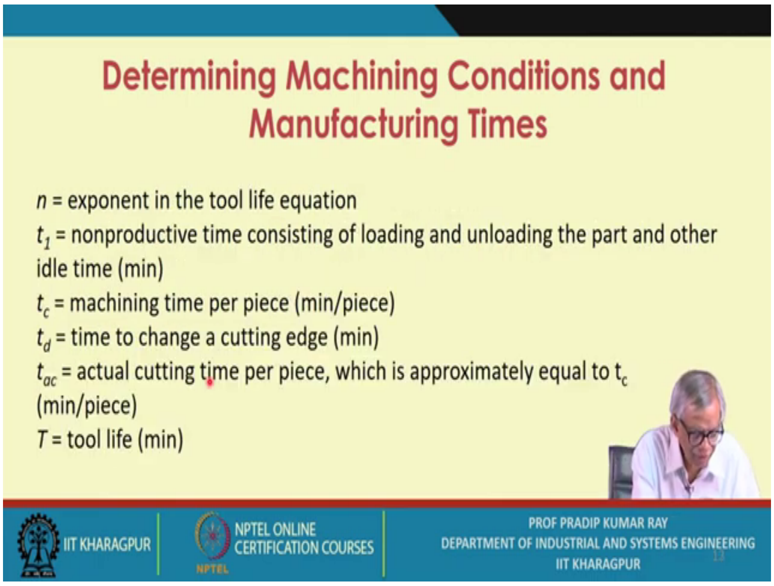

n = exponent in the tool life equation

t_1 = nonproductive time consisting of loading and unloading the part and other idle time (min)

t_c = machining time per piece (min/piece)

t_d = time to change a cutting edge (min)

t_{ac} = actual cutting time per piece, which is approximately equal to t_c (min/piece)

T = tool life (min)

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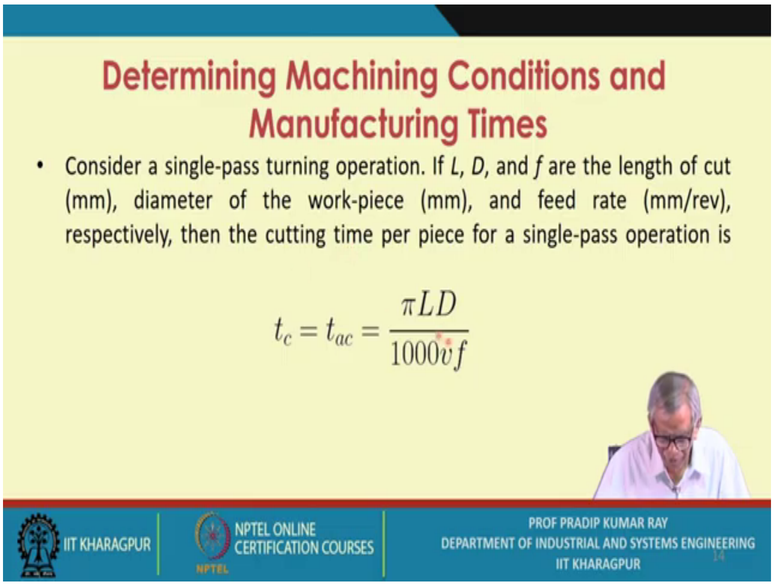

Consider a single-pass turning operation. If L, D, and f are the length of cut (mm), diameter of the work-piece (mm), and feed rate (mm/rev), respectively, then the cutting time per piece for a single-pass operation is

$$t_c = t_{ac} = \frac{\pi LD}{1000vf}$$

$$C_u = c_o t_1 + c_o\left(\frac{\pi LD}{1000vf}\right) + c_o\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}} t_d + c_t\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}}$$

