Automation in Production Systems and Management
Prof. Pradip Kumar Ray
Vinod Gupta School of Management
Department of Industrial and Systems Engineering
Indian Institute of Technology, Kharagpur

Automated CAPP (Part-II)
Lecture - 56
Process Optimization and CAPP

In the previous week we have covered the basics of the process planning approaches where you we have defined what is process planning and what actually you do during process planning and why it is so important in a manufacturing system. And you have understood that there could be many approaches for making a process plan.

Process plan is essentially acting as the link between design and manufacturing. As process planning is a part of CIM and CIM, it also includes many other characteristic features or functions of manufacturing system. Once the process planning details are known, the types of approaches you may opt for in a particular case or under certain condition then related to automated systems, how the process planning is related to FMS or related to concurrent engineering?

We have referred to the 6 steps to be followed for getting a process plan against a particular part or a product. The last step is for a given process, you have to specify the process conditions or the process settings. You determine the process settings in such a way that your performance from the machine tool or manufacturing performance reaches its maximum level maintaining the quality.

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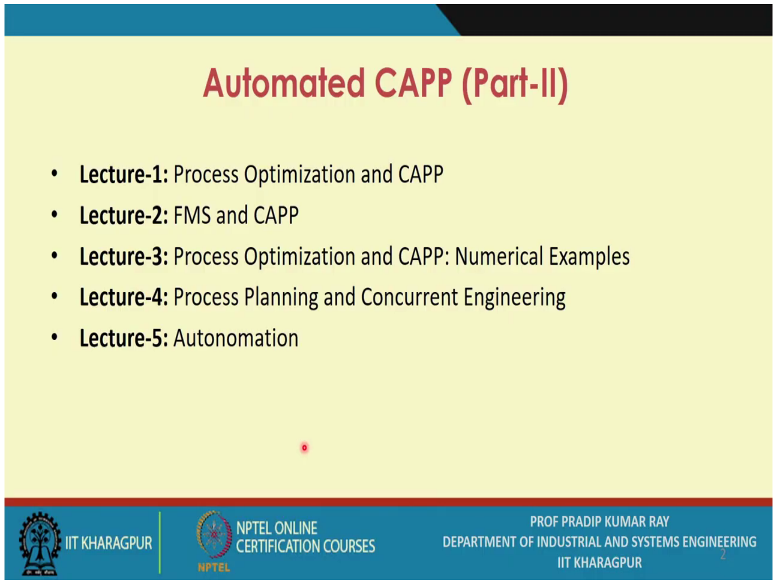

In the 1st lecture session, I will be referring to the process optimization and how it is related to computer aided process planning. In the 2nd lecture session, the relationship between the flexible manufacturing system and CAPP will be discussed. The 3rd lecture session is related to process optimization and CAPP will be referring to a few numerical problems.

How do you determine the optimal process conditions for a given operation? A number of numerical examples we will be referring to. In the next lecture session, the process planning and concurrent engineering, how they are related and in the last lecture session we have mentioned about autonomation.

This is basically a term coined by Toyota production system and it is an automated system.

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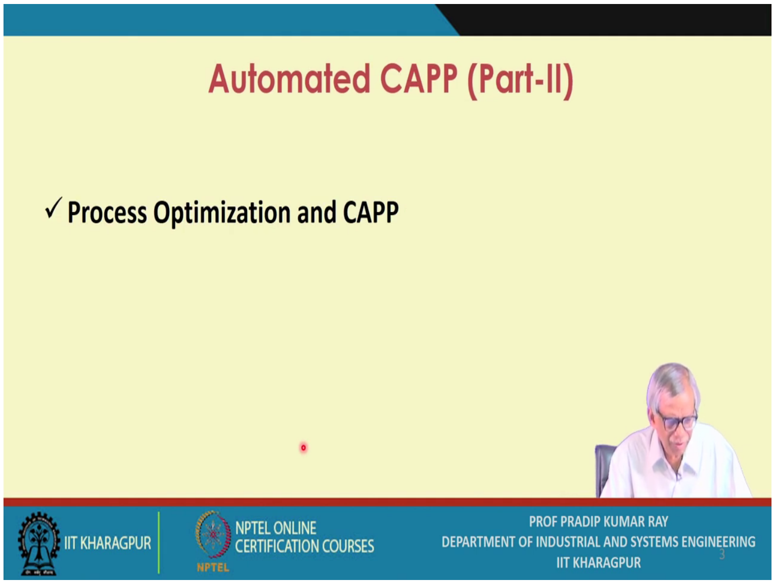

Let us first we discuss about the process optimization and CAPP.

