Manufacturing Automation
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Lecture – 04

Welcome back. So, before we begin the next session let me remind you that we have basically discussed the general aspects of Manufacturing Automation. We have discussed what are the benefits of the automation, why we need the automation, particularly in India, and we were convinced that it will create the new and more interesting jobs than the normal routine works in the mass production. Then we have discussed some of the strategies which are required for manufacturing automation, so that the production capability, production capacity or production rate can be enhanced.

Then, we discussed some of the aspects of the part transfer, we said that there could be in-line flow or the rotary flow and we have accordingly the rotary indexing machines or the in-line machines, which can be used in the flow line automation. Next we discussed about the flow line automation, which, we said, consists of the series of either processing or assembly or sortation or inspection machines, which are connected or integrated by the material handling devices.

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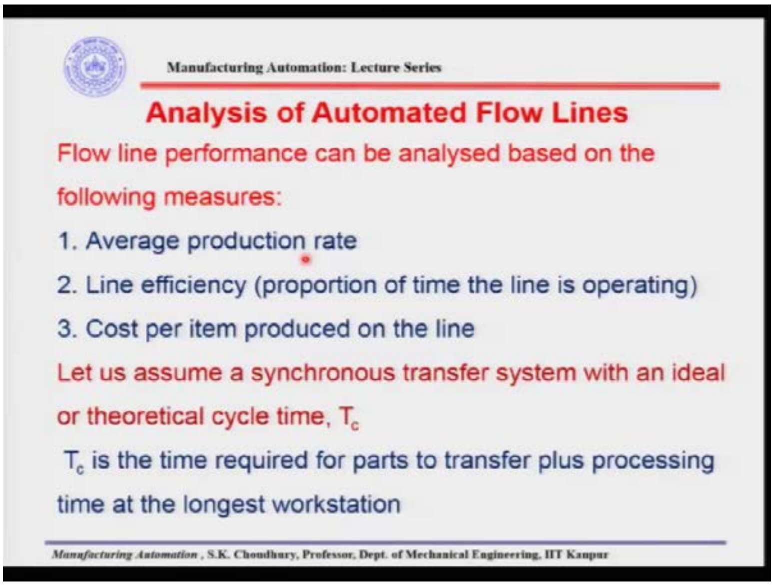

Now, the automated flow lines can be analysed based on the average production rate, as we said, based on the line efficiency and the cost per item produced on the line. These are the topics that we discussed last time. I said that the line efficiency is important because this will dictate us or this will show us what is the proportion of time the line is operating. The rest of the time the line is down, and why the line becomes down that we will discuss now.

Well, to analyse the automated flow lines, let us assume a synchronous transfer system with an ideal or theoretical cycle time T_c. What is synchronous transfer system? I will remind you that it can be the in-line or the rotary indexing, where the parts or the subassemblies are being transferred and then they stop for sometimes for the processing to be over. Cycle time: what is the cycle time? This is the time taken for the processing; either it can be a machining process, it can be a metal forming process or it can be an assembly process. So, the entire task to finish including the transfer of the parts that is the actually ideal cycle time.

Now, the T_c which is the cycle time as we said, this is the time required for parts to transfer plus processing time at the longest workstation. Now, what does it mean? In a flow line we have different machines and all these machines may require different processing time. Some machine may require 4 minutes for example, another adjoining machine may require 4 and half minute of processing time, another machine adjoining to other side can need may need 3 and half minutes of processing time. So, the longest one which is maybe 5 minutes or 4 and a half minutes that has to be considered because then only all the machines would be covered. And, in that case the machine which takes less processing time has to wait for some times for the parts to get transferred.

