Manufacturing Automation
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Lecture – 19

Hello and welcome back to the series of Manufacturing Automation Sessions. So, I would like to remind you that last time we started discussing the precedence diagram for the automatic assembly. And it was said that the precedence diagram helps us in finding out the different ways of getting the assembly. Let us take an example of this small assembly which is the power plug assembly and we said that the any assembly small or big it is better to have on a base plate.

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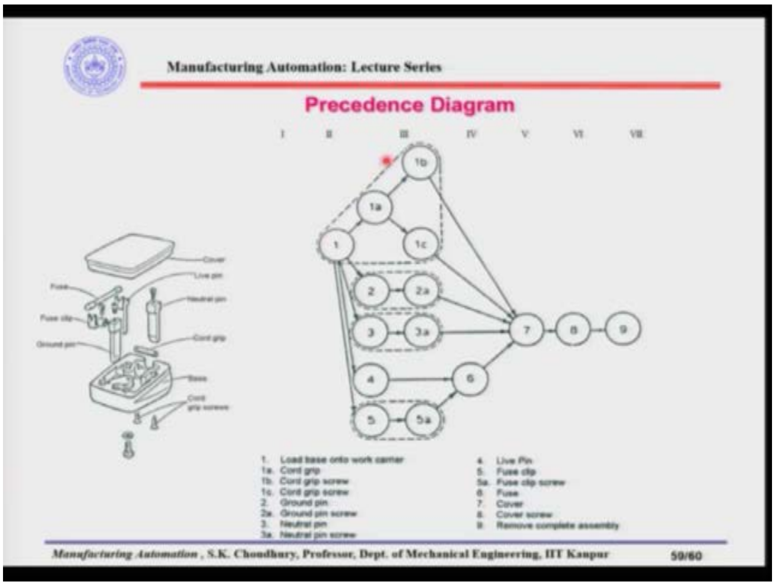

So, this is the base for the assembly of the power plug. On the base, we are trying to assemble the ground pin, fuse clips, neutral pin, life pin, cord grip, cord grip screws and then the cover. So, let us see how the precedence diagram helps us in finding out how many ways the assembly can be performed.

So, in the precedence diagram each activity is given a number and this is encircled. For example, this one is the load base on to work carrier. Since nothing can be done without loading the base onto the work carrier, all the arrows are going from 1 to 1a, 2, 3, 4 and 5. Well 2 is the ground pin, 3 is the neutral pin, 4 is the life pin; 5 is the fuse clip.

Now, with the dotted line the sub assemblies are being shown. For example, 1a is the cord grip which is this, 1b is the cord grip screws which are coming from the other side and 1c this is the cord grip screws as well. So, since the cord grip screws will be coming from the other side rather than the cover or the cord grip; for example, therefore, 1, 1a, 1b and 1c they have been shown in the dotted line which will be sub assembly.

So, after that when the base is loaded onto the work carrier, the second column will be 2, 3, 4, 5 that is; ground pin, neutral pin, life pin and the fuse clip. Now this is given in one column saying that 2, 3, 4, 5 can be made or can be assembled in any order. So, that is why it is given in one column all right. After 2, 2a is given as a sub assembly, because 2 is the ground pin and 2a is the ground pin screws. This is the ground pin and these are the ground pin screws.

So, ground pin and ground pin screws can be made separately as a sub assembly. Similarly, the neutral pin and the neutral pin screws, this is the neutral pin and the neutral pin screw, can be made as a sub assembly separately and then the entire sub assembly can be put here on the base. Now 5 and 5a, 5 is the fuse clip and these are the fuse clip screws so, it can also be made as a sub assembly.

Then it is 6, which is the fuse, after the clips are made so, the fuse is mounted or assembled, after that, this is cover, then it is the cover screw and then remove complete assembly. Now as you can see that these are subdivided in two columns for example, 1 is in one column, column number one, 2 in column number two we have the 2, 3, 4, 5, as I said that they can be made in any sequence and so on. But then 7, 8 and 9 they are separately standalone in the sense that there is no alternative of 7, 8 and 9.

