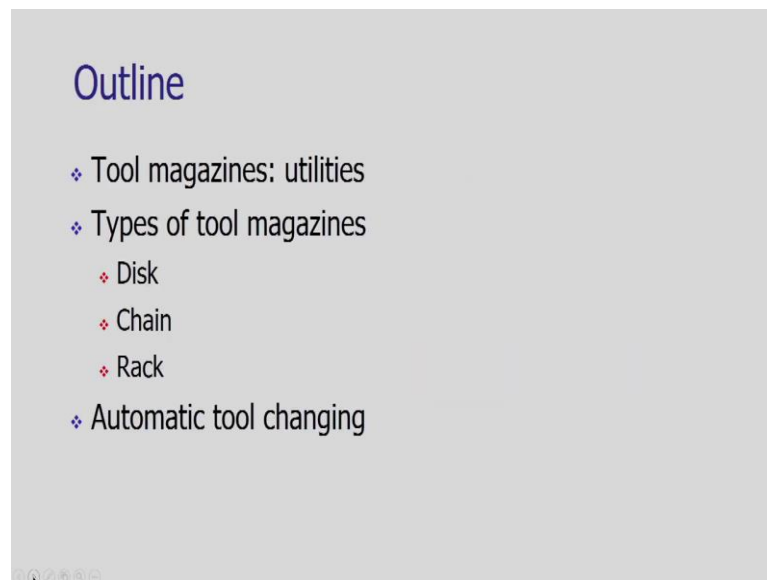


**Automation in Manufacturing**  
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**Week – 08**  
**Mechanisms**  
**Lecture – 02**  
**Application of tool magazines in automation**

Hello and welcome to the week 8 lecture 2 of Automation in Manufacturing. The lecture 2 of week 8 is focused upon Application of tool magazines in automation.

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CNC machine tools are an integrated and important element of an automated manufacturing system. The productivity of entire tool room or the productivity of the automated manufacturing system is dependent upon the tool changing. How efficiently we can change the tool? How efficiently we can manage the tool related operations?

It may be change of the tool, handling of the tool, storage of the tool and maintenance of the tool. The crucial element in the entire operation is the tool magazine. In this lecture, the importance of tool magazine will be studied. There are various types of tool magazines used. These are disk type, chain type, rack type tool magazines. At the end of this lecture, the automatic tool changing operation will also be studied.

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## Introduction to tool magazines and transfer systems

- ❖ Tool changing operation is time consuming which reduces the machine utilization.
- ❖ **Automatic Tool Changer (ATC)** facility: changes tool automatically, reduces the idle time.
- ❖ Large numbers of tools can be stored in tool magazines.
- ❖ Tool magazines are specified by their storage capacity, tool change procedure and shape. The storage capacity ranges from 12 to 200.



The product life cycle have been studied in our previous lectures. The product life cycle has design related operations and it also has the manufacturing related operations. In manufacturing, basically we are transforming the raw material into finished product by using various machine tool arrangements.

In machine tools, the tool is the critical parameter or factor, which is affecting the productivity. There are various time elements associated with the tool. The fundamental time element is the cutting time when the tool is in contact with the work piece. And, during that contact, it is removing the material from the work part. The next is the tool change time and it consumes lot of energy, lot of time during the operation.

We are storing tool somewhere and when we change the tool, there may be chances of having the error as well. When the tool is worn out, we need to either replace the tool, by another new tool, or we have to regrind the tool, and then reuse the same tool. This entire operation is very time consuming. When we are working with very hard material, high strain material, the tool worn out possibilities are very high, the tool is wearing off very height.

Thus, there will be more frequent tool changing operations need to be carried out. These are affecting the productivity. In automation to have the real 100% automation of the manufacturing system, we should have automatic storage of the tools and automatic

changing of the tool from the spindle operation. That is why it is very essential for us to understand to learn the concepts of the tool magazines and the tool transfer system.

