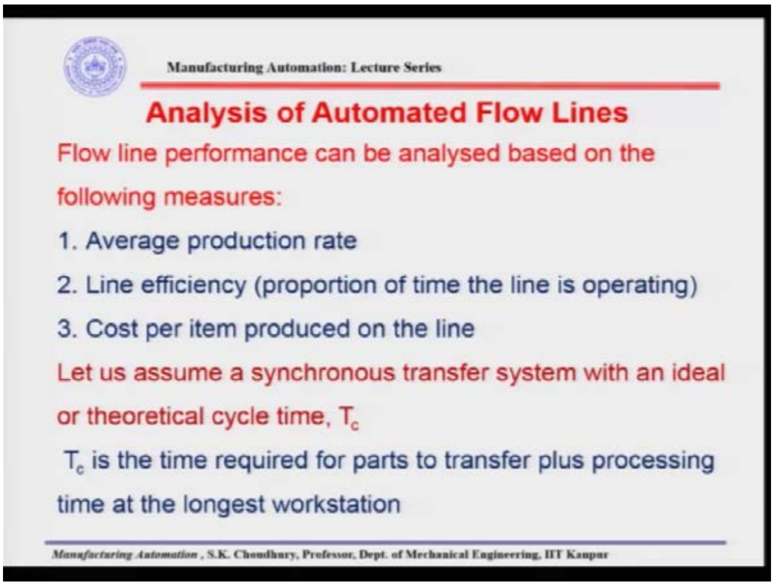
Manufacturing Automation
Prof. Sounak Kumar Choudhury
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture – 05

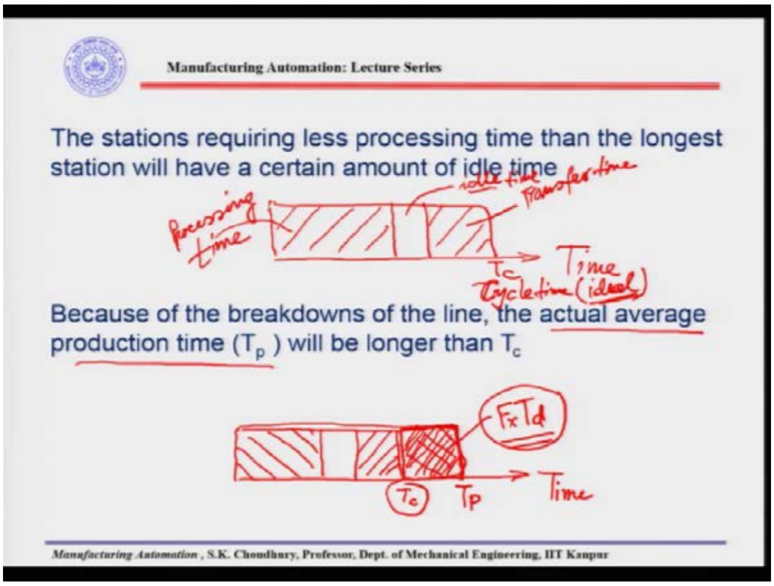
Welcome back. Now let me remind you that, last time what we have discussed is in the analysis of automated flow lines; that the performance can be analysed based on the average production rate, the line efficiency and the cost per item produced.

(Refer Slide Time: 00:38)



So, separately we have seen that how the average production rate could be found out, line efficiency can be found out and the cost per item produced on the line can be found out.

(Refer Slide Time: 00:43)



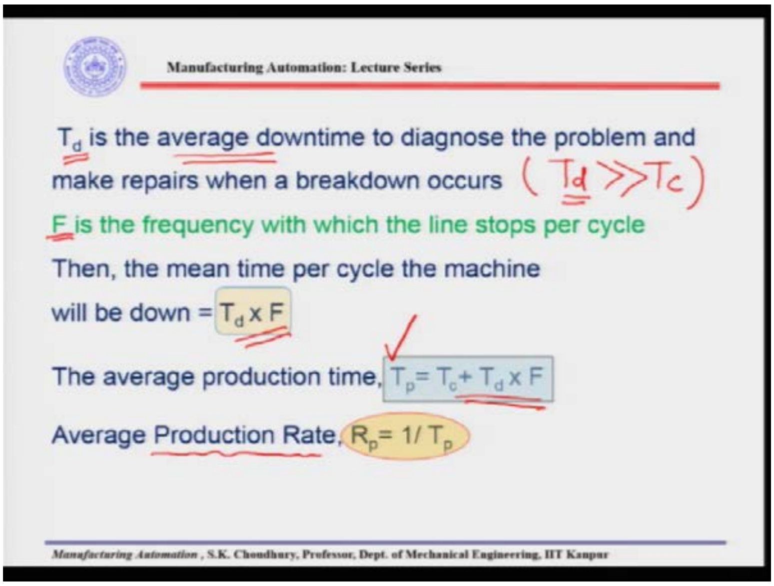
We said and I will like to remind you that, this is the T_c if you look at the diagram that we have drawn last time. It was said that this is the ideal cycle time and this ideal cycle time includes the processing time and the transfer time. Transfer that is required from for the parts or the subassemblies for going from one station to another station, from one work place to another work place. Now this T_c is given for the longest workstation as I said; that means, for the station which needs the longest time for processing, either it is assembling or the processing.