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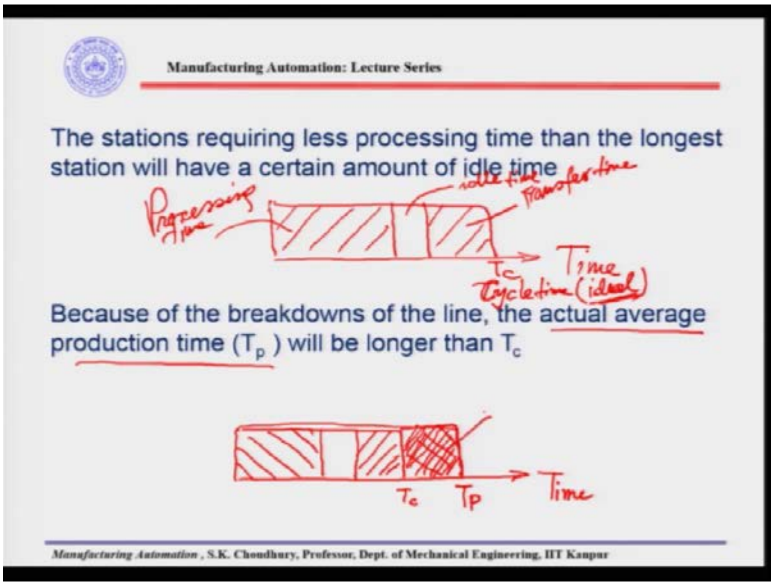

Let us see how it is done. The stations requiring less processing time than the longest station will have a certain amount of idle time. Now, what is that? let us say we have the time along the X-axis. We will find out what is the cycle time. So, this is the cycle time, let us say this much is T_c. T_c is the cycle time as we said that is required for parts to transfer plus processing time at the longest workstation.

Now, in this let us say this much is the time which is taken for transferring the parts and this is the time which is taken for the processing at the longest workstation; that means, the processing time for the machine which will take the longest processing time. Now, those machines which will need less time than the longest processing time, need some idle time. So, this is the idle time. This is the transfer time and this is the processing time.

So, what is happening is that whole time is the cycle time, T_c is the cycle time and this cycle time includes the transfer time and the processing time. Within the processing time, those machines which will be slower, need some idle time. So, that is the idle time that we have. Now, this T_c cycle time we call as the ideal cycle time. This is the ideal one. Ideal one means that this can be achieved if everything goes ok, if there is no downtime no machine breakdown happens then that T_c is the ideal cycle time.

In fact, what happens in practice is that there could be some sort of machine breakdown in a cycle or in few cycles. So, in that case if this is the time and if this is the T_c let us say and here we have the transfer time, here we have the processing time let us say and this is the idle time, but there would be certain breakdown in the machine in the line. So, let us say this is the machine breakdown.

This machine breakdown we will say some actual production time. So, this T_p we will say as the actual average production time. So, actual average production time will be more than the ideal cycle time by the time it takes for taking care of the line breakdown.

Now, let us say that we have T_d is the average downtime to diagnose the problem and make repairs when a breakdown occurs. What we mean is that when the line is working certain breakdown happens and for that breakdown there should be some operator or some technician which will take care of diagnose it and then correct it to re-run the machine and let us say that takes this much of time. How to find out that time? Let us say F is the frequency with which the line stops per cycle.

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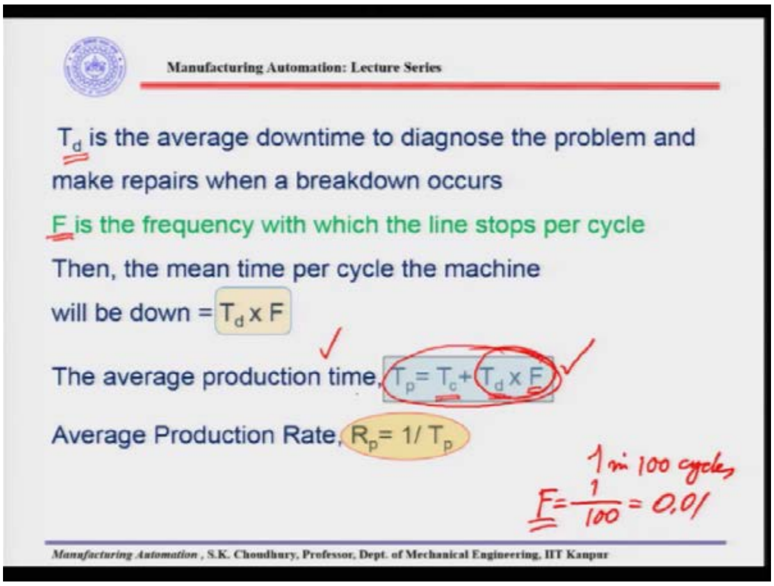