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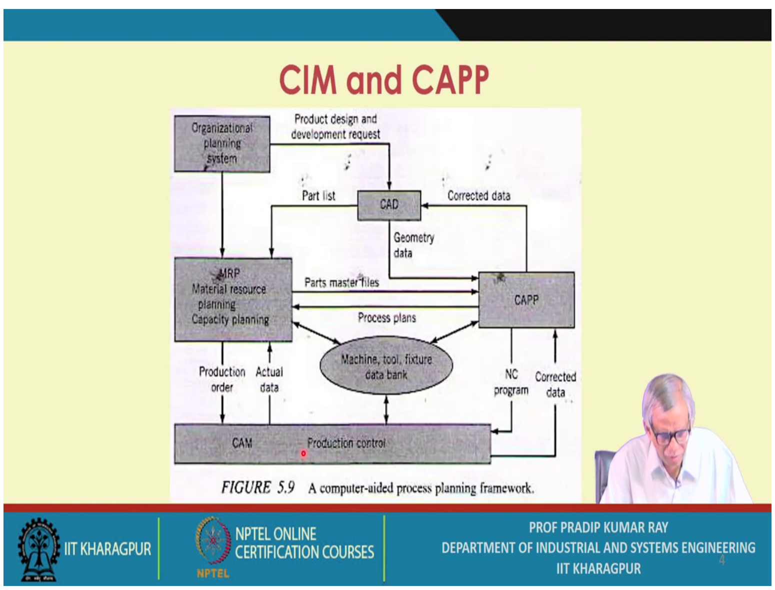

This framework already we have discussed. Computer aided process planning is one of the important components or elements in CIM. CAPP is related to the overall organizational planning.

How it is related to CAD, how it is related to other production control systems like say MRP system, then there are lot many variances of the original MRP system. =CAPP is basically a link between CAD and CAM.

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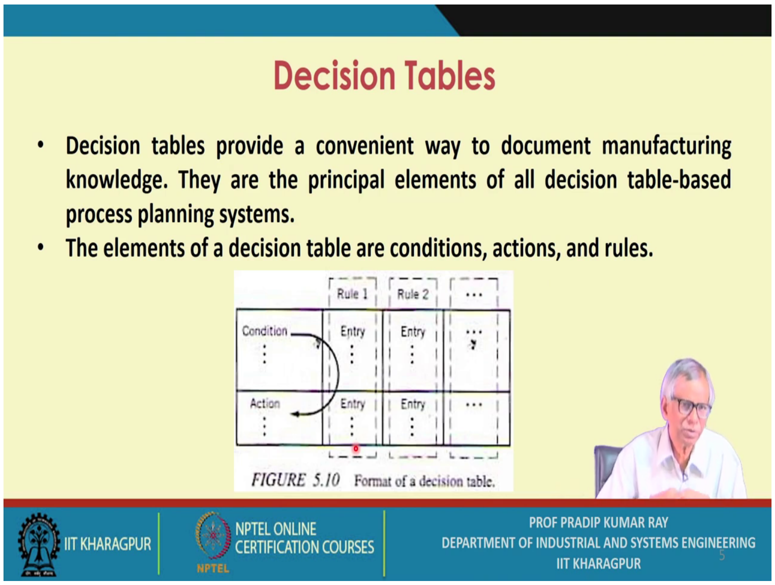

We must try to adopt a system with which this entire process planning approach under certain conditions can be made an automated one. For making it almost 100% automatic, first you start with variant type and then you go for generative type.

The generative type system is fully automated and for creating such an automated system you need to use several kinds of decision tables or other tools and techniques.

You have to specify the condition and you have to specify the rules and for a specific condition and under a given rule what sort of action you have to take.

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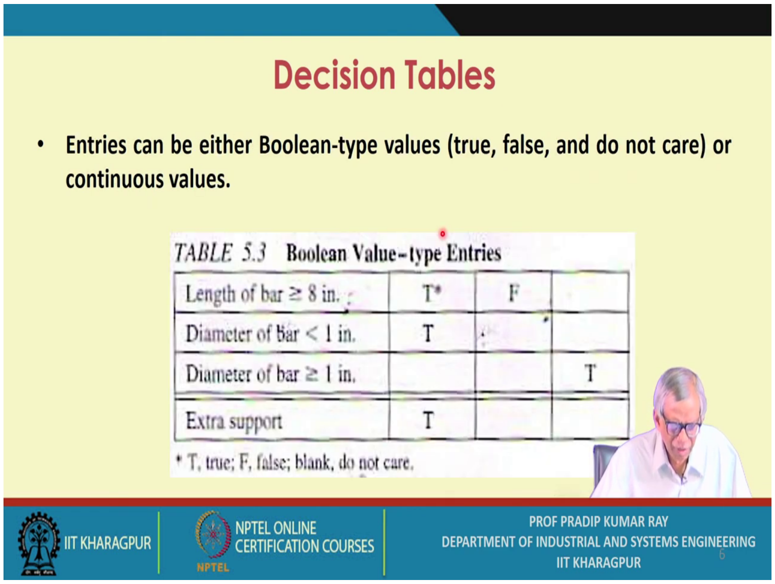

In the entire process planning approach, one important activity is selection under a specific condition.