Therefore, for those machines which will take less time than the longest processing machine time, so that will have some sort of idle time. That means, it has to wait for the longest workstation to complete the job and then do the operation next operation. Now, this cycle time, as I said is the ideal cycle time and this happens if no breakdown happens in the line.

$\frac{1}{T_c}$ will be the ideal production rate. This is the maximum production rate that we can get. But, in practice since we have the automated flow line which will consist of several automatic machines, there, something or other happens, that is, the machine breakdown and because of that some time is elapsed for looking into that for repairing and to rerun the machine.

So, this is the time which we have to consider in the T_c, so that we get the actual average production time. What we actually get is not the maximum one. This T_p therefore, that is that actual average production time will be more than the ideal cycle time by the FT_d .We said that T_d is the time taken to diagnose the problem and make repairs when a breakdown occurs.

(Refer Slide Time: 02:59)



Let me tell you that this T_d is actually much more than the T_c. For example, if a processing time is about 10 seconds, so T_d can be 5 minutes or 10 minutes depending on the type of the downtime. So, what we are talking is that the average downtime, it is not the maximum, on an average how much downtime is for the line. F we said is the frequency with which the line stops per cycle, if it is 1 in 100 cycles it is 0.01 and so on.

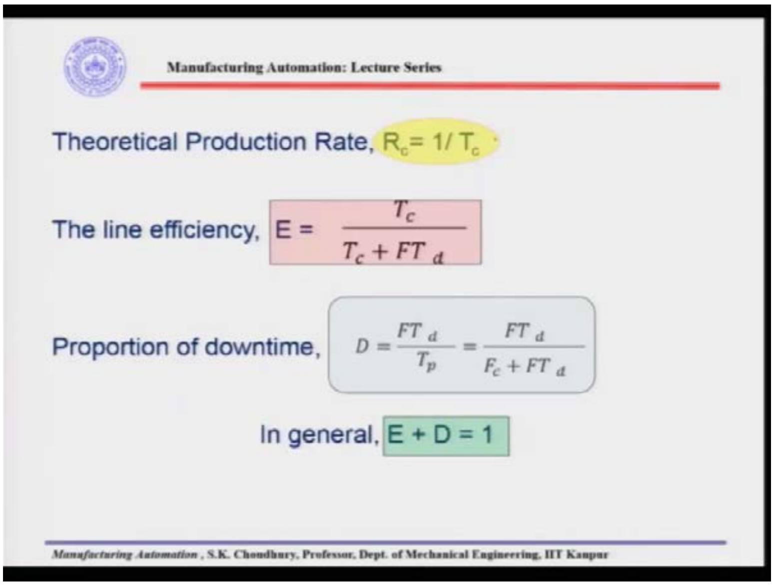
So, the mean time per cycle the machine will be down will be FT_d which we are considering here and adding up with the T_c to find out actually the average production time. Average production time therefore, becomes $T_c + FT_d$ and since we know that

$$Production\ Rate = \frac{1}{Production\ Time}$$

So, the average production rate will be $\frac{1}{T_p}$ and in here all these factors will be known. Therefore, very accurately we can find out what will be the actual average production rate in the line. By the way, coming back I will just like to remind you that I said in one of my lectures that, the time taken or duration of the time after you take the order from the customer and the delivery is reduced in case of the automatic automation, in case of overall manufacturing automation. This is simply because of the fact that we will be knowing very well and very accurately what will be the average production rate.

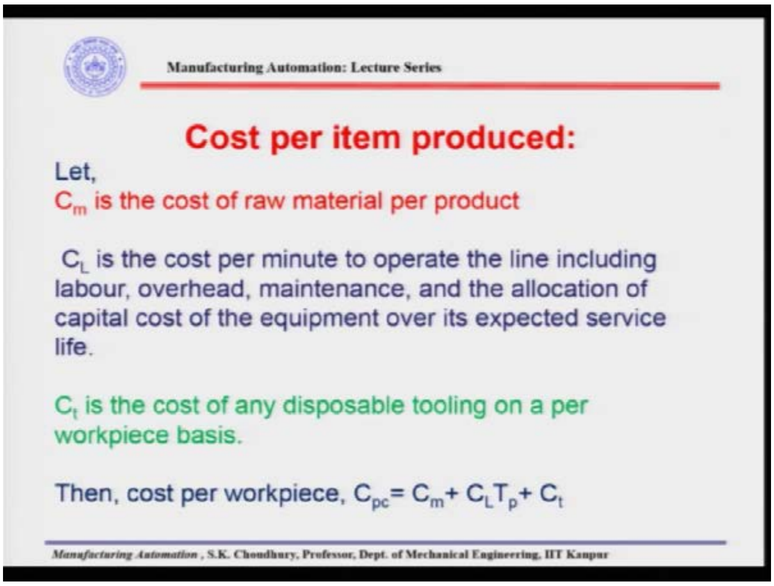
So, everything is known. So, we can say that if I am taking that order today I will be knowing how much time it will take for me to deliver and this is the time that we can maintain.