Let us say the line stops per cycle once in every 100 cycles. So, if 1 in 100 cycles, then, $\frac{1}{100}$ is the frequency. So, this is 0.01. So, let us say this is the F which is the frequency with which the line stops per cycle let us say once in 100 cycles or it may be once in 10 cycles, once in 1000 cycles that depends and on which factors we will discuss later.

Now, T_d is the average downtime to diagnose the problem and make repair when a breakdown occurs and the F is the frequency with which the line stops per cycle.

So, this is actually the FT_d. So, T_p is the actual average production time which will be more than the ideal cycle time by the factor FT_d. So, we can write that $T_p = T_c + FT_d$ and this is the factor which actually counts the line breakdown because of various reasons; if the machine stops or if something went in the machine or the tool is broken or something.

So, this takes let us say T_d time and the frequencies F, so FT_d is the time. Therefore, the actual or the average production time will be more than the ideal cycle time by this FT_d. Now, once we have the average production time, production rate is 1 upon production time. So, the average production rate which is R_p will be $\frac{1}{T_p}$ and T_p we found out by the ideal cycle time and the FT_d.

Here you mind one thing that this can be found out because we know that how much time it takes to process a part. Let us say to machine a part or to assemble a sub assembly we know the T_c which is ideal, then from the experience of the line performance we will be knowing that normally on an average how many breakdowns happen in how many cycles. Let us say one breakdown in 100 cycles on an average so on. So, we know the F.

If we know the F and we know how much time it takes on an average to repair and to re-run the machine then FT_d if we add to T_c we can find out the actual or the average production time and this average production time is the actual production time. Whereas, this T_c if you see, this is the ideal one in the sense that if everything goes if nothing happens and the line is running perfectly well then the T_c is the cycle time. But, it does not happen some I mean most of the time there is something or other because of which that FT_d has to be taken care of.

So, average production rate we can find out if we know the T_p because $\frac{1}{T_p}$ will be the average production rate.

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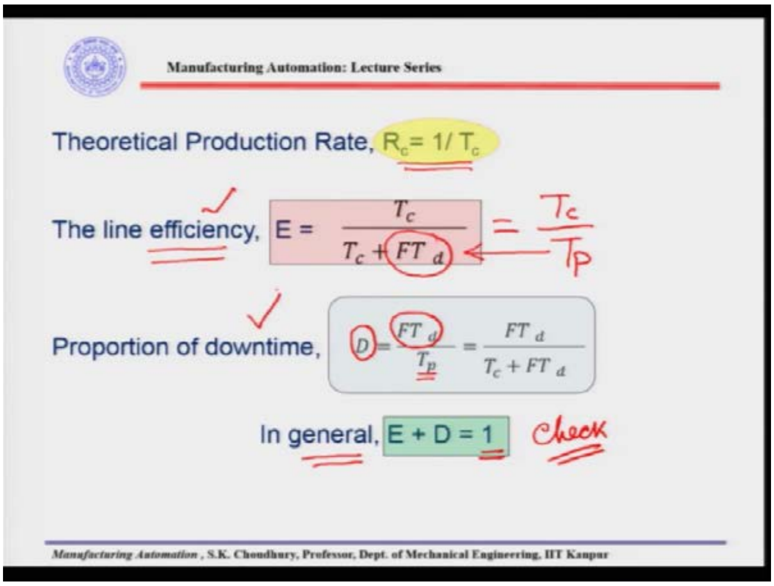

Once we know the average production rate then the theoretical production rate will be $\frac{1}{T_c}$, ok; T_c is the ideal cycle time. So, this is the theoretical production rate; meaning that if nothing happens once again this much production rate will be getting, but since we have that FT_d, the line efficiency we can find out by dividing the T_c and the T_p, and, the T_p we found out $T_p = T_c + FT_d$. So, this actually is $\frac{T_c}{T_p}$ and the T_p , as we said, is the average production time.