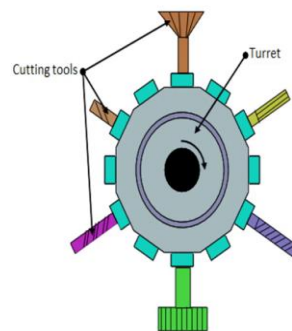
In general, a facility which is providing, the tool changing in automation is called as automatic tool changers. In the magazines we can store or hold, many number of tools they may be ranging from around 12 to 50. Sometimes, we can even have magazines we can which can store more than 100 number of tools may be around 200 number of tools.

Tool magazines are generally specified according to their storage capacity, the procedure to change the tool and the kind of shapes of the tool, the tool magazine is able to accommodate or store.

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### Tool turret

- ❖ Simplest form of tool magazine.
- ❖ Consists of a tool storage without any tool changer.
- ❖ Indexed in the required position for desired machining operation.
- ❖ Advantage of the turret is that the tool can easily be identified, but the time consumed for tool change is more unless the tool is in the adjacent slot.



The first and very simple type of tool magazine or tool storage system is tool turret. In the slide, we can see a tool turret, it is a device which can store multiple number of tools, it can be indexed and that indexing mechanisms we have seen in our previous lecture. The tool turrets are generally used on production lathe machines.

We can index tool very easily, but the changing of the tool from the spindle of the machine tool and from the tool changing facility that it is a tool turret is manual. These type of arrangement does not have any automatic tool changing operation. Tool turrets are basically used in semi automatic mode of the automation.

In some of the in automatic mode of the operations, where we are using small capacity tool magazines, or where we need to store limited number of tools. There as well we can utilize this tool turret kind of arrangement, which is compact. Some of the machine tools they do have the arrangement of changing the tool from the tool turret and loading them to the spindle of the machine tool.

These type of arrangements are nowadays available on the CNC machine tools. But, overall if the tool turret is at a certain distance, it will take certain amount of time, for the travel of the tool from the tool turret to the desired spindle of the machine tool.

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### Tool magazines

- ❖ Tool magazines are generally employed in CNC drilling and milling machines.
- ❖ Compared to tool turrets the tool magazines can hold more number of tools.
- ❖ Duplication of the tools is possible and a new tool of same type may be selected when a particular tool is worn off.

The tool magazine is an advanced or modified version of tool turret itself. The capacity of tool magazines is high in comparison with the tool turret. In general, in tool turret we can accommodate around 15 to 20 tools easily, but when we are trying to have a variety of operation that to be carried out on the work part. Say it may be drilling operations it may be, pocket milling operation, slot milling, finishing so on and so forth. For such operations we need to have an arrangement which can store multiple number of or many number of the tools.

As mentioned the problem of tool wearing, the tool regrinding is very time consuming process. To solve this problem, we can have duplicate tools, we can have multiple number of tools of the same type. When one tool which is there in operation gets worn

out, we can ask the machine tool by using the CNC part program to go for the next fresh tool, which is of the same type.

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## Tool magazines

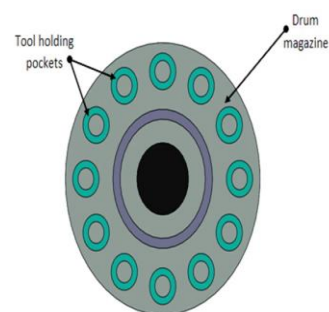
- ❖ The **power required** to move the tools in a tool magazine is **more** in comparison with that required in tool turrets.
- ❖ The following are some of the tool magazines used in automation.
  - ✓ Disc or drum type
  - ✓ Chain type
  - ✓ Rack type

That duplication facility is very much possible with the tool magazines. Of course, the energy required or the power required to move the tools in a tool magazine is more than the tool turret. Since the size of the tool turret is small, naturally the power requirement would be less. There are various types of tool magazines being used in the industry and these are disc and drum type, chain type, rack type.