(Refer Slide Time: 05:16)



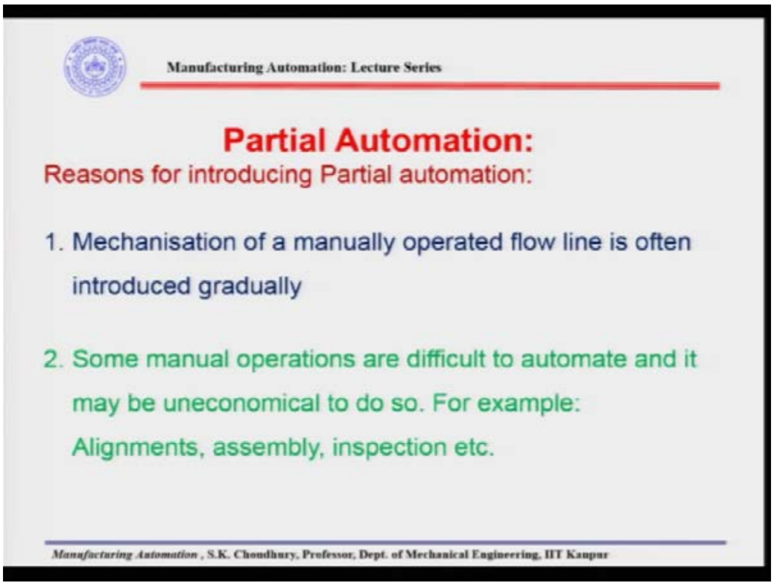
Therefore, since we know the theoretical production rate which will be $\frac{1}{T_c}$ we can find out what is the line efficiency. That means, how efficiently the line is running, for how much time of overall operation time the line is operating. And for how much time the line is down. This is the proportion of downtime. So, $E + D$, as I said, you can check that this is equal to 1, this I have just reminded you.

(Refer Slide Time: 05:41)



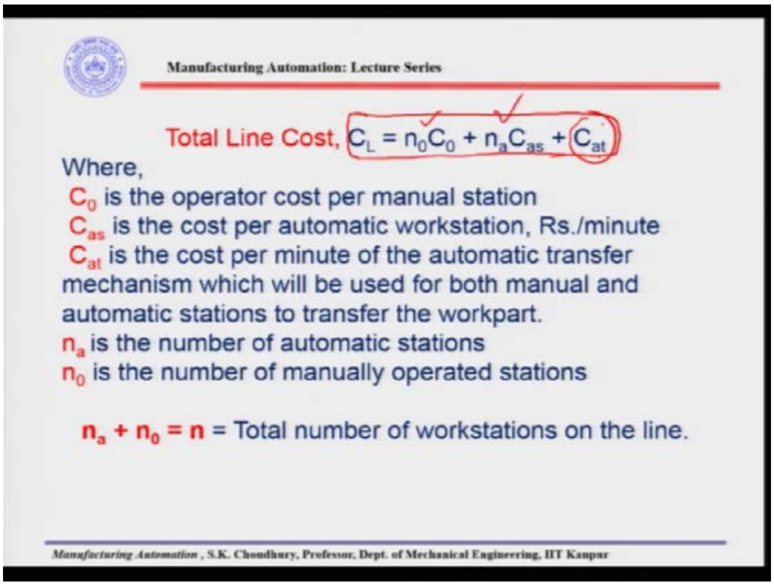
Then, we discuss the cost per item produced and we said that the material cost then the line, is the cost per minute to operate the line and the cost of any disposable tooling is to be considered and this will be the cost per work piece.

(Refer Slide Time: 05:59)



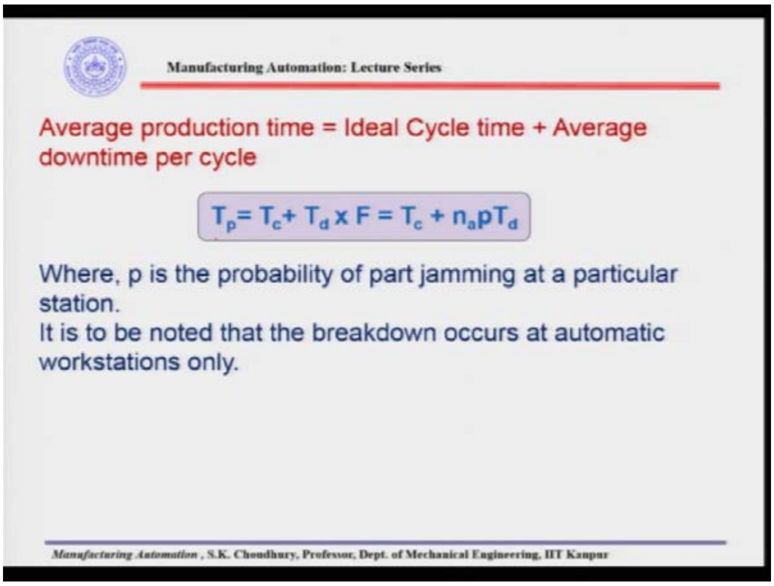
Then, we started discussing the partial automation and we said that there are two reasons; that it cannot be done overnight. Mechanization of a manually operated flow line is often introduced gradually and some manual operations are very difficult to automate. And if we even do that it will be very expensive. So, there would be some manual operations.