So, 7 has to be done first, then 8 and then 9, because as you can see that first cover has to be put, cover has to be assembled, then the cover screws can go from the other side and so, on. So, there is one point here in the assembly process that if the assembly is very big meaning that there are lot of parts to assemble, in that case not to have the large number of assembly work heads and the assembly machine, many times what is done is that assemblies are broken into small sub assemblies and the sub assemblies are made in a line. After that all these other assemblies will be put together as an assembly.

So, in that case what is happening is for example, here as you can see this sub assembly example will be 2, 2a or 1, 1a, 1b and 1c meaning the load base onto the work carrier, cord grip, cord grip screws and cord grip screws are separately. So, they can be made as a sub assembly. For example, in this case the number of work station will be only 4 or maybe it is 3, because the cord grip screws can be made in 1 for both of them 1b and the 1c. So, we divide them into sub assembly and let us see an example that when this power plug assembly is made into sub assemblies then how many ways the sub assemblies can be assembled. Let us see that.

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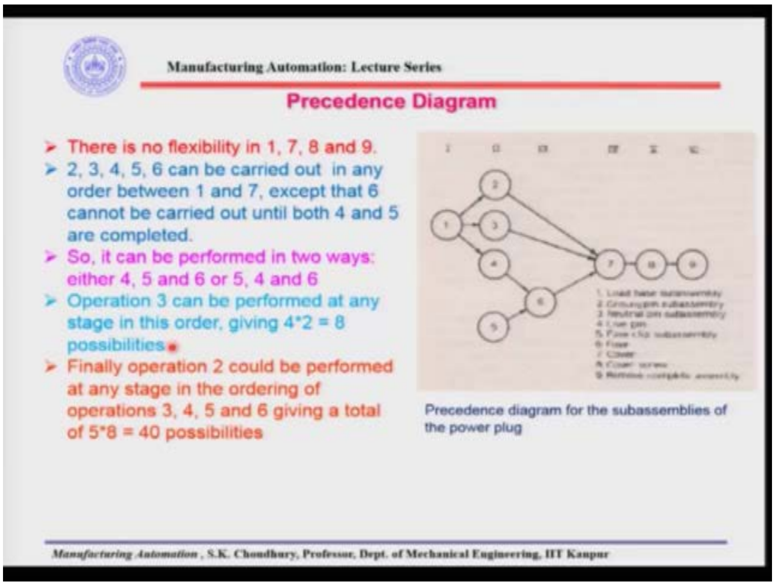

Here is a precedence diagram for the sub assemblies of the same power plug, power plug is the same, but here it is the sub assembly. For example, 1 it is the load base sub assembly, 2 is the ground pin sub assembly; meaning that ground pin with the ground pin screws made together in a separate place and then that sub assembly is given here for the entire assembly.

Now, why we are giving this example? Because this is a smaller number of parts; much smaller number of parts than it is made in practice. For example, in the automatic assembly of other production machines there may be 1000 or 10000 of parts. So, to make all those parts together in one assembly, one at a time, it will need a large number of work heads therefore, there will be possibility of the machine breakdown. That means, out of 1000 machines, somewhere or other 1 or 2 machines may not work. But if we make them, if we break these assemblies, bigger assemblies into smaller assemblies of let us say 10-12 parts, then there will be 10-12 work heads only working together at a time.

So, in that case the possibility of machine breakdown will be much less and then production time can be decreased or production rate could be increased. Let us see this sub assembly. So, 1 is as I said that 1 is the load based sub assembly, 2 is the ground pin sub assembly, 3 is the neutral pin sub assembly, 4 is the life pin, fuse clip sub assembly is the 5, 6 is the fuse, then the cover then the cover screws and then removal of the complete assembly.

Now, as I said there is no flexibility in the sub assembly of 1, 7, 8 and 9. So, therefore, they are given in a separate column. Now 2, 3, 4, 5 they are given in one column. So, there is a flexibility in the sense 2, 3, 4, 5 can be made in a different way. So between 1 and 7; 2, 3, 4, 5 and 6 can be carried out in any order except that 6 cannot be carried out until 4 and 5 are completed.