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## Disc/Drum type magazine

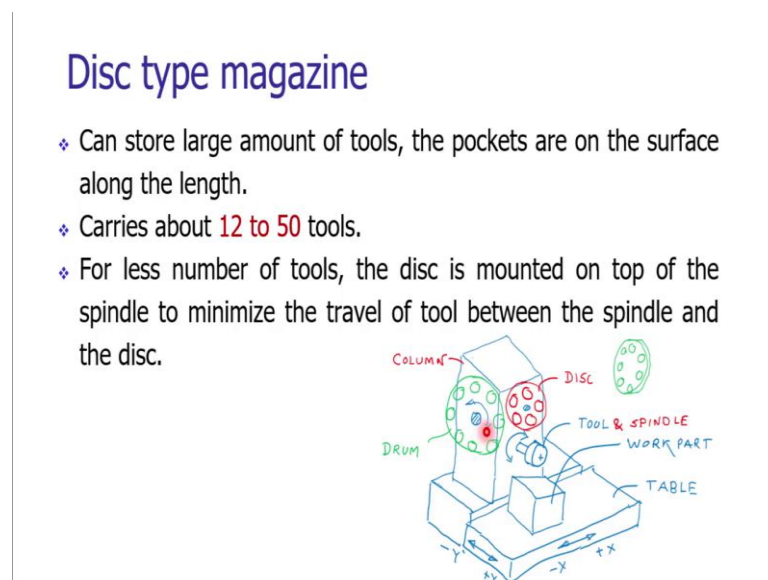
- ❖ Rotates to get the desired tool in position with the tool change arm.
- ❖ Larger the diameter of the disc/drum more the number of tools it can hold.



Let us look at the first type of the magazine, that is disc or the drum type magazine. The arrangement is very simple, we are using a disc or a drum and on the surface of the disc or the drum we are generating tool holding pockets. Inside the tool holding pockets the tools are getting mounted. The drum or the disc will be mounted on a spindle on an indexing mechanism, which we have seen in our previous lecture.

As per the indexing is programmed in a CNC machine tool, we are getting the required tool at the tool pickup station, at the tool pickup point. If we increase the diameter of the disc or the drum naturally you can hold the many number of cutting tools or the processing tools.

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The disc type magazine can store about 12 to 50 number of tools. If we want to increase the number of tools that to be mounted on the disc type mechanism then we have to use various configurations. In general, the disc which is containing these tools is mounted just above the spindle of the cutting tool.

Let us look at the arrangement. In the slide, we can see a typical CNC machining center, here we are having a table on the table the work part is held. There is a column. On the column we are housing the electrical drive. The electrical drive is driving the spindle and on the spindle the tool is attached.

Now, if the disc is of a smaller size and we are accommodating, we are storing, limited number of cutting tools then we can easily have the disc mounted just above the spindle. The reason behind this is that we can reduce the time of tool changing operation. Quickly we can process the work parts. In case the number of tools that are to be used are huge in number, then we cannot accommodate the drum or the disc just above the spindle, then we have to take use of the other side of the column.

Now, on the adjacent side of the column we can mount the drum. The drum will be indexed and there will be a tool changing mechanism we will be seeing that tool changing mechanism in the next slides.

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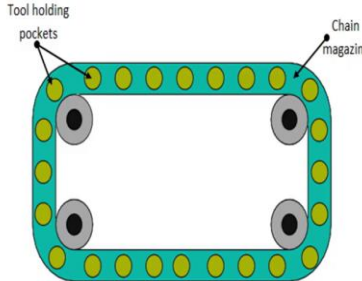
### Disc type magazine

- ❖ Can store large amount of tools, the pockets are on the surface along the length.
- ❖ Carries about 12 to 50 tools.
- ❖ For less number of tools, the disc is mounted on top of the spindle to minimize the travel of tool between the spindle and the disc.
- ❖ For more number of tools, the disc is wall mounted or mounted on the machining center column.
- ❖ If the disc is column mounted then, it needs an additional linear motion to move it to the loading station for tool change.

Thus we can say that, if the disc is mounted on top of the spindle, it will minimize a travel between the tool and spindle to the disc. If more number of tools are to be used, then we can have a wall mounted disc arrangement or we can use the adjacent side of the machining center column. Of course, it will take certain time to get the tool from the wall mounted facility or the column mounted facility.

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### Chain type magazine



The diagram illustrates a chain type magazine. It consists of a rectangular chain with yellow sprockets. Four tool holding pockets are shown, each containing a tool. The chain is labeled 'Chain magazine' and the tool holding pockets are labeled 'Tool holding pockets'.