(Refer Slide Time: 06:24)



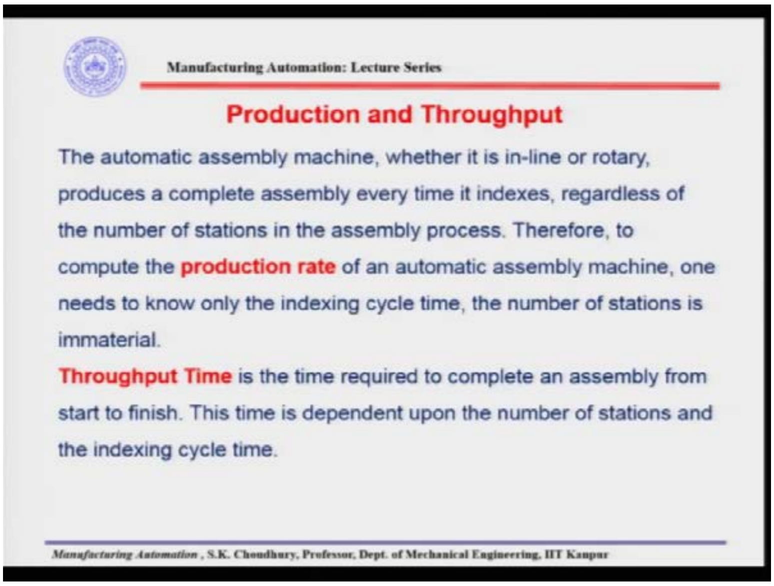
And therefore, the line cost will consider these factors that how many manual operated machines you have and how many automatic machines you have.

(Refer Slide Time: 06:38)



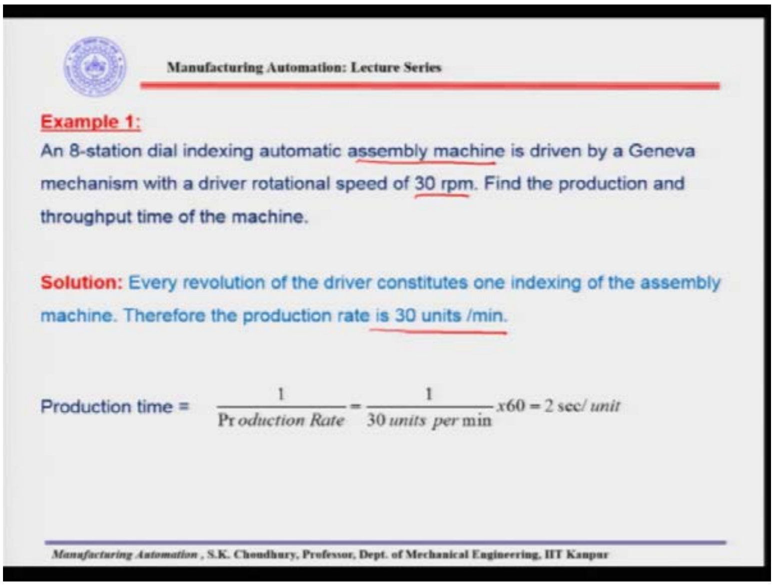
So, the average production time will be accordingly $T_c + FT_d$ that is same in the earlier process. And here it will be, F is replaced by the $n_a p$, where p is the probability of the line break down or jamming the parts. This we have discussed.

(Refer Slide Time: 07:02)



Production and throughput: we said that the throughput time and the production time are different. Production time is whenever one indexing happens there is one complete product coming out and that is the production time. Throughput time is the time that is taken from the beginning to the end for an assembly.

(Refer Slide Time: 07:23)

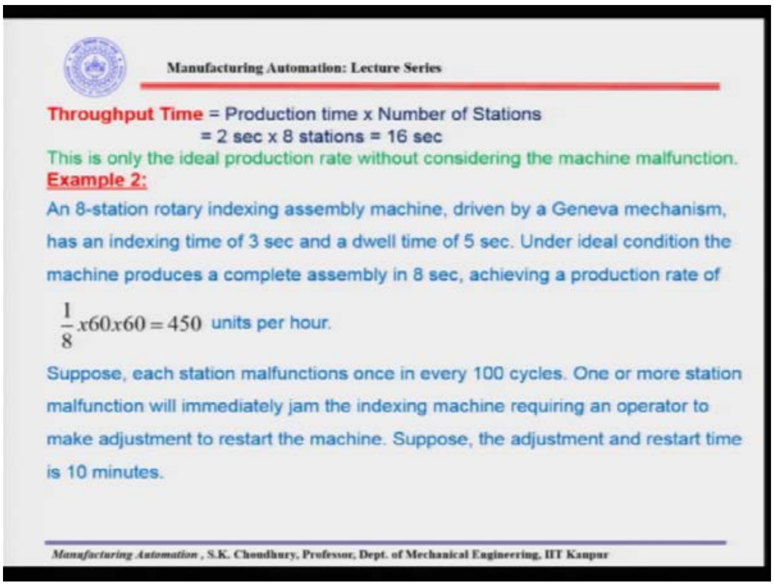


Therefore, throughput time is more than the production time. Let us take an example, suppose we have an 8 station dial indexing automatic assembly machine. And, this is driven by a Geneva mechanism with a driver rotational speed of 30 rpm. Find the production and the throughput time of the machine. I would like to remind you that when we have discussed the Geneva mechanism, it was said that the driver rotational speed is the one which is rotating the pin continuously.

