Manufacturing Automation

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Lecture – 20

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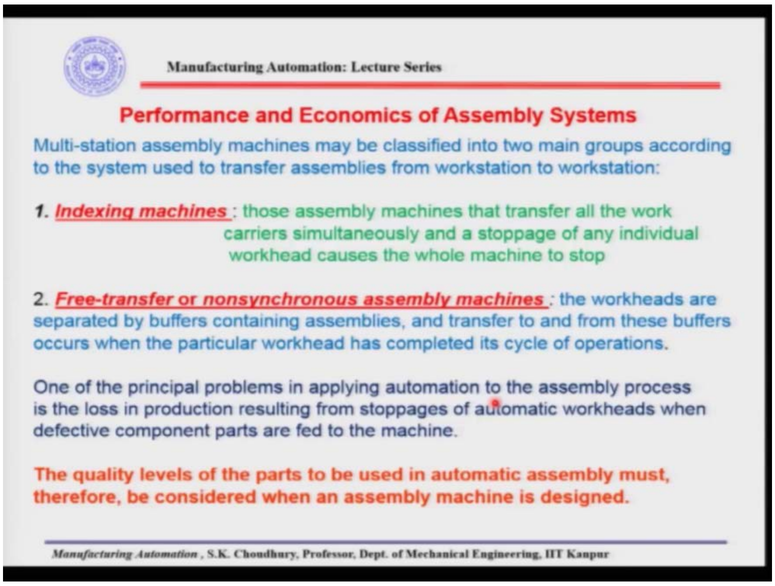

Welcome back to the series of Manufacturing Automation lectures. So, I will remind you that in the last session we started discussing the performance and economics of assembly systems.

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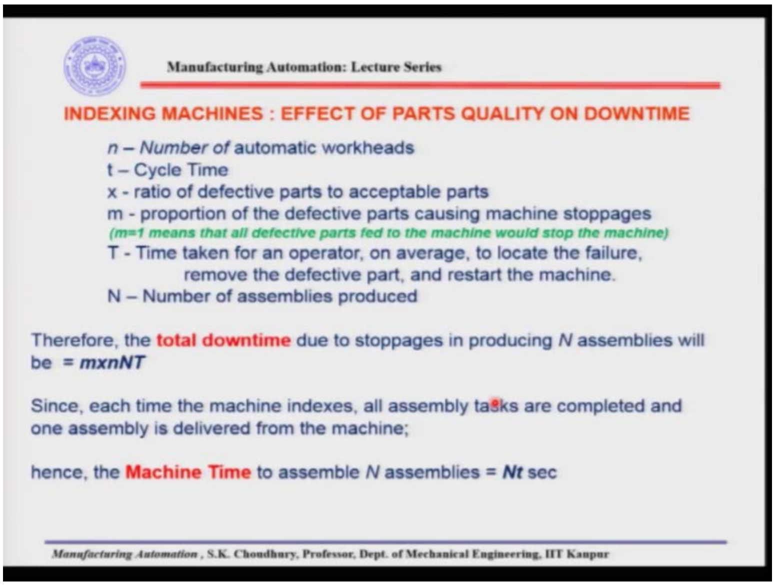

And we said that in case of Indexing Machines the Effect of Part Quality on Downtime can be defined; for that we have taken some parameters and we said that the total downtime taken is $MxnNT$. Where m is the proportion of defective parts causing machine stoppages, x is the quality level of parts, n is the number of automatic work heads in the assembly line, N is the number of assemblies that we are producing and the T is the time taken for an operator to diagnose the problem if the line stops or the machine stops and restart the machine.

So, the machine time to assemble in assembly, if we know the cycle time is t. So, it will be Nt.

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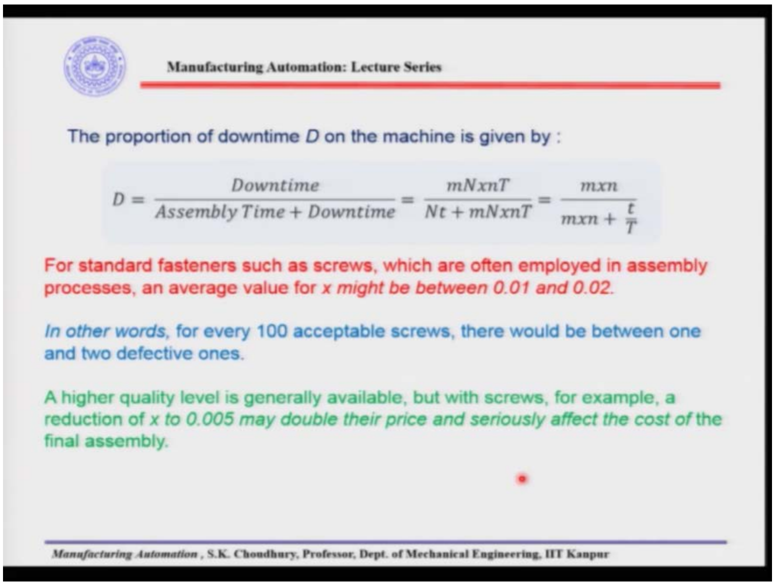

So, we can find out the proportion of downtime; which is the downtime divided by total time and the total time is assembly time plus downtime. So, it will be $MxnNT$ divided by assembly time is Nt and the $MxnNT$. So, we said that for standard fasteners it is somewhere around 0.01, 0.02 is the x that is the quality level. However, if the quality level to be increased for example, from 0.01 to 0.005, then we said that cost will be roughly twice.