There could be multiple choices under a given condition which one you will select. Once the conditions in which a particular process may work, you have to put this data in a specific format and you have to use certain table and these are referred to the decision tables.

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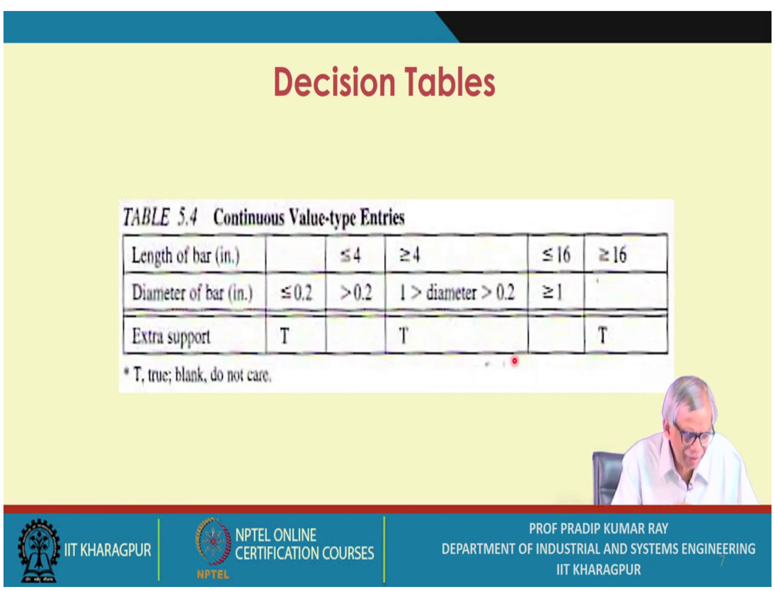

This is one example. The second example is when you use the continuous value type data or information entries whether you need some extra support or not.

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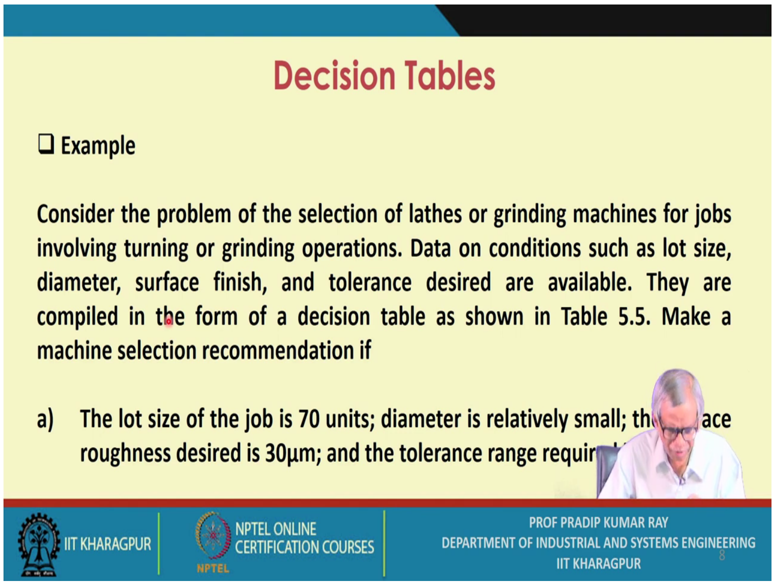

Consider the problem of the selection of lathes or grinding machines for jobs involving turning or grinding operations. Data on conditions such as lot size, diameter, surface finish, and tolerance desired are available. They are compiled in the form of a decision table as shown in Table 5.5. Make a machine 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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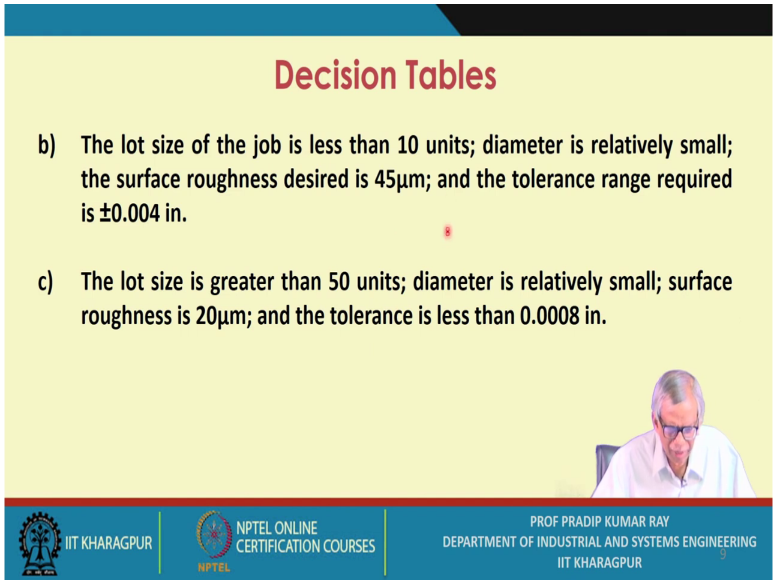

Similarly, two other conditions we have mentioned.