So, here we are taking that example of an 8-station dial indexing automatic machine meaning, that it will index and it will dwell for some times ok. And it is driven by Geneva mechanism so, that driver mechanism is rotating at a rotating the pin at 30 revolution per minute this is the example let us say. Every revolution of the driver constitutes one indexing of the assembly machine. You remember? I said, 10 second per car for the Ford. So, therefore, if it is rotating at 30 revolution per minute; that means, the production rate will be 30 units per minute. Because, each time it is indexing there is one assembly or one product which is coming out. Here it is the assembly machine therefore; one complete assembly will be coming out in one indexing.

So, it will be 30 units in 1 minute. Directly we can find out by knowing the driver rotational speed of the Geneva mechanism. Once we know that $\Pr oduction\ time = \dfrac{1}{\Pr oduction\ rate}$, the production rate is 30 units per minute, so it will be $\Pr oduction\ time = \dfrac{1}{\Pr oduction\ rate} = \dfrac{1}{30} units/\min = \dfrac{1}{30} x60 = 2\sec/unit$. So, this will be the production time.

(Refer Slide Time: 09:25)



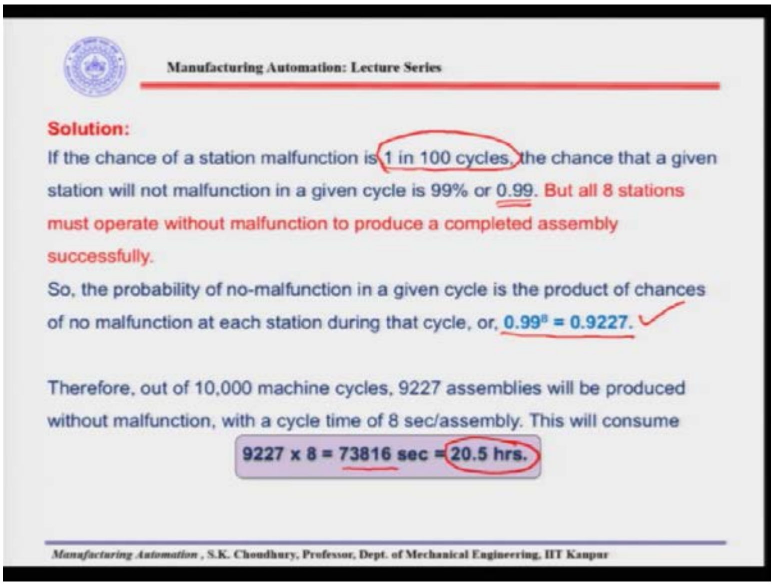
What is the throughput time? Throughput time will be the number of stations into the production time. Because, as you understand and we said that throughput time is the time taken for a complete assembly to be completed. Now, in case of production time the number of machines is immaterial I will once again repeat that, if in the line there are 100 machines or 100 or 1000 machines does not matter, still in one indexing one complete part or one complete assembly can be taken. Now for the throughput time, since it is the complete assembly time, so, it depends on the number of machines.

So, if there are more number of machines, it will take more time, throughput time. Therefore, the production time into the number of stations will be equal to the throughput time. So, as you can see that if the production time is 2 second per unit, the throughput time is 16 seconds. It is obvious. Now, here if you have seen that we have not considered the line breakdown and we said that in ideal case this is the case that if no breakdown occurs then we will have the throughput time as 16 second and we will have the production time as 2 second per unit.

Suppose, there is a breakdown, an 8-station rotary indexing assembly machine driven by a Geneva mechanism again has an indexing time of 3 second we will change that example a little bit considering the breakdown, machine breakdown. Under ideal condition the machine produces a complete assembly in 8 second achieving a production rate of $\frac{1}{8}x60x60$ which is 450 per hour. Suppose each station malfunctions once in every 100 cycles, let us assume one or more station malfunction will immediately jam the indexing machine, requiring an operator to make adjustment to restart the machine. Suppose that adjustment time and the restarting takes about 10 minutes that is T_d.

So, once again I will come back to this T_d, so this is the T_d which is the average downtime to diagnose the problem. So, let us say in this example we have the $T_d = 10$ minutes, that is when the line breakdown occurs the 10 minutes will be taken by an operator to diagnose and to repair that fault and to rerun the line. Now, let us see how this 16 second for throughput time and 2 second per unit as the production time changes only because of 1 breakdown per 100 cycles and there are 8 stations, so this is the second example.