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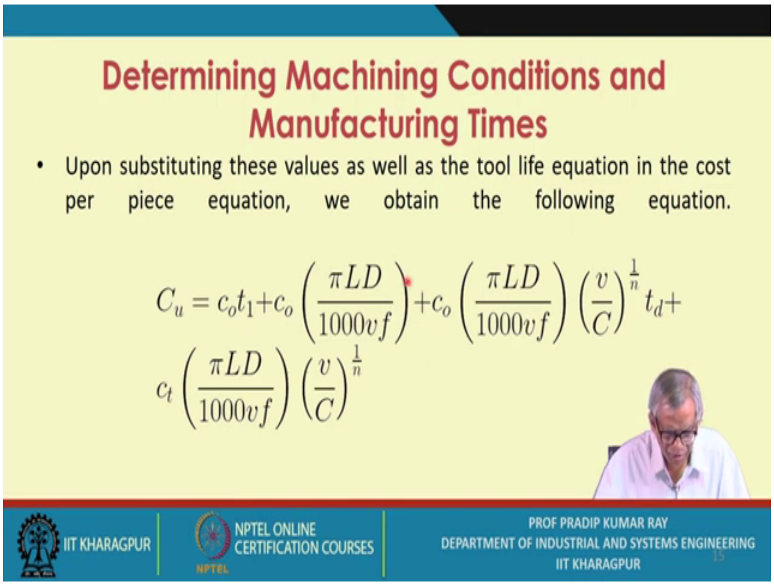

For a single pass turning operation you determine the total cost.

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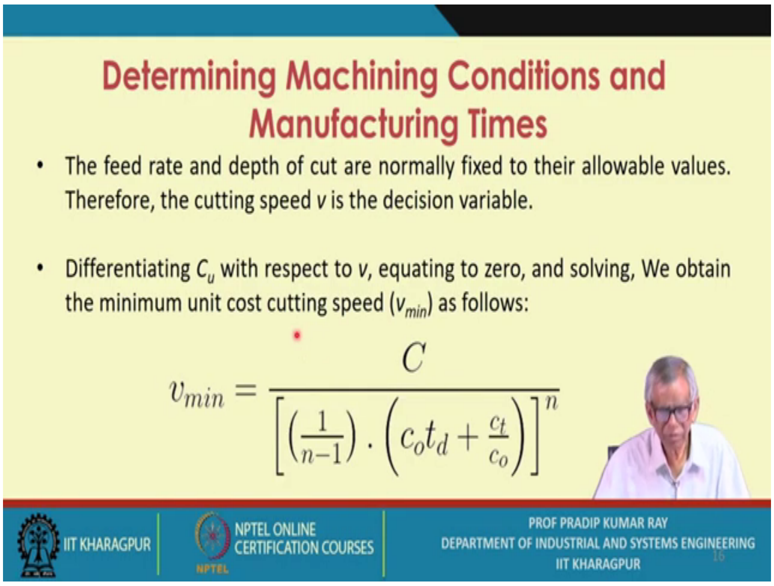

Upon substituting these values as well as the tool life equation in the cost per piece equation, we obtain the following equation.

$$t_c = t_{ac} = \frac{\pi LD}{1000vf}$$

$$C_u = c_o t_1 + c_o\left(\frac{\pi LD}{1000vf}\right) + c_o\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}} t_d + c_t\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}}$$

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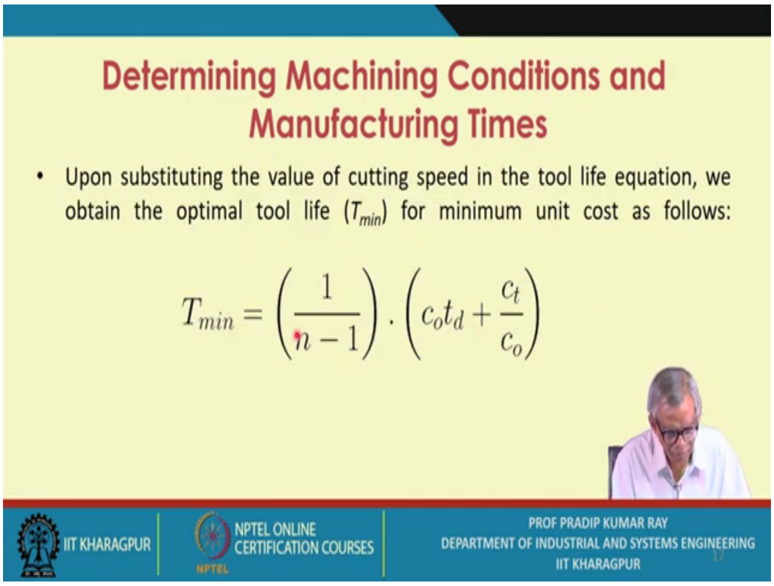