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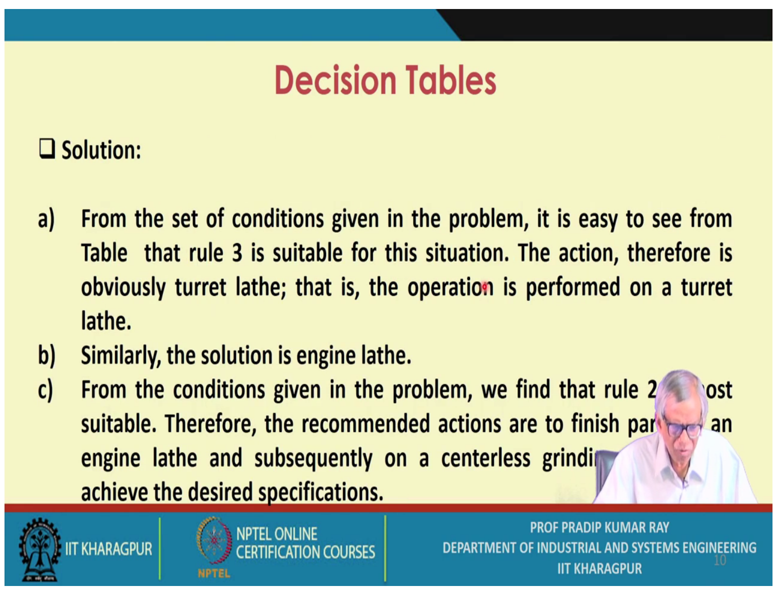

b) The lot size of the job is less than 10 units; diameter is relatively small; the surface roughness desired is 45µm; and the tolerance range required is ±0.004 in.

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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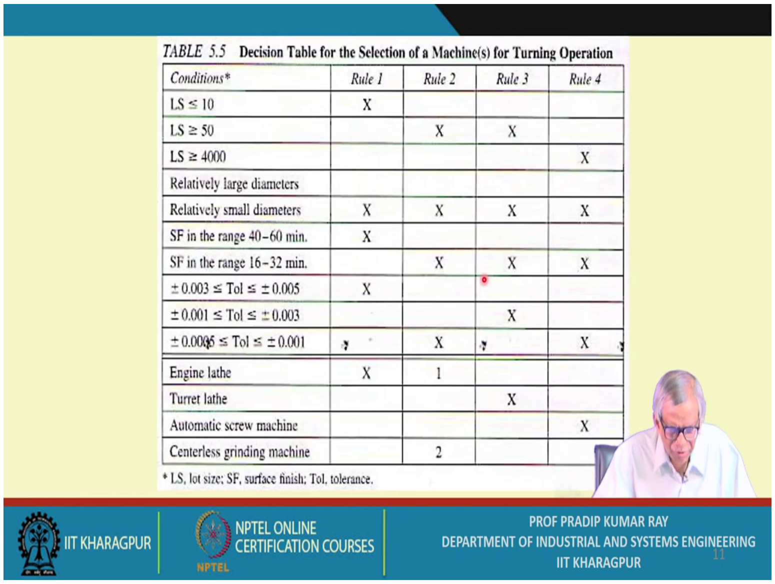

TABLE 5.5 Decision Table for the Selection of a Machine(s) for Turning Operation

*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 a typical decision table format where you have to specify several conditions, several rules as well as your decision or the action; under certain conditions you may use engine lathe. If the conditions change you may have to use the turret lathe and similarly for all other machines.

Similarly, the selection of work holding devices, selection of the cutting tool, selection of fixtures or pallet, selection of the material handling system. This selection is based on not only one important factor, but several factors or several conditions you have to meet simultaneously.