(Refer Slide Time: 12:22)

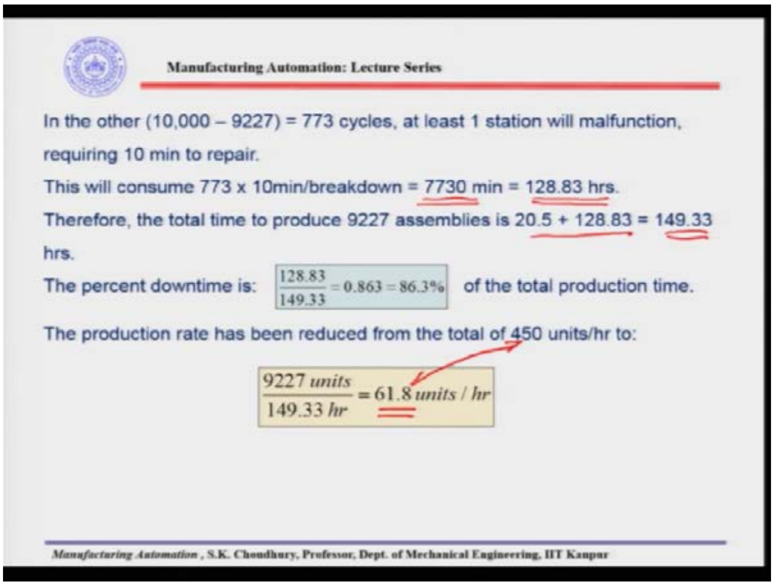


If the chance of a station malfunction is 1 in 100 cycles, the chance that a given station will not malfunction in a given cycle is 99% because, 1 in 100 cycles, the probability is 0.99; one station malfunctioning does not mean that all other machines will work. So, this probability stands valid that all 8 stations must operate without malfunction to produce a completed assembly successfully.

So, the probability of no malfunction in a given cycle is the product of chances of no malfunction at each station during that cycle. So, there are 8 stations and no malfunctioning probability is 0.99. The probability of no malfunctioning in a given cycle will be 0.99^8 , to the power number of stations which is 0.9227. What does it mean that 0.9227; that means, out of 10000 machine cycles 9227 assemblies will be produced. Is it clear? Once again, I will repeat, it is 1 in 100 cycles the machine malfunctions, station malfunctions.

So, the station will not malfunction that probability is 0.99 or 99%. So, all 8 machines should work. Therefore, 0.99^8 is the probability. So, out of 10000 machine cycles, 9227 cycles will work; that means, these many assemblies will be produced, i.e., 9227 without malfunction. And, the cycle time is 8 second per assembly, let us consider, and this will consume then 9227 x 8 sec = 73816 seconds = 20.5 hours. So, this is the time taken for assembly, if 1 machine or 1 workstation malfunctions in 100 cycles.

(Refer Slide Time: 14:45)

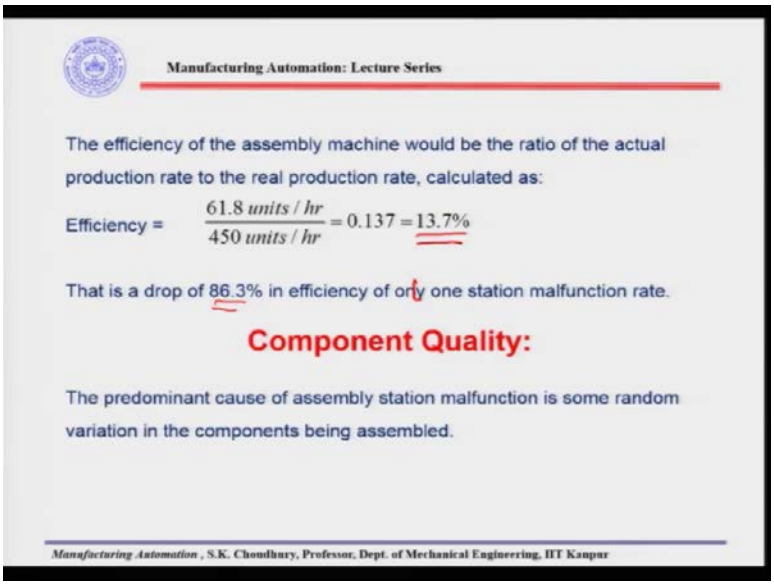


Now, what about other cycles? In 10000 there are 9227 assemblies produced and in 773 cycles at least 1 station will malfunction. So, that requires 10 minutes to repair. So, there are seven 773 cycles of malfunctioning each requiring 10 minutes per breakdown, so it will be 773 x 10. So, this will be 7730 minutes that is 128.83 hours of the breakdown. I would like to once again point out that 20.5 hours it takes to process the parts or to make the parts; whereas, if even 1 breakdown happens in 100 cycles it takes 128.83 hours this is the real practical example.

So, the total time to produce 9227 assemblies will be 20.5 hours and we have 128.83 hours. So, the total is 149.33 hours, out of that most of the time is taken by the downtime. That means, when the machine is down and we have to repair and we have to re-run the machine so that means, the percentage of downtime will be $\frac{128.8}{149.33} = 86.3\%$ of the total production time that the percentage downtime we are having. That means, 86.3% the machine is down, just imagine, we are talking about one breakdown per 100 cycles.

The production rate has been reduced from the total of 450 units per hour. Why we are talking about 450 units? We have already said that. That means, we have the 450 units per hour which is the ideal one. If machine breakdown did not happen, then we would have produced 450 units per hour; instead of that what we are having is that we have 9227 units produced in 149.33 hours and this has taken 61.8 units per hour. So, just compare that we could produce ideally without break down 450 units per hour; and now we are producing 61.8 units per hour only because of one station breakdown in 100 cycles.