- ❖ When the number of tools is more than 50, chain type of magazines are used.
- ❖ The magazine is mounted overhead or as a separate column.
- ❖ The tools are identified either by their location in the tool holder or by means of some coding on the tool holder.
- ❖ Tools can be duplicated.
  - ✓ one is active for machining
  - ✓ the second one is used when the duplicate tool is needed since the active tool is worn out.

The next type of magazine is chain type magazine. In this arrangement we are using a long chain, which is operated by the sprockets; these sprockets are driven by electric motors. In the chains we are having pool holding pockets, as the chain is moving which is driven by the sprockets we are getting the required indexing of the tools. Based on the required tool a tool changing mechanism will take out the tool from the chain magazine and that will be inserted into the spindle.

In general, the number of tools are more in the chain type magazines. When we are talking about more than 50 number of tools, then these type of arrangement is suitable rather than the drum or the disc. To accommodate more than 50 the drum side size would be very high very large and the inertia would be very high and that may affect the rigidity of the machine tool as well, because we are hanging the drum or the disc overhead.

In general, the chain type magazines are mounted as a separate entity, separate column is designed and developed, and over which we are mounting the chain type of magazine. There is a systematic coding need to be done for each and every tool, which is there in the chain magazine, the numbers are provided, the numbers are encoded in the automatic system that is designed to operate the chains, in synchronization with the machine tool operation.



The machine control unit has to be programmed by taking into consideration of the location and the tool number of the chain magazine. The advantage of tool magazine is that we can duplicate the tools. We can have multiple number of tools of the same kind, which will save our lot of time in case of the tool worn out. Tool wearing of it is very usual in the high speed machining or in heavy duty machining.

We can have an active tool for machining, but the second one may be there in our store in the magazine, which can easily be used once the previous one is worn out.

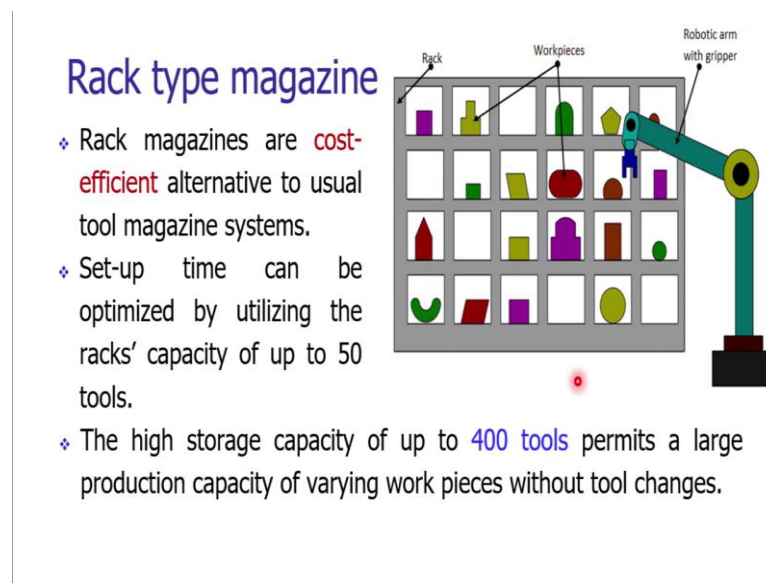
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In the slide we can see chain type of magazine; you cannot notice here a variety of tools are mounted. These are the drilling tools, milling tools, the end milling operation tools, cutting operation. The end milling may have a variety of capacity tools, there is a duplication of tool as well. This is the tool changing mechanism. This tool changing mechanism is having an arm, the both the ends of the arm are both the ends of the arm are utilized for tool changing operation.

This is the separate column which is designed and developed to host the chain type of tool magazine. We will have a detailed discussion on the tool changing facility in the coming slides.