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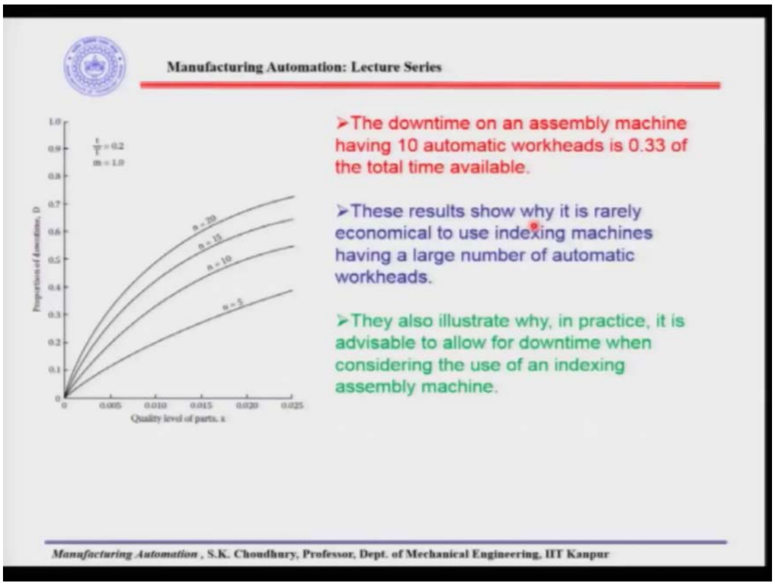

So, we have seen that there is a curve here. So, depending on the number of machines n = 5, 10, 15 and 20, you can find out that more the number of machines more will be the proportion of downtime in one word. So, these results show; why it is rarely economical to use indexing machines having a large number of automatic work heads. Because larger the number of workheads, more will be the probability of downtime; for example, suppose you take 0.01 is the χ.

So, this is the quality level of parts. So, 0.01 χ this is the proportion of downtime for number of machines 5; whereas, it is much more in case it is 10, even more when it is 15 and more it is 20. It is understood that more the number of machines more will be the possibility of the downtime. They also illustrate why, in practice it is advisable to allow for downtime when considering the use of an indexing assembly machine. What it means is that, sometimes we may allow this down time rather than defective parts going inside and spoiling the machine.

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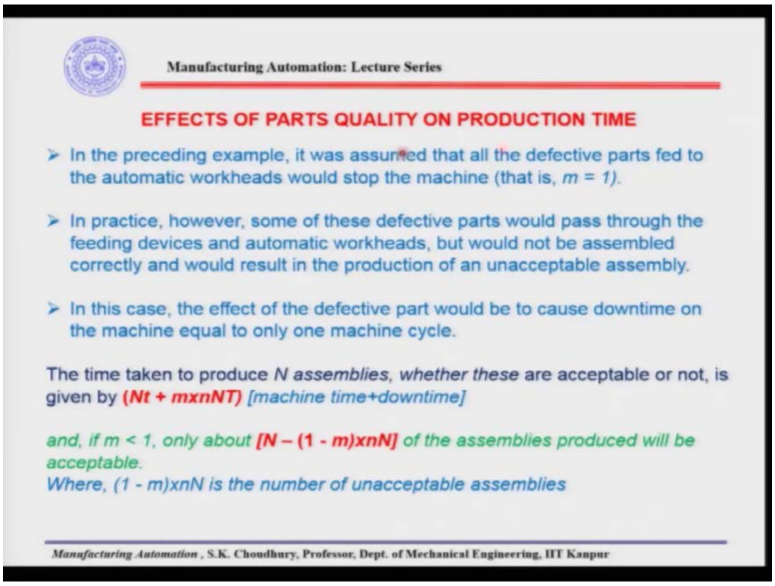

Effect of part quality on the production Time: let us see; in the preceding example, it was assumed that all defective parts fed to the automatic work heads would stop the machine we said that the m is equal to 1. And in our earlier discussion we have seen, that if m is less than 1 means not all defective parts will go and stop the machine. In practice; however, some of these defective parts would pass through the feeding devices and automatic work heads, but would not be assembled correctly and would result in the production of an unacceptable assembly this is what I discussed last time. In this case, the effect of the defective part would be to cause downtime on the machine equal to only one machine cycle.

Meaning that assembly will be made, but it will be unacceptable; so in one cycle one assembly we are making, since it is unacceptable, so therefore, we are wasting one machine cycle. The time taken to produce capital number of n capital N assemblies, whether these are acceptable or not, this will be machine time plus downtime, this is the total time this is what we have seen. Now if m is less than 1, let us say not all defective parts stopping the machine only about capital $N-(1-m)xnM$ of the assembly is produced will be acceptable.

What does it mean? Total number of assemblies we are producing N and $(1-m)xnN$ will be unacceptable assemblies. Where the defective part goes in it is assembled we are losing one cycle time for one unacceptable assembly, but the assembly is unacceptable because the defective part went in, but it did not stop the machine. So $1-m$, therefore if m is equal to less than 1, xnN is the number of unacceptable assemblies.

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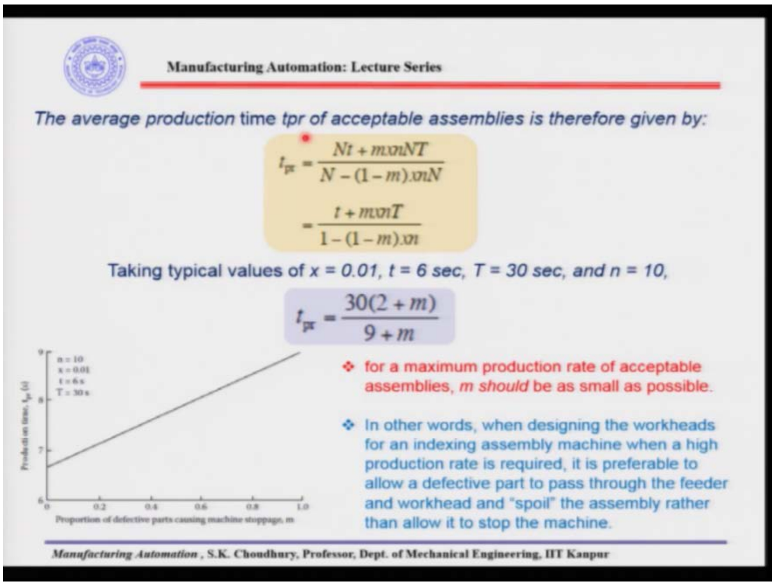

The average production time t_{pr} of acceptable assemblies is therefore given by: the total time and the number of unacceptable number of acceptable; I mean assembly is produced that is N total assemblies minus unacceptable assemblies. So, this is the total number of assemblies produced. So, this will be simplified this can be simplified as $\frac{t + mxnT}{1-(1-m)xn}$.