Let us see 4 and 5: live pin and the fuse clip, meaning that fuse which is 6, cannot be assembled before the fuse clip sub assembly and the live pin subassembly go in. You can see that in here for example, here is the fuse clip and here is the live pin; so, before the fuse clip and live pin, the fuse cannot go in. So, after the live pin is inserted and the fuse clip with the screws inserted here, then the fuse can go in. So, that is why it is said that 6 cannot be carried out before the 4 and 5 are completed.

Next it can be performed in two ways; like 4, 5 and 6 or 5, 4 and 6. Meaning that if we have this, we can do the fuse clip first then live pin or live pin first then fuse clip and then the fuse can be inserted. So, there are two ways of doing that; first 4 and then 5 then 6 or first 5 then 4 then 6 all right. Operation 3 can be performed at any stage in this order; that means, there are two ways of doing that and in this order we can perform the operation 3 which is the neutral pin sub assembly in any way in any order. So, there will be 1, 2, 3, 4, into 2 ways that will be 8. So, number of possibilities will be 8 then. Finally, operation 2 could be performed at any stage in the ordering of operations 3, 4, 5 and 6 and earlier it was we have seen there are 8 possibilities. So, now, there are 1, 2, 3, 4, 5, into 8 will be 40 possibilities.

So, you can see that for a small sub assembly like this which is power plug sub assembly, we have 40 different ways to do that even when we have the 1, 7, 8 and 9 there is no other possibility. They are rigid. So, only in 2, 3, 4, 5, and 6 there are 40 possibilities. So, if we are talking about a big assembly for example, or big sub assemblies for example, there could be many ways and we can select the best possible way for us depending on our capability, depending on our convenience we can take the best possible way and it is all shown by the precedence diagram. This is the advantage of the precedence diagram particularly when the assembly is very big and a very large number of parts involved in the assembly process.

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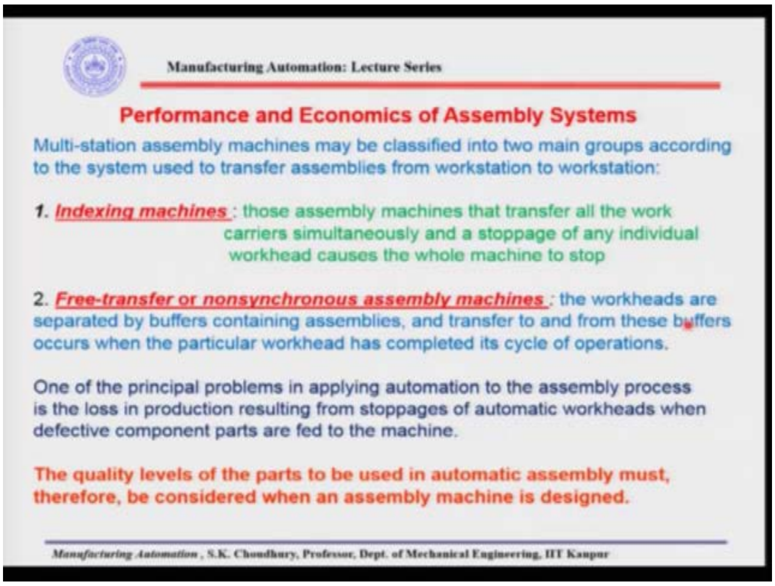

Our next topic; we will discuss the performance and economics of assembly systems. This will be our last topic in this series of lectures. So, what does it mean that when an assembly system works, let us see how effectively it can be exploited. How effectively it can work. Multi station assembly machines may be classified into two main groups according to the system used to transfer assemblies from workstation to workstation. This we have discussed earlier like there are two basic groups, either it can be an in-line indexing type or it can be free transfer or non-asynchronous assembly machines.

Now, in case of indexing machines as we discussed earlier, we have an indexing table and the workstations are located around that indexing table. Now the part will go from one station to another station, meaning the sub assembly, will go from one station to another station indexing and then it will dwell for some times till the sub assembly operation is over in that work head. Now in case of free transfer or non- asynchronous assembly machines we do not have the indexing table and therefore, we have the buffer stock in between.