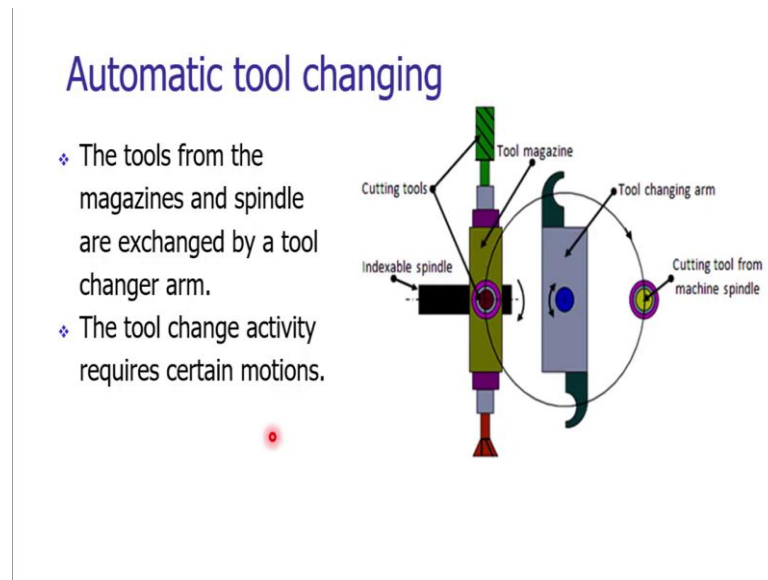
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The next type of magazine is rack type of magazine. This is cost efficient, because we can hold more than 300, may be around 400 number of tools in the rack type of magazines. Inside the rack the tools are stored and we need to have a robotic based arrangement to select to get the required tool from the rack and then mount that tool in the spindle of the machine.

Here we can see a robotic arm with gripper arrangement, which is used to get the required tool. Of course, the racks can be utilized to store the workpiece as well. Thus we can have an integrated or a single system, which will hold the workpiece, which will hold the tools as well, and the robotic based system is feeding the workpiece to the machine tool, and it is orienting the cutting tool in the spindle of the machine tool itself. Single rack would be very useful to have the automated production operations.

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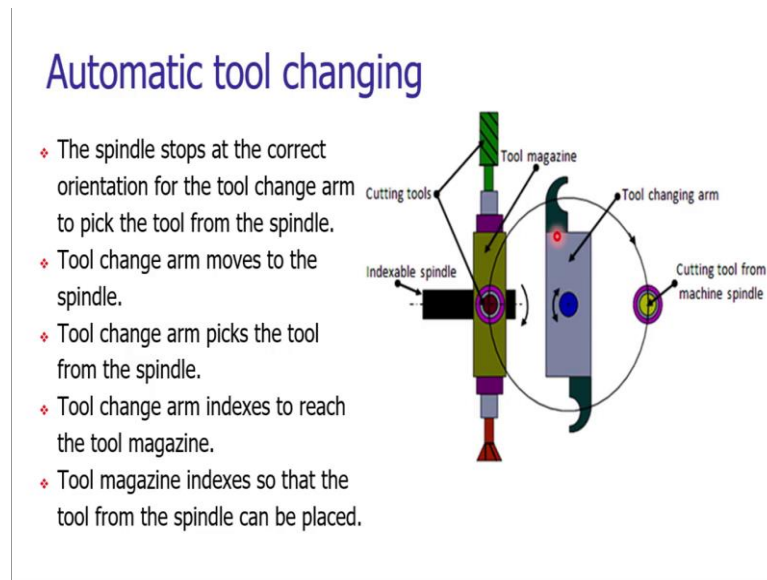


Now, let us see how the tool changing operation is being carried out. In general there are many variants of tool changing operation. Let us look at a simple tool changing operation by using a tool changing arm. In the slide we can see a cutting tool which is mounted on the machine spindle. The spindle axis is perpendicular to the plane of paper i.e. perpendicular to the plane of paper and consider the tool is mounted over here.

This is the tool magazine; the tool magazine is mounted on the indexable spindle. On the periphery of the tool magazines various tools are mounted, various tools are held. Let us look at this situation, this particular tool its axis is also perpendicular to the plane of paper. Now to have the efficient or to have the proper tool change operation, we have to select the arrangement in such a way that, the axis of the tool that to be chosen should be parallel to the axis of the machine spindle itself.

This axis is parallel to the axis of the machine tool spindle and there is the mechanism of tool changing arm, whose axis of swiveling is also parallel to the tool spindle and the axis of the cutting tool that to be chosen. To carry out the tool change operation we need to go through certain motions.