Taking typical values of let us say x equal to 0.01 that quality level of parts is 0.01; meaning that out of hundred parts one part is defective. Cycle time is 6 second for example, this is an example taken and the time taken for an operator to diagnose the problem if machine stops and restart the machine is 30 second and the number of automatic work heads will be 10.

So, if you put these values in this equation we will have the average production time t_{pr} is equal to $t_{pr} = \frac{30(2+m)}{9+m}$. So, if we draw the curve now, for different values of m. So, we will get the t_{pr} and the curve will be like this ok. So, in this axis we have the production time, average production time 6, 7, 8, 9, second this is for this example, for this equation. And in the x axis we have the proportion of defective parts causing machine stoppage m. So, we have the m here and t_{pr} we will find out the t_{pr} it gives a straight line. So, what it says is that for a maximum production rate, maximum production rate of acceptable assembly; m should be as small as possible for small m, t_{pr} is minimum. So, the production rate which will be $\frac{1}{t_{pr}}$ it will be maximum.

So, it is said here for a maximum production rate of acceptable assemblies m should be as low as possible, this is one example, one conclusion that we can draw. In other words when designing the work heads for an indexing assembly machine, when a high production rate is required, it is preferable to allow a defective part to pass through the feeder and work head and “spoil” the assembly rather than allowing it to stop the machine. You understand we discussed it as last time that we have to find out whether machine stoppage is more convenient for us or more economical for us or having an unacceptable assembly more economical for us. Here is the curve which says that the m should be minimum, m should be minimum means let it go let it spoil the assembly. So, this is the one conclusion second conclusion that we can draw.

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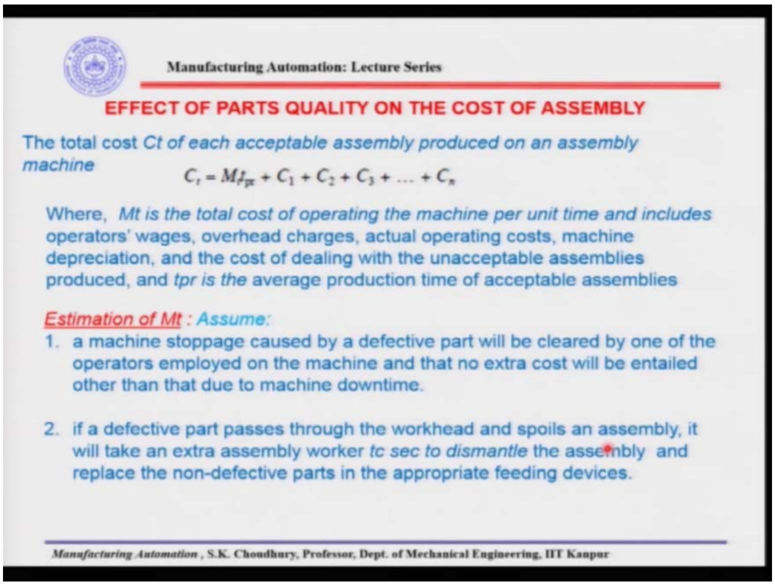

Effect of part quality on the cost of assembly: so we said that part quality is higher then the cost will be higher. The total cost C_t of each acceptable assembly produced on an assembly machine is given by this; this is M_t into t_{pr}, t_{pr} is the average production time. M_t is the total cost of operating the machine per unit time and that includes operators wages, overhead charges, actual operating cost, machine depreciation.

These things we have discussed earlier; that means, how much machine life you are using, how much money you are paying for to the operator, how much money you are spending for the overhead that is the electricity, the building, the hydraulics, the pneumatics and so on everything is included in this M_t. $C_1 + C_2 + C_3 + ... + C_n$ these are the number of parts.

So, each part will cost some money. So, this is included here. Estimation of M_t for doing that we assume that a machine stoppage caused by a defective part will be cleared by one of the operators employed on the machine and that no extra cost will be entailed other than that due to machine downtime. And if a defective part passes through the work head and spoils an assembly, it will take an extra assembly worker t_c second to dismantle the assembly and replace the non defective parts in the appropriate feeding devices this is assumed.