So, if a machine stops, in that case the other machines may not suffer till the buffer stock is filled up or buffer stock is available. So, indexing machines are those assembly machines that transfer all the work carriers simultaneously and a stoppage of any individual work head causes the whole machine or line to stop. Now here of course, the disadvantage in the indexing machines will be that if one machine stops, the other machine will be stopping, but keeping in mind that indexing machines are used for small parts, small assemblies, small number of machines so, we assume that the stoppage of the machines will be rare.

And particularly, like I said that a big assembly could be broken into sub assemblies and the sub assemblies can be assembled first. So, those kinds of small sub assemblies can be assembled in the indexing machines for example. Now free transfer or non asynchronous assembly machines, the work heads are separated by buffers as I said. Buffer contains subassemblies or parts and transfer to and from these buffers occurs when the particular work head has completed its cycle of operations.

So, the buffer stock is as I said initially when we have discussed the buffer stock, it is actually a locking of capital, but it is required particularly in the free transfer machines, where a large number of machines are there and the possibilities of the machine down will be higher. So, in this case what happens is that one machine which will finish the sub assembly will keep it in the buffer and from the buffer the next machine will take up the sub assembly as and when next machine requires.

So, in that case the machine time can be different in 2 subsequent machines, because the machine number 2 does not wait for the machine number 1 to finish, because machine number 1 will finish and put the sub assembly in the buffer and from the buffer the machine number 2, that is the next machine will take up. So, those are the free transfer machines. One of the principal problems in applying automation to the assembly process, as we know, is the loss of production resulting from stoppages of automatic work heads, when defective component parts are fed to the machine.

This we have discussed earlier. So, there could be two situations; one is that when a defective part goes in then the defective part either cannot go and stop the machine, or it will go, and it will make an unacceptable assembly. These are the two possibilities which we will discuss here as well. Now the quality level of the parts to be used in automatic assembly must therefore, be considered when an assembly machine is designed. Meaning that quality level of the parts which are going to the sub assembly or the assembly should be high enough so that the machine does not stop or the work head does not stop. This is the idea here.

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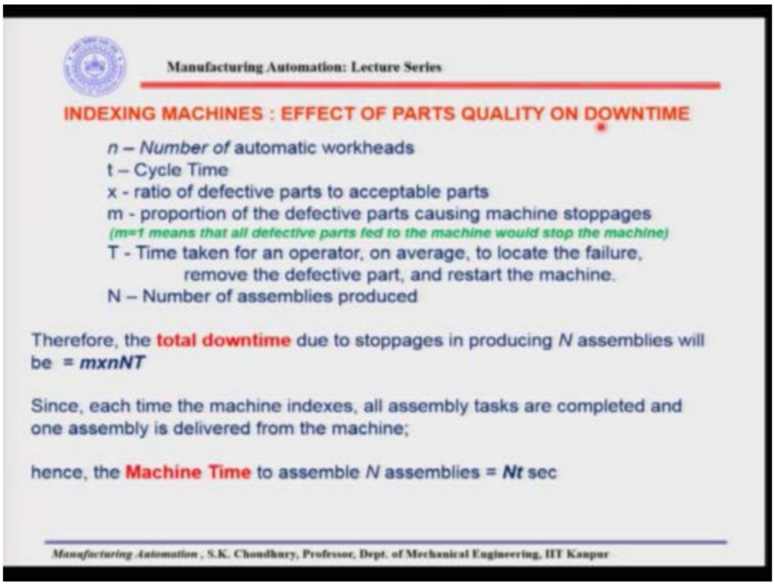

Let us discuss first the indexing machines and the effect of part quality on the downtime. Meaning that if we have different quality of parts then how the downtime of the machine will behave; that means, we will find out the down time. Now in this analysis let us say n is the number of automatic work heads, t is the cycle time, x is the ratio of defective parts to acceptable parts. What does it mean?