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Let us see what are these motions? It is essential that the spindle should stop at correct orientation for the tool change arm to pick up the tool from the spindle. What is the first motion? Proper orientation of the cutting tool in the machine spindle, there is pick up of the tool that to be replaced from the machine spindle.

Swiveling of the arm to collect the tool from the spindle, we have to move in a clockwise direction to get the cutting tool, the tool arm is moving in this direction, it will collect the cutting tool from the machine spindle. Picking up of the tool from the spindle. At the same time the other end of the arm is getting engaged with the tool that to be put in the machine table.

This tool is to be utilized, when we are taking out this particular tool; the tool that to be taking out we will get engaged with the other end of the swiveling arm, tool changing arm. Then the swiveling has to be carried out as the arm is getting swiveled the tool which is taken out from the spindle will be kept at. For initial 90 degrees of the rotation of the tool changing arm; the tool changing arm will be in contact with machine tool spindle, where the cutting tool is mounted.

It will pick up the cutting tool, then for the next 90 degrees it will come in this particular situation, where it is having the taken out cutting tool and it is having the cutting tool that to be mounted in the spindle.

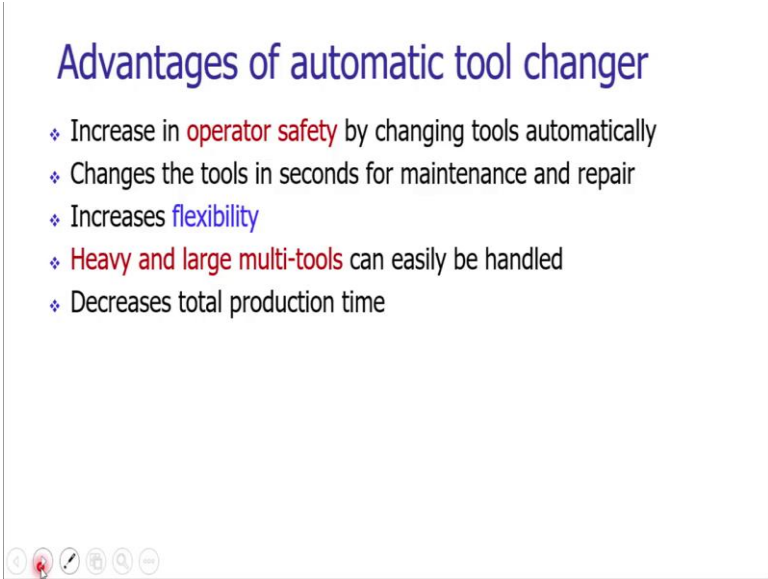
Well now we have to wait here for some time, because the destination of this particular tool is not the same destination from where we have taken the fresh cutting tool. If, this is the case of duplication we can put this cutting tool in the same location, but that is not the case in general. In case of different types of cutting tools the destination of the tool which is taken out may be different.

For that purpose, we have to wait or we have to hold the tool changing arm in this situation. After, that we have to index the tool magazine; the tool magazine will index in an incremental way and it will take the empty or the required empty slot where we need to put this particular used cutting tool.

It is predetermined, it is a pre stored, it is a pre programmed number, and that pre programmed number spot will be indexed by the MCU as the vacant slot will come to get the use tool, then the next 90 degrees would be operated. As we are operating the next 90 degrees then the tool will be put at the desired location and simultaneously there would be mounting of the next tool.

In this way we can have the efficient tool changing operation carried out. Single tool changing arm is taking out the tool from the tool magazine, it is feeding, it is mounting, the tool inside the machine spindle and helping to automate the entire tool changing operation. As mentioned the tool changing operation is the time consuming, that is the bottleneck and it is affecting the lead time of the product manufacturing.