So, the average production time is the ratio of the ideal cycle time and the average production time. So, this is equal to $\frac{T_c}{T_c + FT_d}$ because $T_p = T_c + FT_d$ that we have seen here; So, we know the theoretical production rate, we know the line efficiency and then proportion of down time; proportion of down time means that for how much the line is down. Here we are not calling the machine because a line consists of several machines they are integrated, and they are integrated with the material handling device.

Therefore, the proportion of downtime of the line is given by $\frac{FT_d}{T_p}$, the time the line is down divided by the actual average time T_p. So, this will actually be $\frac{FT_d}{T_p} = \frac{FT_d}{T_c + FT_d}$.

So, this way we can find out for how much time the line is down. If we know that then we can in general check that the E plus D should be equal to 1. If we see that

$\frac{T_c}{T_c + FT_d} + \frac{FT_d}{T_c + FT_d} = 1$. So, this is a check.

So, we know that how much time the machine is up, that is efficiency and how much time the machine is down.

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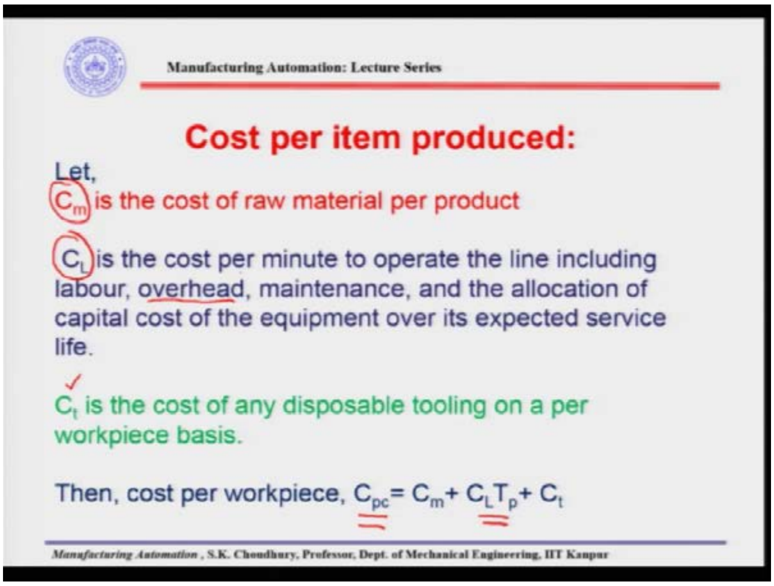

Next, let us see what is the cost, how to find out the cost per item produced in the automated flow line. Let us say that C_m is the cost of raw material per product. Suppose, we are discussing the machining or production of the particular part. So, C_m is the, the cost of the blank; cost of the raw material per product. C_L is the cost per minute to operate the line including labour, overhead, maintenance and the allocation of capital cost of the equipment over its expected service life.

Let me explain it to you what is it. C_L will include how much money we are spending per minute to operate the line. How to find out that? We have installed the line, we have certain cost which have been incurred and let us say it is given that the line, life of the line will be, let us say 10 years. So, we can find out what will be the cost per minute because we have overall cost for installing the line and the line life is 10 years. So, that is the cost per minute to operate the line.

Now, this will also include the labour, how much you are paying for the operators if there are any of the other maintenance people which are involved in that. Overhead; overhead is something which we pay to run the line. For example, the line is under the roof, that is a building. The building has some cost. We have the electricity, for that we need the investment; we have the hydraulics, pneumatic lines, we have the disposal of the chips and so on. So, everything included in that overhead. Maintenance: if anything happens in the line, in that case it has to be repaired, it has to re-run. So, that maintenance charge has to be included here and the allocation of capital cost of the equipment over its expected service life.