So, x is ratio of defective parts to acceptable parts, means that this actually gives you the quality ratio that how good a part is, what type of quality the part will have; x is reflecting the quality level of the parts, m is the proportion of the defective parts causing machine stoppages. Meaning that if m is equal to 1 for example, then all the defective parts going into the machine will stop the machine means that all defective parts fed to the machine would stop the machine. If m is less than 1 in that case not all defective parts will go and stop the machine, but they will make an unacceptable assembly, because the part is faulty, it will not stop the machine but it will make an unacceptable assembly. Let us keep that in mind.

Now, T is the time taken for an operator, on an average to locate the failure, if the machine stops or the line stops to remove the defective part and restart the machine. So, if you remember this, we discussed earlier that this is the time an operator will spend to find out what happened and then diagnose the problem and then re-run or restart the machine.

N is the number of assemblies produced in the line. Therefore, the total downtime due to stoppages in producing N assemblies will be depending on the m, that is proportion of the defective parts causing machine stoppage. It may be is equal to 1 or it may be less than 1, that is m. Then it will depend on the quality factor of the parts which are going into the sub assembly that is x. Then it will be number of automatic work heads. Larger number of automatic work heads will have the larger possibility of the downtime that is what we said. So, the total downtime is a direct factor of the number of automatic work heads as well.

Then depending on how many assemblies we are producing; if we are producing more number of assemblies; that means, more time the machines will be working and downtime possibilities will be more. So, it is a direct function of the N which is the number of assemblies produced and the T which is the time taken for an operator on an average to locate the failure, remove the defective part and restart the machine. So, once again total downtime we are having equal to $mxnNT$.

Since each time the machine indexes all assembly tasks are completed; mind it we are discussing the indexing machines. So, in indexing machines as I said last time, once it indexed, in that case one complete assembly will be obtained at the output. So, since each time the machine indexes all assembly tasks are completed and one assembly is delivered from the machine at the output, at the output level; hence the machine time to assemble n assembly since it is taking t is the cycle time into the number of assemblies produced. So, the machine time will be $n\,t$.

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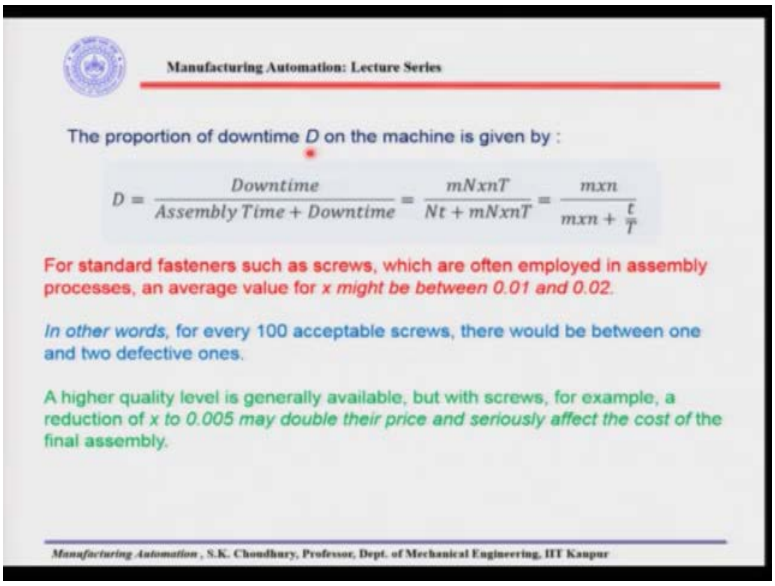

Therefore, the proportion of down time D on the machine is given by the downtime and complete time. So, it will be downtime plus assembly time plus down time. So, assembly time plus downtime is the complete time taken for the assembly and since we are finding out the proportion of downtime so, this will be downtime divided by the total time. So, downtime we have seen that this is $mxnNT$, divided by machine time or assembly time will be capital Nt which is the number of assemblies into the cycle time plus the same downtime $mxnNT$.

So, that can be simplified as $\frac{mxn}{mxn + \frac{t}{T}}$. For standard fasteners, such as screws, which are often employed in assembly processes, an average value of x might be between 0.01 to 0.02. Now why we are discussing this x, because this is the quality level of parts. So, here if you see that the proportion of downtime D is directly proportional to the x.