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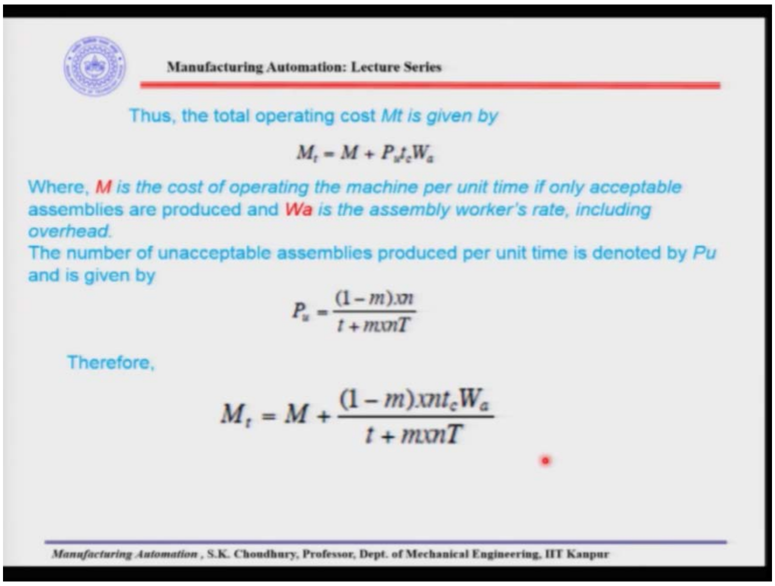

So, therefore, the total operating cost M_t will be equal to M some cost will tell you what is the cost and into P_u t_c and the W_a. Whereas, this M is the cost of operating the machine per unit time if only acceptable assemblies are produced, W_a is the assembly worker's rate including the overhead.

And the t_c is the cycle time. P_u which is the number of unacceptable assemblies produced per unit time which is equal to $\frac{(1-m)xn}{t+mxnT}$, this you can find out from earlier equations. Therefore, M_t which is equal to $M_t = M + \frac{(1-m)xnt_c W_a}{t+mxnT}$.

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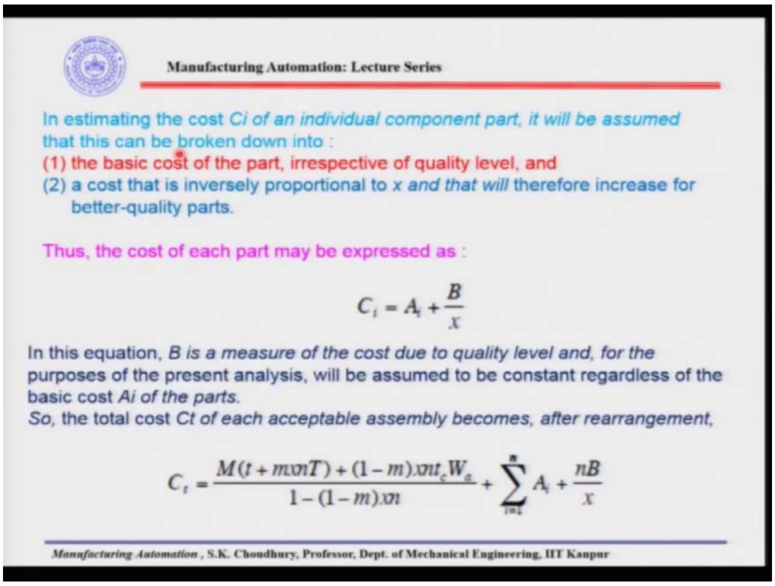

In estimating the cost C_i on an individual component parts that is C_1, C_2, C_3 up to C_n, it will be assumed that this can be broken down into two parts; one the basic cost of the part that is the raw material irrespective of the quality level and the cost that is inversely proportional to x and that will therefore, increase with the better part quality.

Meaning that one part quality, one part cost is the basic material cost and another part, another cost is that when we are giving the value to the part, to the work piece. And if the quality level is very high, the part cost will be very high. Thus the cost of each part may be expressed as $C_i = A_i + \frac{B}{x}$. A_i is the fixed cost that is the raw material and $\frac{B}{x}$ meaning that it will be inversely proportional to x; x is more that means, C_i is less. So, therefore, it is inversely proportional and B is the measure of the cost due to quality level and for the purpose of the present analysis it will be assumed to be constant, this B will be assumed to be constant.

So, the total cost C_t will be M plus this, plus unacceptable assembly is divided by this plus total number of parts that we have. So, each part will cost something here and for the quality level of parts. So, we are adding all of them together and we are having this equation. So, this part we have seen earlier also and from here it is coming. So, altogether we are trying to find out this C_t, which we have written here; find out the value of the M_t, t_{pr} we found out earlier- average production time and C_1, C_2, C_3 up to C_n will have two components; raw material and $\frac{B}{x}$ that is inversely proportional to the quality level.

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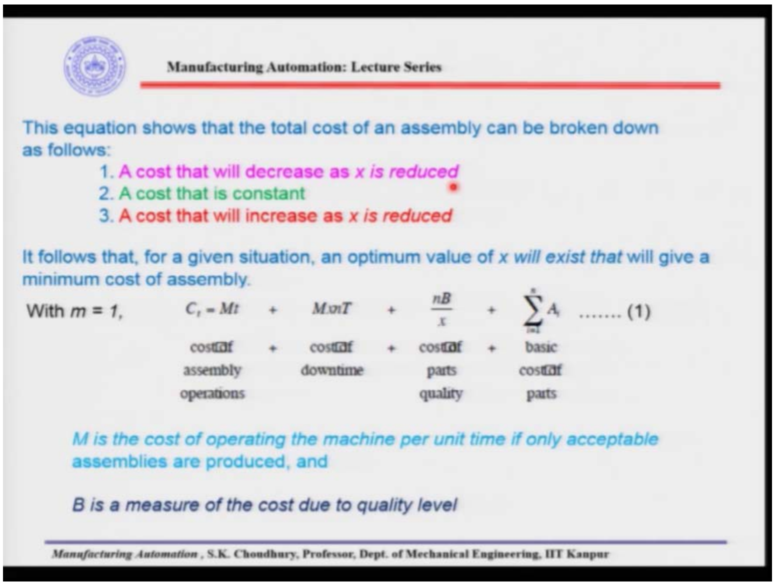