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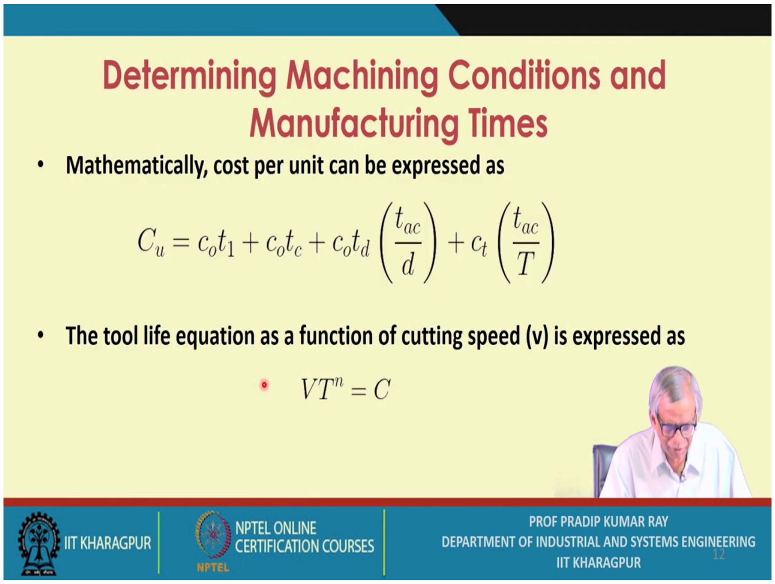

When you the start developing the process plan, you start with manual experience-based process planning approach. Now, I have already mentioned that there are 6 steps involved in creating a process plan and the last one is- you have to determine the machining conditions or manufacturing conditions.

The parameters first you have to select and you must specify the optimal values of this process parameter against a particular operation and you need to maintain certain quality, because this operation will be carried out on certain work part.

You carry out this operation in such a way that the quality related standards as well as the specifications are to be maintained or are to be achieved. Now, you determine these processing conditions in such a way that first is- the cost of production should be as minimum as possible.

The second condition is you need to maximize the production rate; per unit time how many units you are required to you produce, can you maximize this quantity?

You have to minimize the per unit processing time. The third condition is- you produce a lot of items, your lot size is, say, 500 units.

Make sure that for producing a lot you take minimum manufacturing lead time. I will set the machining conditions in such way that the third condition; that means, minimization of the throughput time I can achieve.

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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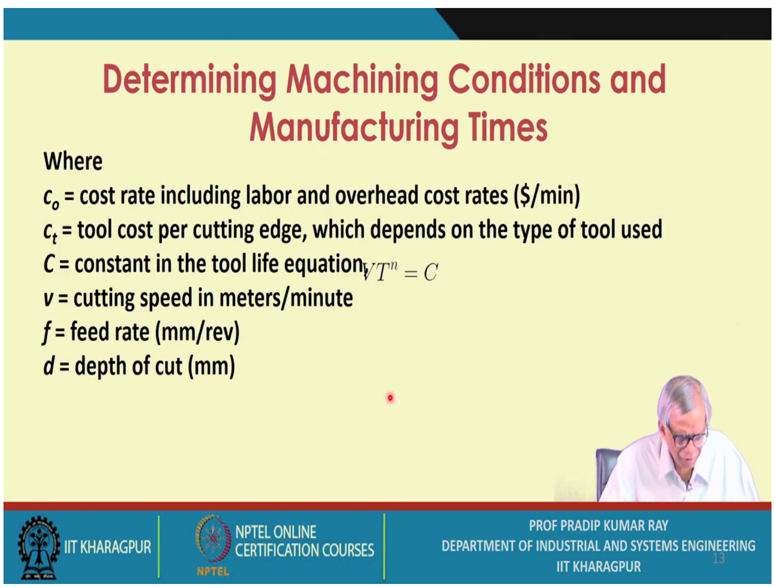
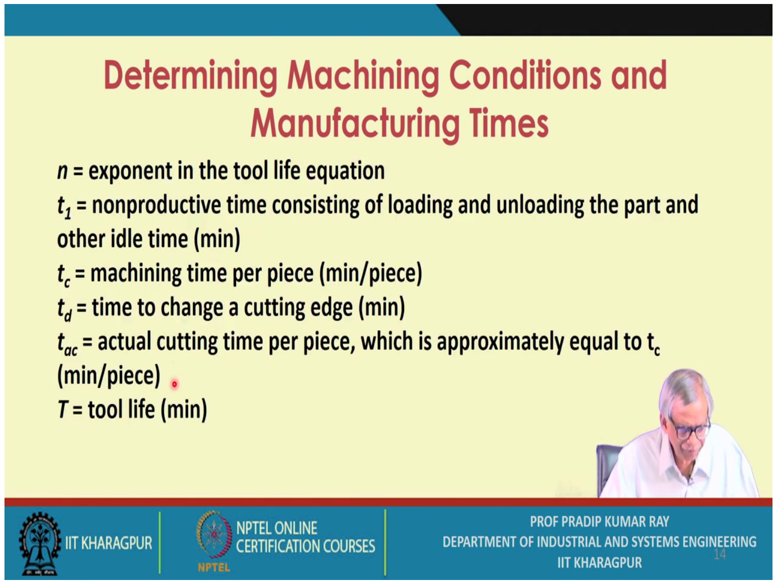


Where,

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) (Refer Slide Time: 18:09)