So, this is like how much we have spent, as I explained it to you earlier, and how much time we require for that particular operation for which we are finding out the cost. Now, all these things will be included in the C_L which is the cost per minute and overhead and the capital investment. C_t is the cost of any disposable tooling on a per work piece basis. So, during the operation we will have some fixtures and those fixtures will be required for particularly machining or assembling the parts. So, this cost is the C_t.

Therefore, the cost per piece will be equal to $C_m + C_L T_p$ because C_L is the cost per minute. So, that has to be multiplied by the T_p that we have found out. This is the T_p which is $T_c + FT_d$ and that will give you the $C_L T_p$ plus the cost of any disposable tooling which is the C_t. So, this all together $C_m + C_L T_p + C_t$ will give you the cost per piece. So, this is easy to find out that how much will be the cost per assembly or per piece which is being machined on the line.

So, as you understand that this is different than what we have done in the case of finding out the cost of an workpiece which is being manufactured in a standalone machine. Because in the standalone machine we do not need many of these things, but we need something else so, those are to be included. So, in this case this is the cost per workpiece when it is being done on the automated flow line particularly.

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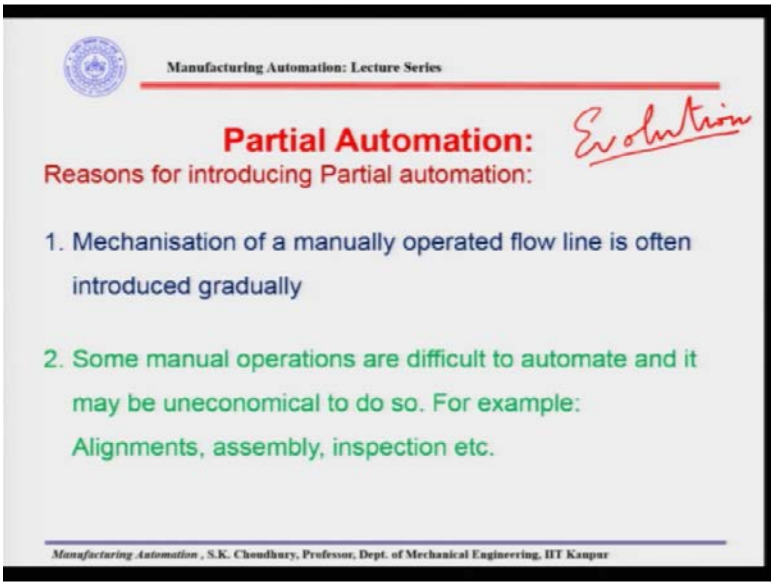

Let us discuss next topic that is the partial automation. What is the partial automation? Meaning, in the beginning if you remember I told you that automation actually begins where the mass production leaves off. That means, that automation cannot come overnight it is a gradual process and this we call as an evolution. See, there are two words; one is the ‘revolution’ and another is the ‘evolution’.

So, this is an evolution because it does not happen overnight and we are not throwing out all the positive aspects of the mass production. Therefore, initially we cannot overall install the automation, but it will be partial automation; that means, there will be some manual operations in the process. Now, there are two basic reasons why the partial automation should be introduced. First is the mechanization of a manually operated flow line is often introduced gradually, as I said just now, and the second reason is that some manual operations are difficult to automate. I actually told you earlier also and it may be uneconomical to do so. For example, alignments, assembly, inspection etcetera.

Let me give you an example. Suppose, there are elements of bearing, let us say cylindrical bearing, and each of these elements have to be tested for any scratch or any defect. There are millions of them in the production of the bearing and if we have to have an automatic machine with some sensors for checking each of these elements for any kind of crack or any kind of small scratch, this will actually take a very sophisticated machine and it will be very expensive; whereas, the human being can do it much faster and it is in a much easier way and more accurate way probably. So, that is the reason where we actually introduce some manual operations in the automation and this is called the partial automation therefore.