The feed rate and depth of cut are normally fixed to their allowable values. Therefore, the cutting speed v is the decision variable

Differentiating Cu with respect to v, equating to zero, and solving, we obtain the minimum unit cost cutting speed (v_{min}) as follows:

$$C_u = c_o t_1 + c_o\left(\frac{\pi LD}{1000vf}\right) + c_o\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}} t_d + c_t\left(\frac{\pi LD}{1000vf}\right)\left(\frac{v}{C}\right)^{\frac{1}{n}}$$

$$v_{min} = \frac{C}{\left[\left(\frac{1}{n-1}\right)\cdot\left(c_o t_d + \frac{c_t}{c_o}\right)\right]^n}$$

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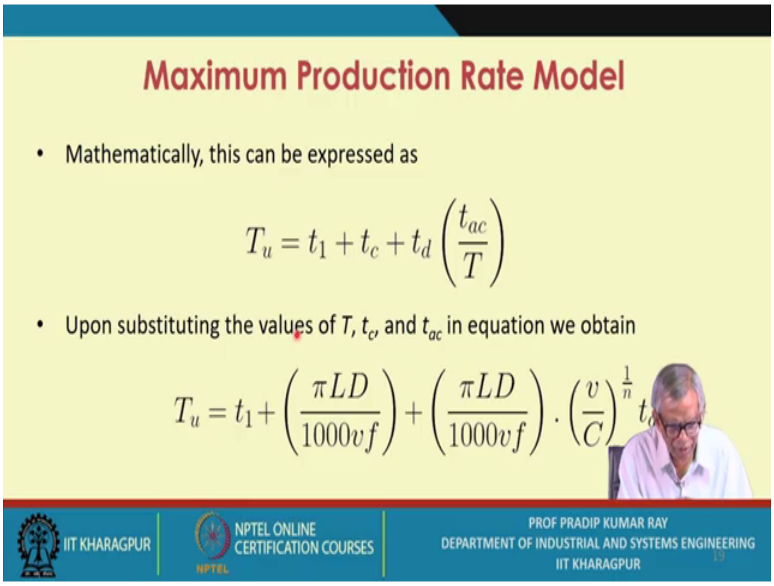

Upon substituting the value of cutting speed in the tool life equation, we obtain the optimal tool life (T_{min}) for minimum unit cost as follows:

$$C_u = c_o t_1 + c_o \left(\frac{\pi LD}{1000vf}\right) + c_o \left(\frac{\pi LD}{1000vf}\right) \left(\frac{v}{C}\right)^{\frac{1}{n}} t_d + c_t \left(\frac{\pi LD}{1000vf}\right) \left(\frac{v}{C}\right)^{\frac{1}{n}}$$

$$T_{min} = \left(\frac{1}{n-1}\right) \cdot \left(c_o t_d + \frac{c_t}{c_o}\right)$$