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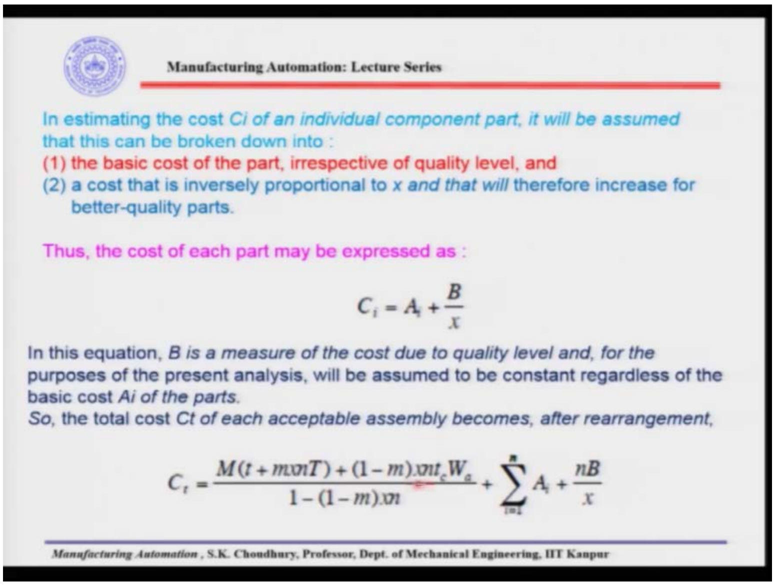

Now, this equation, this equation shows that; a cost that will decrease as x is reduced, a cost that is constant and a cost that will increase as the x is reduced. Here for for the first term, if x is reduced, cost is reduced, for the 2nd term, if x is reduced nothing happens because it is constant is the raw material, for the 3rd term if x is reduced it will be higher.

So, there are three different causes we can find out. And it follows that, for a given situation, an optimum value therefore, of X will exist that will give a minimum cost of assembly; obviously, since in this equation the X reduction of X is reducing this, reduction of x is no effect and reduction of X is increasing this. So, therefore, there must be a, an optimum value of this C_t and therefore, an optimum value of the X. So, we will find out that for m is equal to 1; what this equation boils down to this alright and m here capital M, I will remind you is the cost of operating the machine, B is the measure of the cost due to quality level.

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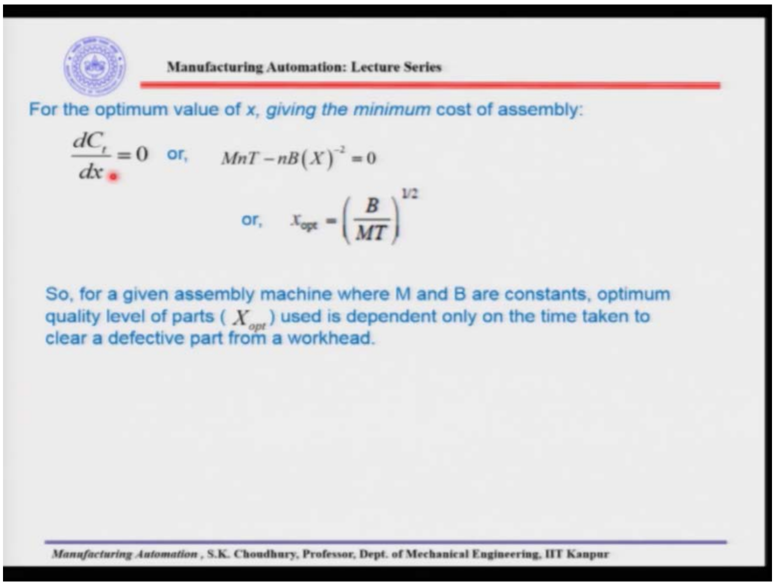

So, for optimum value of the X, will take the first derivative equal to 0; so, if we take the first derivative of this equation, you will find that this will be $MnT - nB(X)^{-2}$ which will be equal to 0. So, X optimum will be $\left(\frac{B}{MT}\right)^{1/2}$.. So, for a given assembly machine where M and B are constants, optimum quality level of part used in is dependent only on the time taken for clearing the defective part from a work head.

Because B and M we assume to be constant. So, therefore, the optimum level of the part quality is inversely proportional to the root over T. And capital T is the time taken for an operator to diagnose the problem and restart the machine. So, this is the conclusion that we can make from this equation.

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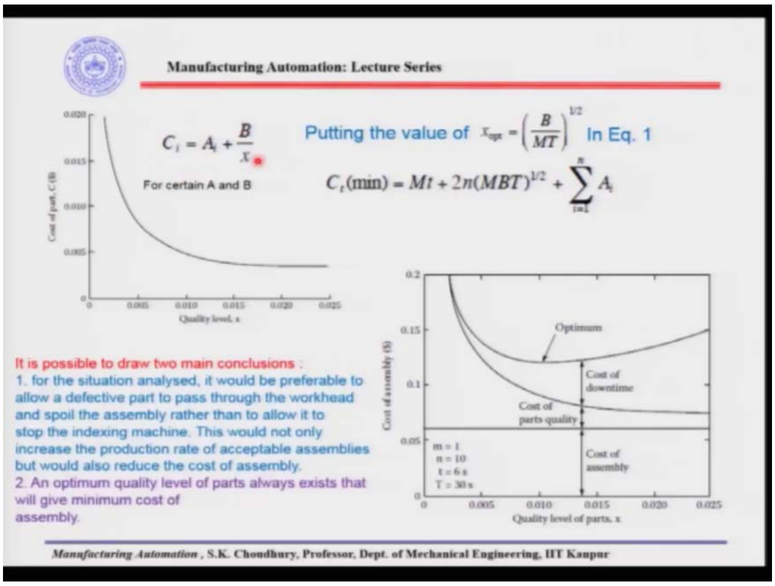

Now, if we draw the curve for the parts for example, for certain A and B values, In that case the cost of part here and the quality level here the equation goes like this. Meaning that as the quality level is here the cost is I mean, quality level this is then and the number is increasing then the cost will be decreasing; that means, the higher quality the cost will be higher. Higher quality will be of this side ok.