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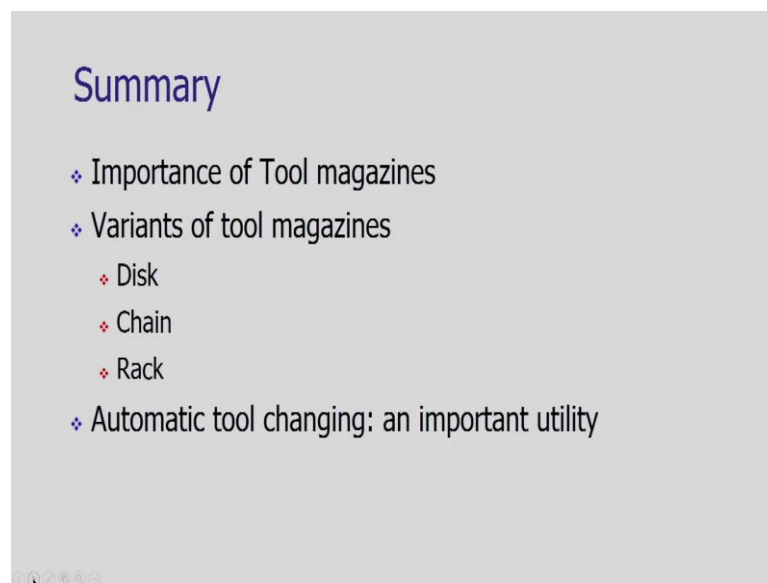
### Advantages of automatic tool changer

- ❖ Increase in **operator safety** by changing tools automatically
- ❖ Changes the tools in seconds for maintenance and repair
- ❖ Increases **flexibility**
- ❖ **Heavy and large multi-tools** can easily be handled
- ❖ Decreases total production time

In general, it can be said that there are various advantages of using this automatic tool changing. The huge tools may be having very high temperature and the tool changing operation may harm the operator or the worker. When we are carrying out this automatic tool changing operation, certainly it is enhancing the safety. The changing of the tool is at a rapid way.

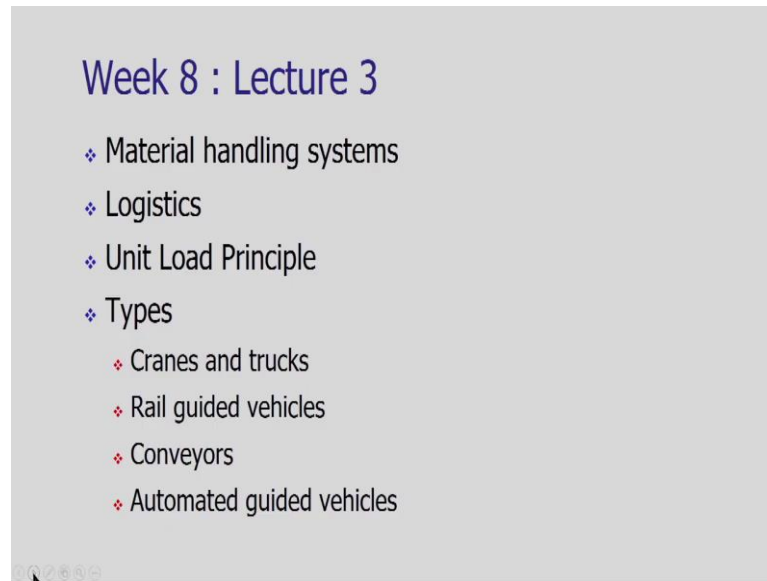
We are changing the tool in seconds and that is boosting the productivity, we are having a great flexibility. We can accommodate the huge variety of the cutting tools in the magazine and that enhances the capability of the CNC machine tool. We can easily handle heavy or the large tools, heavy size tools can easily be handled, certain tools the weight is very high for the human being as well it is difficult to handled. Overall it is reducing the production time, it is enhancing the efficiency of the system and that will lead to more productive environment.

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Let me summarize the lecture 2 of week 8 that is the tool magazines used in the automation. In this lecture we learnt the importance of tool magazine, we understood the principle of operation of a tool magazine, we have seen various variants of tool magazines, such as disk, type, chain type, rack type; at the end we studied the concept of automatic tool changing operation. And, we found that it is an important utility in the automated manufacturing systems.

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In the next lecture that is lecture 3 of week 8, we will be learning about the material handling systems, we will see the concept of logistics, the definition of unit load principle. And then we will have an elaborate discussion on cranes, trucks, rail guided vehicles, conveyors, and automated guided vehicles, which are used in the automation.

Thank you.