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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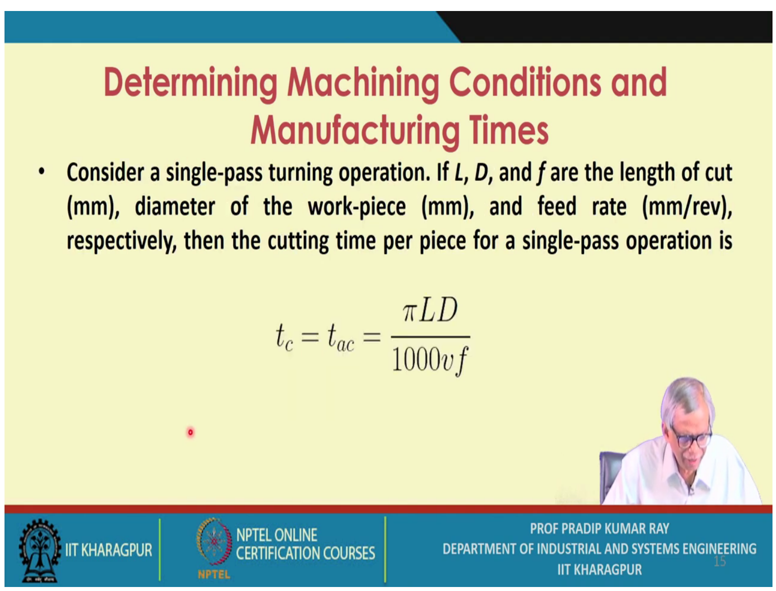

The first equation is related to unit cost and we assume that this cost equation is a continuous one and it is differentiable. You have to determine the decision variables in such a way that the unit cost is minimum.

First you take the partial derivative with respect to a particular decision variable and then set it equal to 0, that is the necessary condition and then you need to fulfill the sufficient conditions. This will be positive for the minimization and for maximization it should be negative. Now, let us take one example and that example is essentially a turning operation.

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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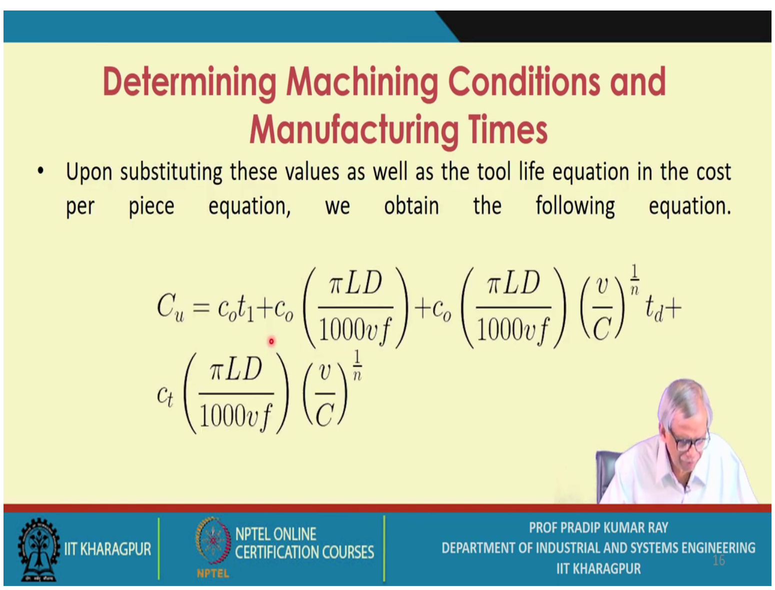

Upon substituting these values as well as the tool life equation in the cost per piece equation, we obtain the following equation.

$$t_c = t_{ac} = \frac{\pi L D}{1000 v f}$$

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

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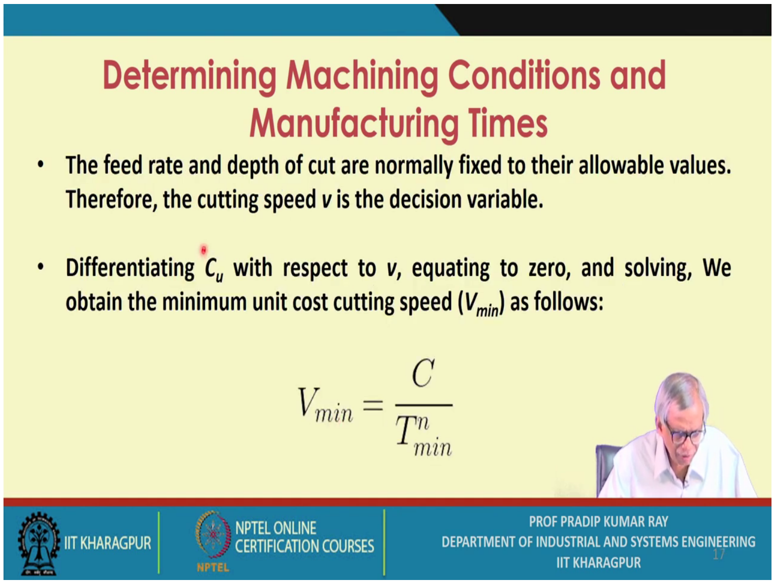

The feed rate and depth of cut are normally fixed to their allowable values. Therefore, the cutting speed *v* is the decision variable.