Now, putting the value of x optimum as B by MT root over which we have found out in the earlier equation, we can see this. And from here we can find out these curves; these curves are made for cost of assembly and the quality level of parts. And you will see that there are different qualities with different costs, that is the cost of downtime, cost of quality of parts, cost of assembly and altogether we will have a curve like this; where we will always have an optimum value of the quality level, for which the cost is minimum. So, this is the conclusion which is drawn from here

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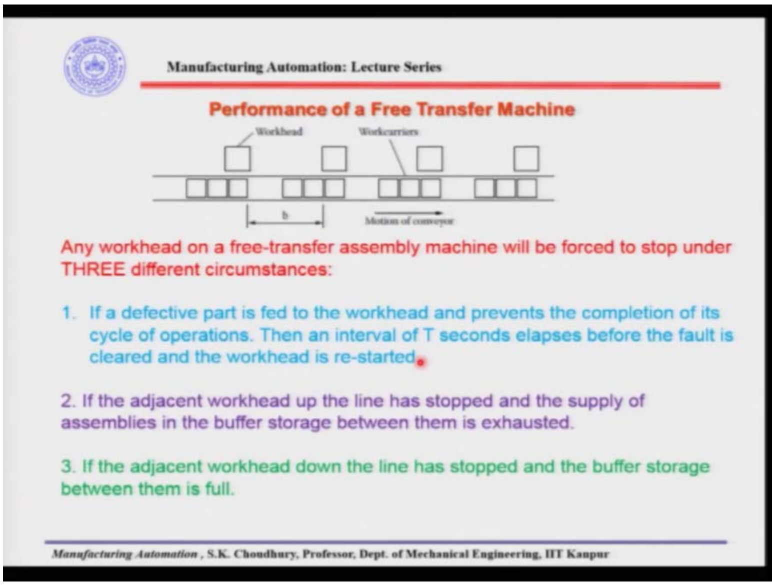

Now, let us see we have seen so far, the indexing machine. Now let us see the Free Transfer Machine. I will simply give you a glimpse of the free transfer machine what happens in comparison to indexing machine, and here what are the problems that exist. So, in the free transfer machine we will always have more number of parts, that is output will be always more; because one machine stoppage will not affect the other machines working, because there is a buffer stock in between, there can be an analysis made.

So, to say that even for a minimum number of buffer stock, we will always have a more number of output in the free transfer machine in comparison to indexing machines for example. Any work head on a free transfer assembly machine will be forced to stop under three different circumstances. Suppose we have this as a free transfer machine, so we have the work head 1 2 3 and 4, in between the work head we have the buffer stock. Let us say the buffer stock maximum size is b and suppose in between we can have some buffer stock which is number a.

If a defective part is fed to the work head and prevents the completion of its cycle of operation, then the work head will stop. Then an interval of T second elapses before the fault is cleared and the work head is restarted. That is one reason when the work head can stop; that is a defective part goes in and an operator takes T time to fix it. Other reason is if the adjacent work head up the line is to this for example, if this work head stops then the supply of assemblies in the buffer stock between them if it is exhausted, then this machine has to stop. Because these machine stops means, it is no longer supplying the sub-assemblies to the buffer and this machine has no way to take up the buffer from the buffer, so it will stop.

Third reason is that if the adjacent work head down the line for example, if this machine stops and the buffer stock is full. Then if the buffer stock is full then this machine when working it cannot put the sub-assemblies that here it has completed to this buffer because it is full. So, it has to stop. So, these are the three different reasons why one any of the transfer machine in the line can stop overall.

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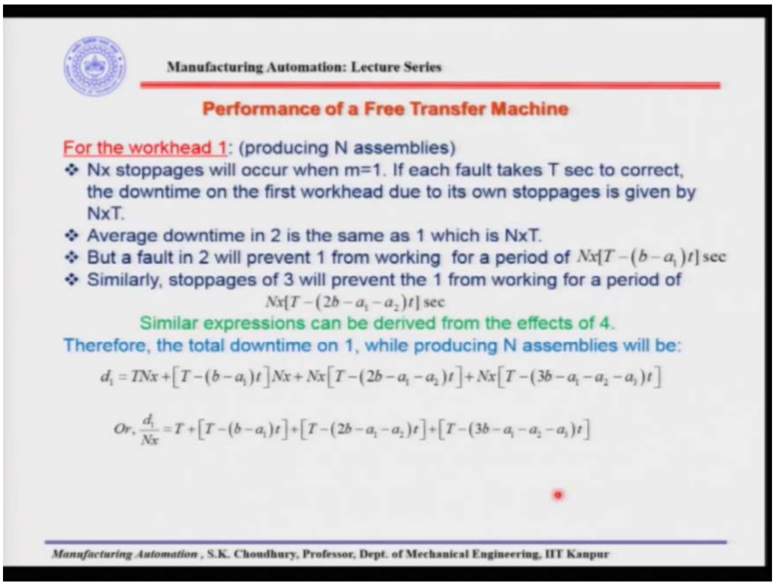

Performance of a free transfer machine will overall, we will see, this is producing N assemblies. So, N into small x stoppages will occur when m is equal to 1. Because all the defective parts will stop the machine.

If each fault takes T seconds, so it will take of downtime will be Nx and the T that is the first work head. Average downtime in second machine is the same as in the first machine which is NxT, but a fault in the second machine will prevent the first machine from working for a period of $Nx\left[T-(b-a)t\right]$.