So, in the partial automation what happens? The total line cost will be given by another formula rather than the $C_{pc} = C_m + C_L T_p + C_t$. Mind it that this is the formula what we are using for finding out the cost in the automated flow line where we have the complete automation.

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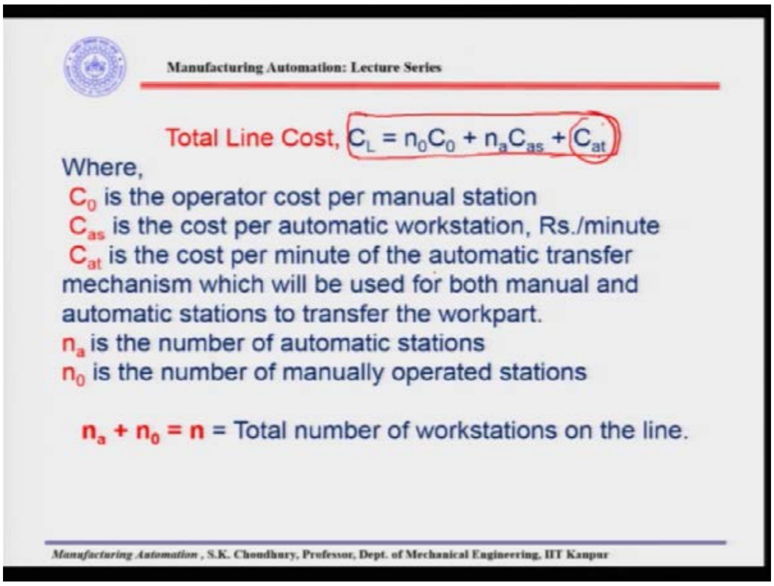

And this is the one that we are talking about where we have still some manual operation or manual machines. Now, here the total line cost will be equal to $n_0C_0 + n_aC_{as} + C_{at}$. Now, n_0 is the number of manually operated stations, it could be any number. This is multiplied by the C_0 which is the operator cost per manual station, i.e., how much we are paying to the operator for operating the manual station plus n_aC_{as}; n_a is the number of automatic stations and C_{as} accordingly is the cost per automatic workstations which will be rupees per minute. This two plus C_{at} which is the cost per minute of the automatic transfer mechanism which will be used for both manual and automatic stations. So, you can see that C_{at} is not multiplied by neither n_0 nor n_a because this is the cost per minute of the automatic transfer machine automatic transfer mechanism which is the material handling device.

So, this automatic transfer mechanism, since it is used for both n_a and the n_0, that is the manual stations and the automatic stations. Therefore, this will be overall plus C_{at}. So, that is how we can get the total line cost which is equal to the multiplication of the manual operations and the cost plus automatic operation and the cost plus separately the cost per minute of the transfer mechanism. Now, of course, $n_0 + n_a$ will be the total number of machines or workstations on the line. This is understood.

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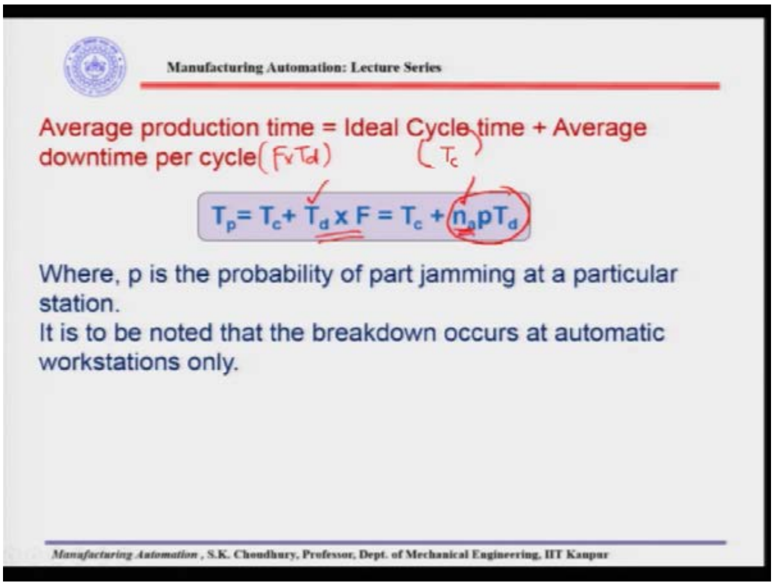