Differentiating C_u with respect to *v*, equating to zero, and solving, We obtain the minimum unit cost cutting speed (V_{min}) as follows:

$$V_{min} = \frac{C}{T_{min}^n} = \frac{200}{(84.56)^{0.20}} = 82.337 \text{ m/min}$$

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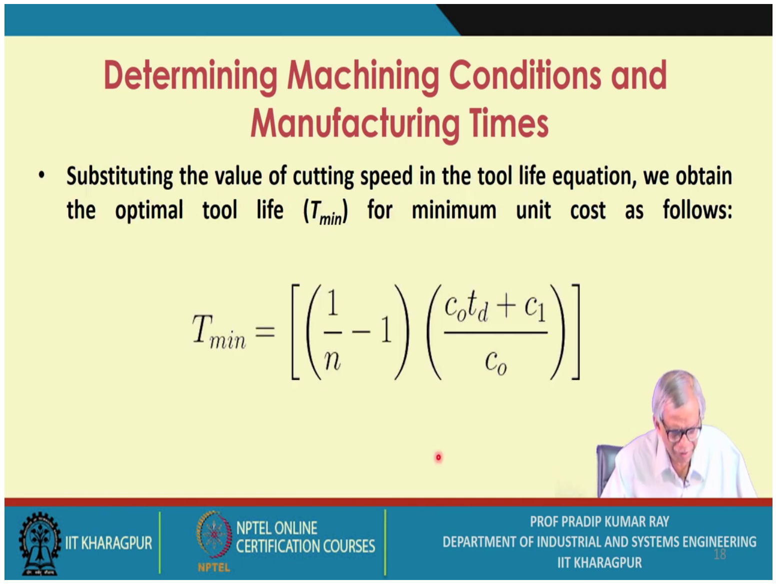

Upon substituting the value of cutting speed in the tool life equation, we obtain the optimal tool life (T_{min}) for minimum unit cost as follows:

$$T_{min} = \left[\left(\frac{1}{n} - 1\right)\left(\frac{c_o t_d + c_1}{c_o}\right)\right]$$

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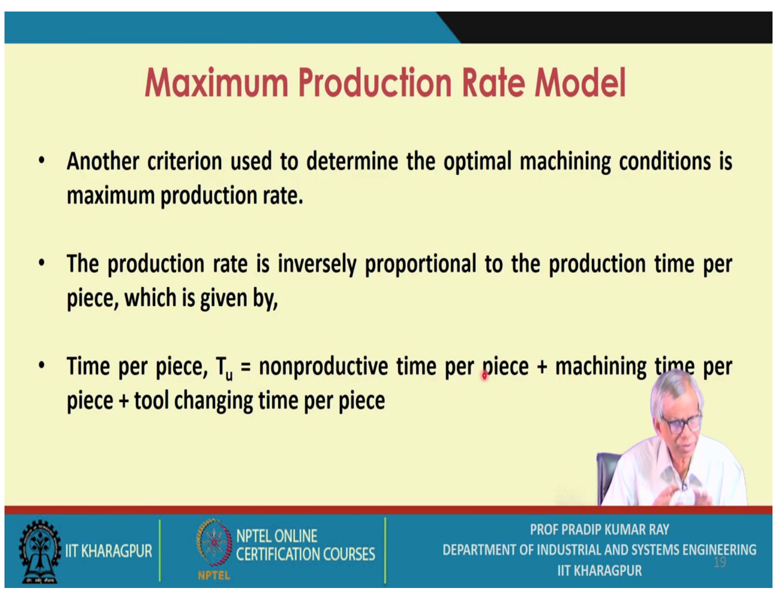

Another criterion used to determine the optimal machining conditions is maximum production rate.