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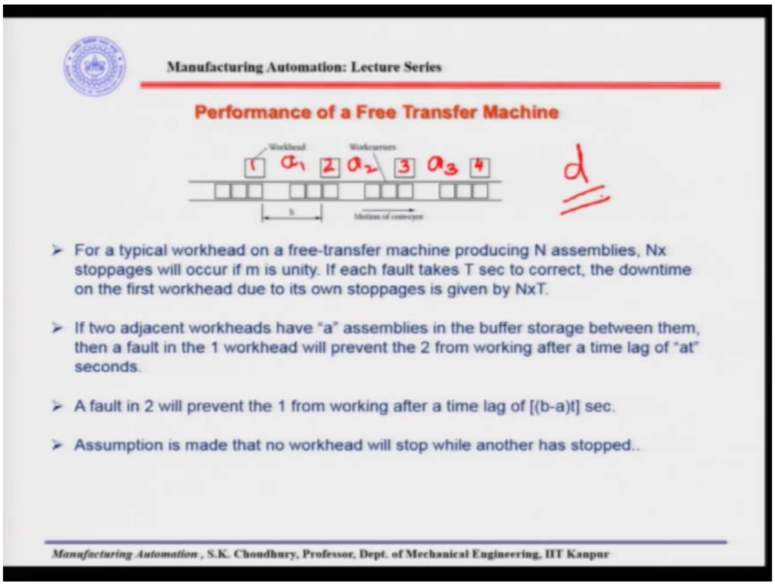

Let us discuss what is that. Fault in 2 so, fault in 2 means that it will still supply it to the buffer till the buffer is filled up. Suppose here it is a 1 we can have the a 1 sub-assemblies. So, b minus a 1 till that time into t cycle time it can work, but then after that it has to stop. So, a fault in 2 will prevent 1 from working for a period of $Nx\left[T-(b-a)t\right]$. Similarly stoppages of 3 will prevent the 1 from working for a period of let us see, here there is a this is the third work head, it will if it stops it will prevent the 1 from working up to one the here it is b number, here it is b number, number b.

So, 2 b minus a 1 minus a 2 let us say here it is a 1, here it is a 2 number of sub-assemblies into t alright, and NxT. NxT is the total down time minus this value, Nx into this value. So, overall it is $Nx\left[t-(2b-a_1-a_2)t\right]$. Now the similar expressions can be made, can be derived from the effects of 4 of the 4 I mean to say, see what we have done is right. Now what we have done is the stoppage of effect of the stoppage of 1 on it is own, effect of stoppage of 2 on the 1, effect of stoppage of 3 on the 1 and 4 on the 1.

Similarly we can do it for this station work head that is the, what will be the effect of defective part going in the second one that will be Nx and that T. What will be the effect when it stops on this 2, what will be the effect when the third work head stops on the 2 and what will be the effect when the fourth work head stops on the 2. And similarly for 3 and 4, that is what we are telling.

So, similar expressions can be derived for all these four work heads. Therefore, the total down time on 1 while producing N assemblies, total down time will be 4 parameters that is the NxT this is the effect of the defective part going into that machine 1, this is the effect of stopping the machine number 2 the on the 1 on the machine 1, this is the effect of stopping the machine number 3 on the machine number 1, and this is the effect of stopping the machine number 4 on the machine 1 alright.

Similarly, from here we can find out that $\frac{d_1}{Nx}$ this is equal to this expression that we are simplifying. Now this expression it is for the work head number 1, this is the down time of work head number 1. Similarly we can find out what is the down time for work head number 2, what is the down time for work head number 3, and what is the down time for work head number 4. So, we can have $\frac{d_1}{Nx}, \frac{d_2}{Nx}, \frac{d_3}{Nx}, \frac{d_4}{Nx}$ equation, same as we have done for the $\frac{d_1}{nx}$.

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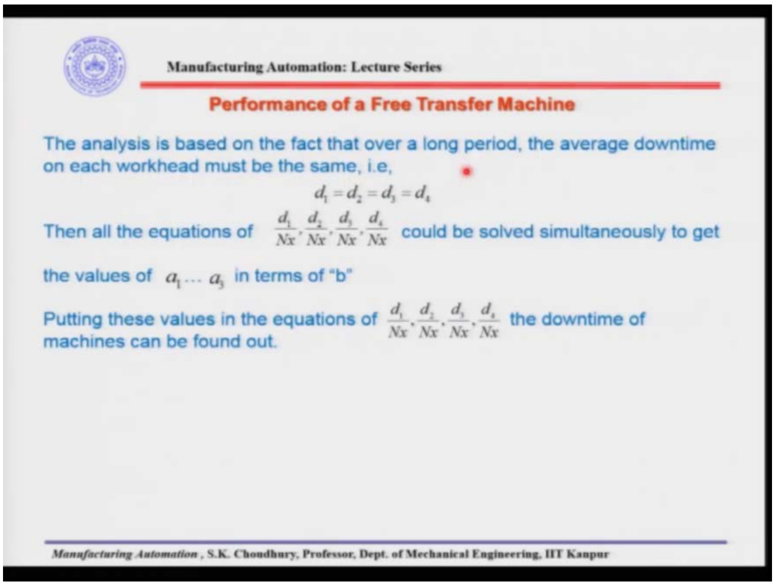

Now, analysis is based on the fact that over a long period of time the average down time on each work head must be the same ok, because they will be equalizing. So, therefore, $d_1 = d_2$, d is the down time, for machine number 1 is equal to down time for machine number 2 machine number 3 and 4 and so on. So, therefore, all these four equations can be simultaneously solved to find out the values of a_1, a_2, a_3, a_4. What is a_1, a_2, a_3, a_4 is that the number of parts what is here is a_1 number of parts a_2, number of parts i.e., number of sub-assemblies in the buffer.