So, the average production time, will be again the ideal cycle time and the average downtime per cycle which we said as the FT_d. Ideal cycle time plus average downtime per cycle we said FT_d that we are writing as $n_a pT_d$; n_a we have seen is the number of automatic workstations in the line, p is the probability of part jamming at a particular station.

Since these are the automatic machines, so, those machines can have the breakdown by jamming the parts. The parts may jam into the automatic workstation whereas, it may not happen in the manual workstations. Therefore, these has to be considered that what is the probability of part jamming at a particular station and that has to be multiplied by the number of automatic work stations and of course, the T_d remaining. So, the F is equal to now $F = pT_d$.

Now, this is to be noted that the breakdown occurs at automatic workstations only and therefore, it is only the n_a here is considered.

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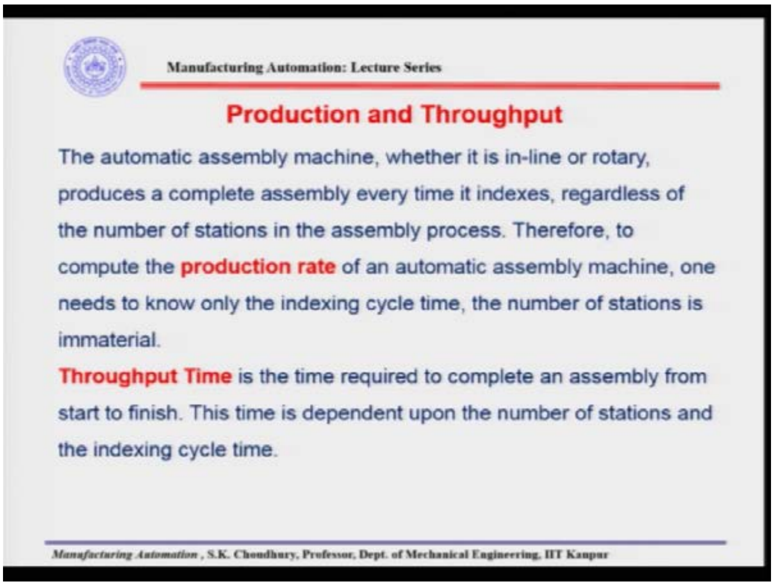

So, let us look into the next topic which will be the production and the throughput. I will give you the overview of the production and the throughput what it is and the details we will discuss in the next class. Production and throughput: production time; we know the production rate we have seen that production rate is 1 upon the production time.

Now, in automatic assembly machine, whether it is in line or rotary produces a complete assembly every time it indexes. This is very important to understand. That is how in the first lecture I told that 10 second was the time taken by Henry Ford to get one car; that means, each 10 second it indexes one car is coming out. It does not mean, by the way, that the whole car is made within10 seconds.

So, there is an indexing machine, the assembly is made in different workstations. So, once it is indexing, at the final stage one complete product is coming out, regardless of the number of stations. There could be hundred workstations or two hundred workstations, every time it indexes you get one complete assembly or a complete product. Therefore, to compute the production rate of an automatic assembly machine one needs to know only the indexing cycle time. The number of stations is immaterial.

Now, (Refer Time: 25:31) throughput time is the time required to complete an assembly from start to finish. So, the throughput time will be always more than the production time. How much more we will see in the next class.

Thank you.