(Refer Slide Time: 17:38)



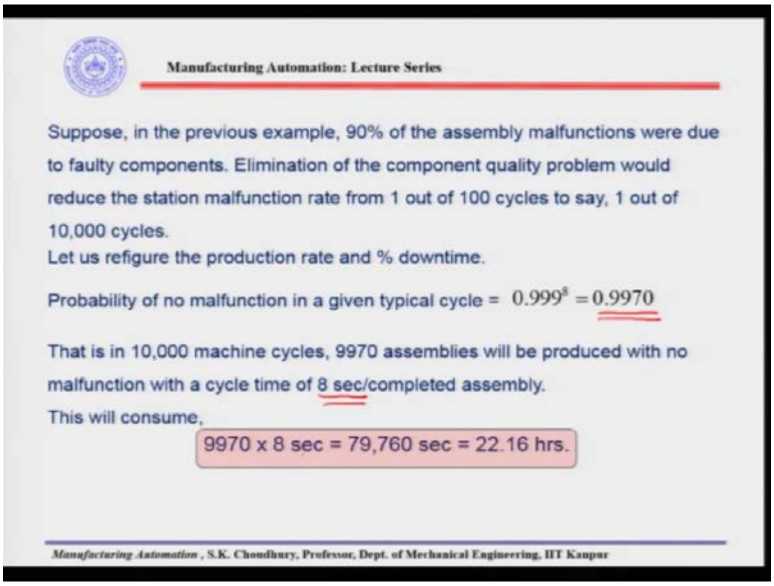
So, the efficiency of the assembly machine would be the ratio of the actual production rate to the real production rate and that can be calculated as $\frac{61.8}{450} = 13.7\%$ of efficiency. Just imagine, 86.3% drop in the efficiency of only one station malfunction, 86.3% drop because the 13.7% only is the efficiency, meaning that only 13.7% of the total production time the machine is working, that is the efficiency.

Let us go further. Let us talk about the component quality. Why the breakdown occurs? Machine breakdown basically occurs if a component, faulty component comes to the machine and gets stuck. That means, suppose you are assembling an assembly and in that assembly component goes in, which is a defective component; that means, the component, let us say, dimensions are not proper or the tolerances are not proper.

So, the machine does not know it and will try to fit in, but it will not go then the machine stops. Once the machine stops, the subsequent or the adjoining machines, since they are integrated, also will suffer. They have to stop. We will discuss that in details later. But the predominant cause of assembly station malfunction is some random variation in the components being assembled. That random variation is basically the quality of the parts.

Because, the part is of inferior quality, it actually goes in and makes a defective assembly, and stops the machine.

(Refer Slide Time: 19:38)



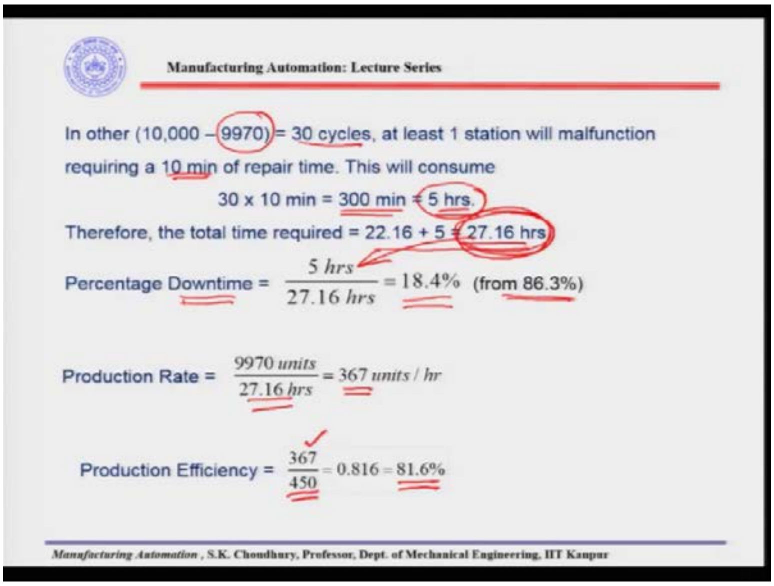
Suppose, in the previous example 90% of the assembly malfunctions were due to faulty components; and the faulty components, I told that this may be due to wrong tolerances or the length or the diameter is not proper and so on. Elimination of the component quality problem would reduce the station malfunction rate, let us say from 1 out of 100 cycles to say 1 out of 1000 cycles. Suppose, in ideal condition, that means, condition is such that we have improved the product quality, in the sense that the parts quality which will go to the assembly, quality has been enhanced.

And, because of the higher quality of the parts which will be assembled, now the machine breakdown will be less. Let us suppose, that in our earlier example we have 1 out of 100 cycles breakdown, now it will have one out of 1000 cycles breakdown. Let us refigure the production rate and the percentage of downtime because of that. Now, probability of no malfunction in a given typical cycle will be 0.999 because, 1 out of 1000 cycles is malfunctioning.