So, a_1, a_2, a_3 in these equations we have, here all everywhere we have this. So, a_1, a_2, a_3 we can find out by simultaneously solving these equations ok. Putting these values in the equations of $\frac{d_1}{Nx}$, $\frac{d_2}{Nx}$, $\frac{d_3}{Nx}$, $\frac{d_4}{Nx}$ like one of them has been shown here $\frac{d_1}{Nx}$. And as you understand, the similar equations can be derived for $\frac{d_2}{Nx}$, similar for the machine number 2, for machine number 3 you can derive same way the $\frac{d_3}{Nx}$ and $\frac{d_4}{Nx}$. So, there will be four equations those equations can be simultaneously solved to get the values of a_1, a_2, a_3. When you are putting these values here, in case there is any negative value in the bracket they have to be rejected.

And then again those four equations have to be solved by rejecting that bracket parameter where the value is negative. Again find out the value of the a_1, a_2, a_3 a fresh, again put them in these equations and again we have to test whether the bracket value is not negative. If it is negative we have to repeat the process ok, keep on doing that and you will find out the, what will be the d for the overall the line. Because as we said that overall what will happen is, the $d_1 d_2 d_3$ and d_4 they will have to be same. Therefore, the small d is the downtime that we are finding out for the entire line consisting of these 4 machines.

If small d is found out, you can find out what is the proportion of downtime. Because proportion of downtime is as we said that is the downtime divided by total time, and total time will be knowing as we have done it earlier and therefore, we can find out the values. So, I hope it is clear, that if we have in this case, we have actually given that example of 4 machines 1 2 3 and 4. So, the number of machines can be much more than that, and the way of finding out the d which is the downtime is the 1, that we have described be it 5 machines or 100 machines, the same way you can find out.

Once again the basic thing is that, we have to say, that what is the effect of each of them? I will repeat once again, so that it could be clear. That when you are considering the work head 1 finding out the downtime of work head 1, you have to find out three things, that the effect of this work head itself when a defective part goes in; that means, NxT alright capital T is the time taken for diagnosing the problem. Then what is the effect of stopping 2 on the 1? So, in this case since there are 4. So, there would be 4 parameters; effect of stopping 3 on 1 and effect of stopping 4 on 1.

Similarly, when you are analyzing or finding out the downtime for work head number 2, you have to find out the effect of the defective part going into the 2 that is again NxT the same, but then there will be effect of stopping 1 on the 2. And once again I will tell you that if the 1 stops in that case 2 can still work because there are buff there are sub-assemblies in the buffer stock, it can take from the buffer stock till the buffer stock is empty.

So, buffer stock suppose there are a_1 number of parts. So, $b-a_1$, b is the buffest of volume maximum number that can be taken. So, that will be the time into t cap into small t which is the cycle time that is the time till the 2 can work if the 1 stopped. Now for example, if here I will repeat it once again from here now stoppage of 3 let us say, stoppage of 3 will prevent 1 from working for a period of this much ok. So, when we are talking about the stoppage of 3, we will have the effect from this buffer and also from this buffer. So, therefore, what we have considered is this, $2b-a_1-a_2$ and that will be till the cycle time small t it will work.

And therefore, the stoppage of 3 will prevent 1 from working for a period of $NxT-(2b-a_1-a_2)t$. So, overall what we are saying is suppose you have a large number of machines in that case, although it will be difficult, but you have to consider the effect of stoppage of all machines on that machine for which you are actually considering the downtime.

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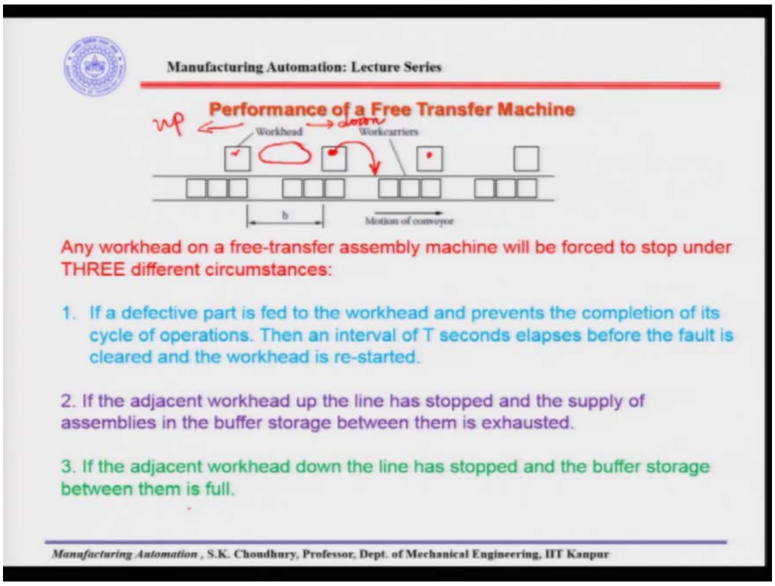

One thing I would like to repeat once again here, that how any work head on a free transfer assembly machine will be forced to stop under three different circumstances. See for example, here this is I am repeating once again for clarity, because this is somehow little difficult to understand. Suppose you have a work head here alright. Now a defective part goes in this to the work head and prevents the completion of it is cycle of operation alright.

Then an interval of capital T time will be spent elapses before the fault is cleared and the work head is restarted. Now suppose this is up the line, and this is down the line ok. Now if the adjacent work head up the line, this one up the line, if it stopped and the supply of buffer storage between them is exhausted, there is none. So, in that case this machine will stop, because it cannot take any sub assembly from here it is empty. So, that is the second reason.

Third reason is, that if the adjacent work head down the line stops, for example, if this machine stops, in this case this machine can work and put this sub-assemblies in the buffer till the buffer stock is full. So, if the adjacent work head down the line has stopped and the buffer storage between them is full; so, I hope this is clear I have repeated that and this is little difficult to realize. So, that is what I wanted to describe, I wanted to discuss in this course of manufacturing automation.

Thank you for your attention.