The production rate is inversely proportional to the production time per piece, which is given by,

Time per piece, T_u = nonproductive time per piece + machining time per piece + tool changing time per piece

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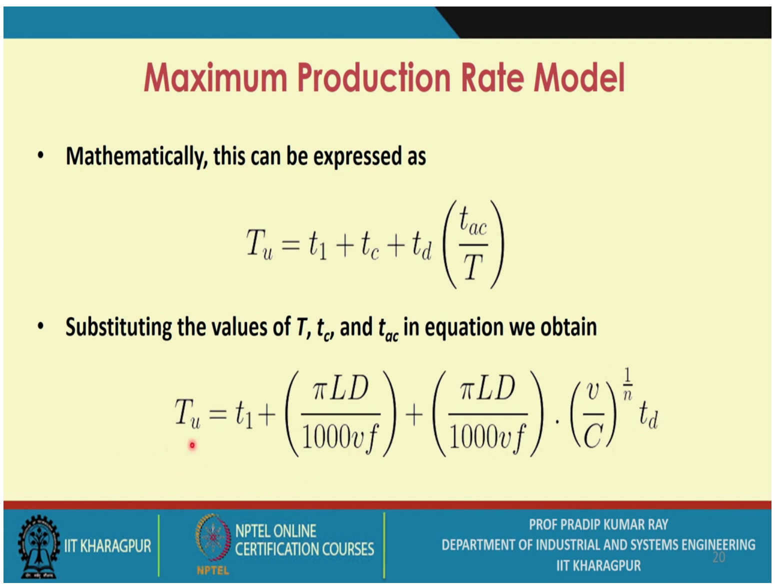

Mathematically, this can be expressed as

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

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

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

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

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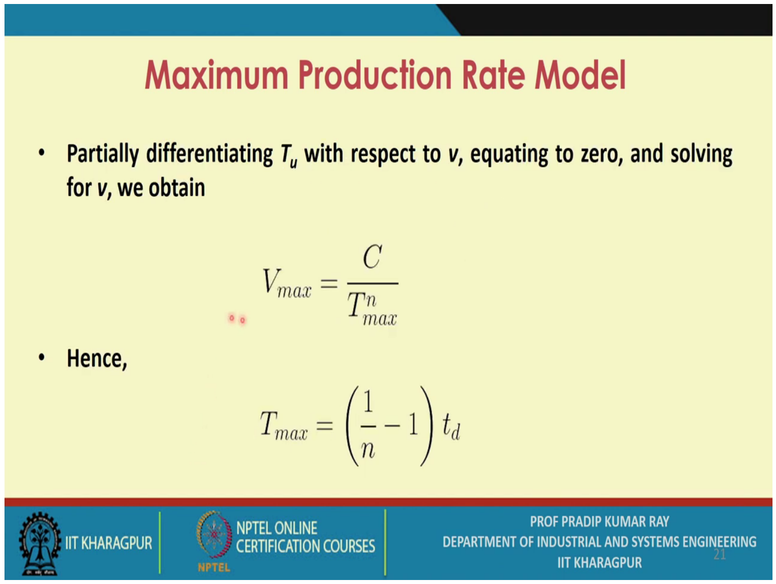

Upon partially differentiating T_u with respect to v, equating to zero, and solving for v, we obtain

$$V_{max} = \frac{C}{T_{max}^n}$$

And hence,

$$T_{max} = \left(\frac{1}{n} - 1\right) t_d$$

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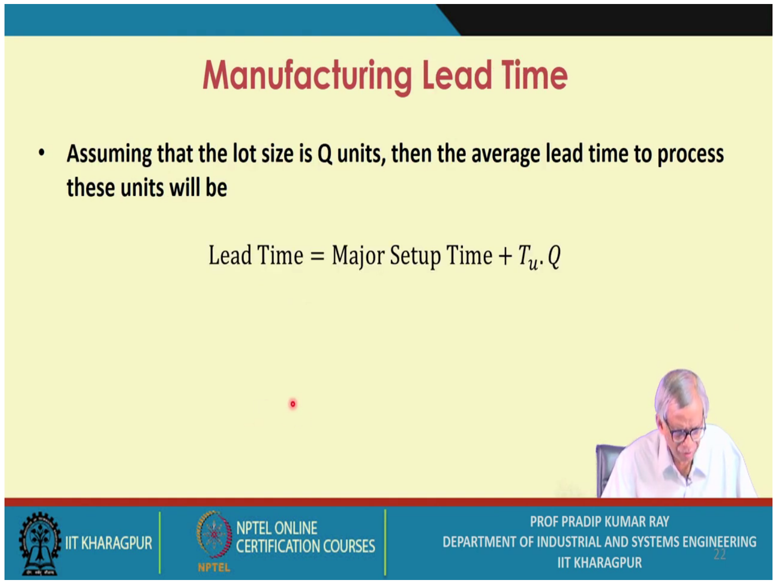

Assuming that the lot size is Q units, then the average lead time to process these units will be

Lead Time = Major Setup Time + $T_u.Q$

We refer to the manufacturing lead time. Here, the setup time you should consider and one setup for a particular batch. This is basically the quantity or the batch size per unit time. So, you get the manufacturing lead time expressions and make sure that manufacturing lead time is minimum.

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List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River.
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.
- Singh, N. Systems Approach to Computer-integrated Design and Manufacturing, Wiley