So, 1000 - 1 = 999 it will function. That means, it will not malfunction 0.999 and all the 8 machines have to be in the non malfunctioning position. So, 0.999 to the power 8 will be point 0.9970 and this means that out of 10000 parts or 10000 machine cycles 9970 assemblies will be produced without any malfunction because, the line is up for those many cycles. And cycle time is 8 second per completed assembly. So, it will take 9970 x 8 sec = 22.16 hours.

So, if we have 1 malfunction in 1000 cycles because, we have improved the quality of the parts we will now have 22.16 processing time.

(Refer Slide Time: 22:03)



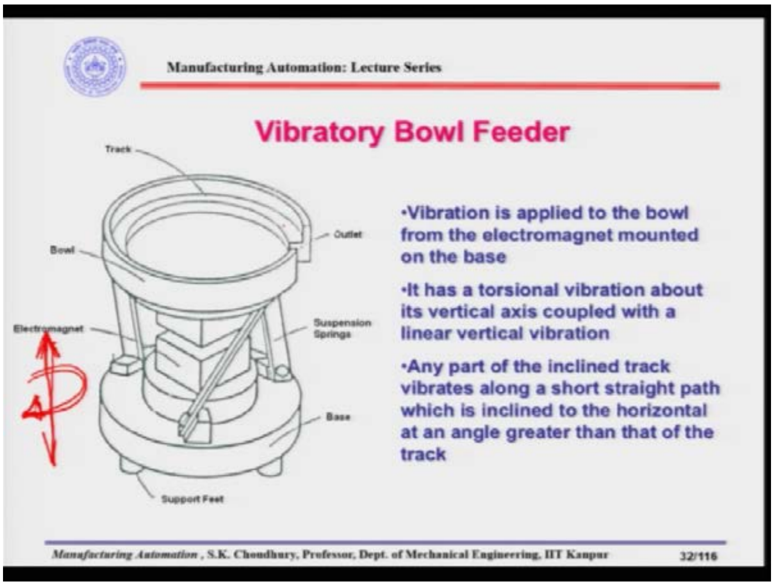
What happens with the other? In other 10000 minus 9970 this is 30 cycles at least one station will malfunction; and that will require 10 minutes of repair time this will consume 30 x 10 = 300 minutes that is 5 hours, 5 hours will be the downtime. That means, it will take 5 hours to take care of the downtime to rerun the machine to diagnose the problem and so on. So, the total time required will be we have 22.16 hours plus we have 5 hours.

So, this will be 27.16 hours. It is total time required. So, the percentage downtime we can find out that we have the $\frac{5hours}{27.16hrs} = 18.4\%$. The percentage downtime we had earlier, I will like to remind you, when we had the breakdown per 100 cycles was 86.3. And, here the downtime is much less and it has become 18.4% because we have improved the product quality. Now the production rate will be 9970 units that we are producing for a total of 27.16 hours.

So, this will give you 367 units per hour. And therefore, the efficiency is earlier ideal one, I have shown it to you, was 450 ideally; if breakdown occurs as 1 breakdown in 1000 cycles it will be 367. So, the efficiency is $\frac{367}{450} = 81.6\%$. So, this will give you 81.6% efficiency. Efficiency has grown up much more. So, here what we are saying is that the improvement in the product quality is actually bringing down the downtime. That means, the machine efficiency is going up, the machine breakdown will be less. What is the consequence? We cannot really improve the product quality just to get this because, while improving the product quality, we are also investing money in that.

And those details we will discuss at a later stage, but you have to understand that although, we are getting the production efficiency much higher by improving the product quality, which are assembled, it is not that easy. It has to be properly justified, it has to be weighted. And, then decision can be taken about how much improvement in the product quality you can get so that overall you can get the cost per piece ideal or lower. Next topic that we will be discussing is the feeder for small engineering parts which go into the assembly for the assembly process and, the feeders which are used for feeding those small engineering parts to the workstation for assembly.

(Refer Slide Time: 25:39)



One of the most popular, most important and the most used feeder is the vibratory bowl feeder. As you can see in the diagram here, in the three dimensional picture, a pictorial view given. Here we have the bowl feeder, overall this is the bowl, and here we have the outlet. The bowl is closed here. Inside the bowl there is a track along the outer wall of the bowl. The entire bowl is supported by the suspension springs to the base of the bowl feeder and in the base there is an electromagnet.

So, that electromagnet actually imparts the vibration to the bowl and anything that is located in the bowl. Now, these small engineering parts will be located at the base of the bowl and as the electromagnet imparts the vibration, the vibration causes the parts to ride along the track of the vibratory bowl feeder and finally, come out of this feeder. This is the outlet. Now, how it happens and why it happens? The vibration is applied to the bowl from the electromagnet mounted at the base, here is the electromagnet it has a torsional vibration about its vertical axis, coupled with a linear vertical vibration.

So, what it does, this electromagnet? It actually produces a vibration like this vertically and a vibration like this, there is a torque. It has a torsional vibration, this is the torsional vibration about its vertical axis coupled with a linear vertical vibration - this is the linear vertical vibration and there is a torsional vibration. So, because of that, as a result, the small parts which are located at the base will be forced to ride along the track of the bowl feeder and it will come out of the exit. The detailed analysis and how to design the vibratory bowl feeder we will discuss in the next class.

Thank you very much.