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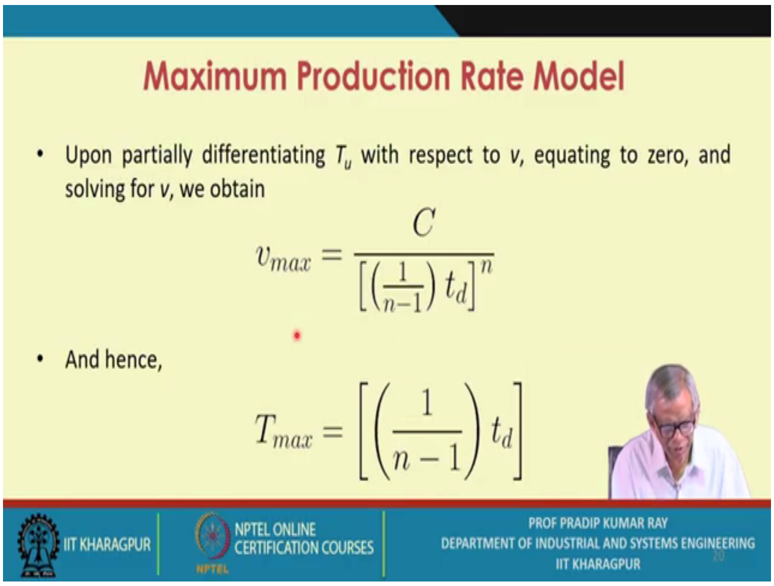

Mathematically, this can be expressed as

$$C_u = c_o t_1 + c_o \left(\frac{\pi LD}{1000vf}\right) + c_o \left(\frac{\pi LD}{1000vf}\right) \left(\frac{v}{C}\right)^{\frac{1}{n}} t_d +$$
$$c_t \left(\frac{\pi LD}{1000vf}\right) \left(\frac{v}{C}\right)^{\frac{1}{n}}$$

$$T_u = t_1 + t_c + t_d \left(\frac{t_{ac}}{T}\right)$$

Upon substituting the values of T, t_c, and t_{ac} in equation we obtain

$$T_u = t_1 + \left(\frac{\pi LD}{1000vf}\right) + \left(\frac{\pi LD}{1000vf}\right) \cdot \left(\frac{v}{C}\right)^{\frac{1}{n}} t_d$$

Upon partially differentiating T_u with respect to v, equating to zero, and solving for v, we obtain

$$v_{max} = \frac{C}{\left[\left(\frac{1}{n-1}\right) t_d\right]^n}$$
$$T_{max} = \left[\left(\frac{1}{n-1}\right) t_d\right]$$

And hence,

$$v_{max} = \frac{C}{\left[\left(\frac{1}{n-1}\right) t_d\right]^n}$$
$$T_{max} = \left[\left(\frac{1}{n-1}\right) t_d\right]$$

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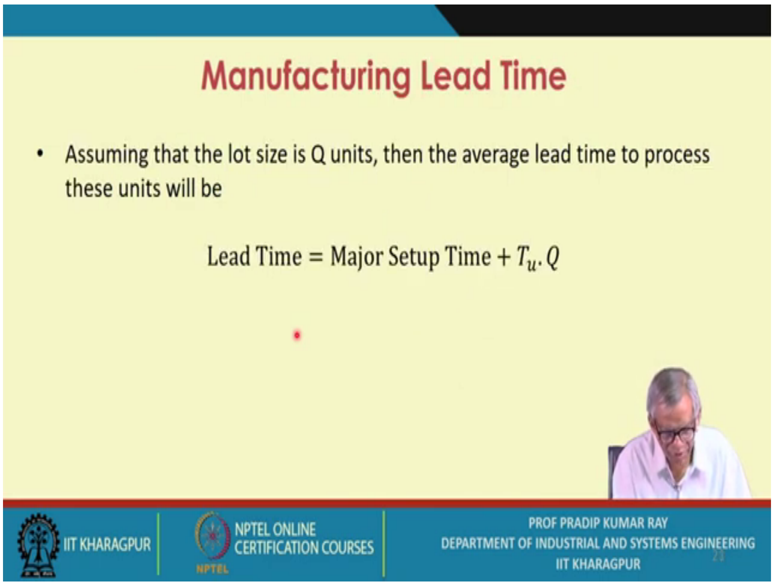

Similarly, you can calculate the lead time.

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