So, if we can vary this or if we if we can decrease or increase that, in that case our proportion of downtime, D will be changed. So, therefore, we are saying that majority of the parts, small parts are screws so, there x might be between 0.01 and 0.02. Meaning that out of 100 parts, 1 may be defective if it is 0.01 or 0.02 out of 100 parts 2 parts are defective, 2 parts means in this case we are talking about the screws.

Because these are the small parts which are used maximum. In other words for every 100 acceptable screws, there would be between 1 and 2 defective ones, depending on the value of the $x = 0.01$ or 0.02. So, what will happen that whenever this kind of parts will go, if it is one part in 100 so, in 100 cycles 1 cycle will be down, because the screw is unacceptable; meaning that it can go to the assembly either it can stop or assembly work head or it can spoil the assembly.

The higher quality level is generally available, but with screws for example, a reduction of x from 0.01 to 0.005 for example, 0.005 you can interpret as out of 1000 there are 5 screws which will be unacceptable, may double their price and seriously affect the cost of the final assembly. So, there is a contradiction, if we are increasing the quality level of the parts, the assembly downtime will be less, but at the same time the cost of the assembly will be increased; obviously. So, you have to judiciously find out that what is important for us; whether the part level can be increased we will invest more money and then down time will be reduced or in some cases we can allow these defective parts to go and spoil the assembly but we will not stop the machine.

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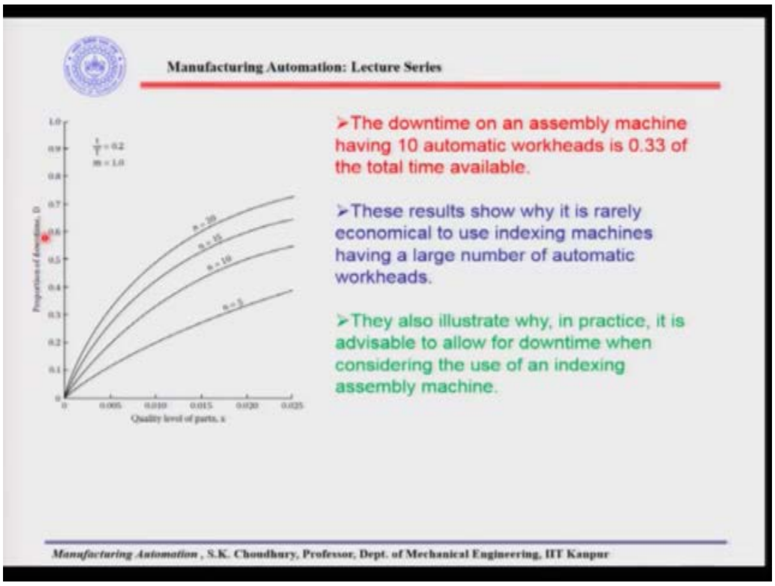

So, these are the two aspects that we will discuss now, let us see. Now if we draw the curve, this is the proportion of down time and this is the quality level of parts; quality level of parts is x all right. So, here the quality level of parts we are telling as out of

1000 there are 5 parts defective, out of 1000 there are 10 parts, 15, 20, 25, and so, on. So, here we are taking the proportion of downtime as 0.1, 0.2, 0.3, 0.4 and so on up to 1.

So, by the way proportion of downtime also is expressed in percentage all right. So, for example, 0.2 is 20 percent, 0.9 is 90 percent and so, on. The downtime on an assembly machine having 10 automatic work heads is 0.33 of the total time available from the curve. Meaning that these curves are made for different number of work heads 5, 10, 15 and 20 and also for some constant parameters like t, that is the cycle time; divided by time taken for an operator to find out the fault and restart the machine and then m is equal to 1; that means, all defective parts going into the machine stop the machine that is the m is equal to 1, I said to you.

Now for example, for 10 work heads this will be for an assembly machine of 10 it is about 0.33. So, for a particular quality level of parts we are saying that you can find out what will be the proportion of downtime for the number of parts, either 5, 10, 15 or 20. Subsequent results how we can get it and whether we need the large number of machines and what is the difficulty in having the larger number of machines we will discuss in the next session.

Thank you very much.