UNIT 12 TOOL MANAGEMENT IN ADVANCE MANUFACTURING SYSTEMS

Structure

12.1 INTRODUCTION

Fewer the parts produced by the system, lesser the parts available for the sale and this lead to the lower income generated by the system. Tool management in advanced manufacturing system takes into account automatic tool changer, calculation of tool number, tool management policy and various tool storage strategies. Tool management is very important aspect in tool engineering which is used for effective utilization of various tools for efficient production. This section deals with the description of automatic tool changer, enumeration of tool number and several policies dealing with tool storage policies.

Objectives

After studying this unit, you should be able to

- understand automatic tool changer,
- calculate the tool number,
- understand performance of tool management system, and
- understand tool storage policies.

12.2 AUTOMATIC TOOL CHANGER

Automatic tool changer (ATC) is often used with automated tool-storage devices in CNC machines to improve its tool carrying capacity. The advantages of automatic tool changer are as follows :

- ATC increases the machine tool's productive time.
- It significantly reduces the times for changing worn tools.
- It provides storage of the cutting tools, which are returned automatically to the machine tool after carrying out the required operations.
- New cutting tools are automatically delivered to the machine by the tool-changing system.
- The rotating magazine holder can provide tool-storage capacities ranging from 60 to 240 cutting units, with up to 24 different types of tool geometries.

- The integration of these mechanisms into machine tools can easily be ensured with a view to achieve superior performance.
- These systems can cover a wide range of size and options to suit most machining applications.

Therefore, these are the benefits of installing such systems, but how do they achieve such attractive production advantages, and how do they operate? This is discussed in next section.

12.2.1 Automatic Tool-changing Mechanisms on Turning Center

Cutting units can be stored in either a drum or a disc type of storage device. A typical example of the storage facilities and their automatic tool-changers is shown in Figure 12.1. The rotary tool-changer swivels between the tool magazine and the machine's turret. Each gripper can rotate through 90^o, to deliver tools to the front face of the turret. The tool-changer simultaneously removes the cutting tools from the disc magazine and the turret and then it rotates through 180^o.

The new tool is delivered to the turret and accurately positioned in the correct orientation, whilst the used tool is replaced in its correct turret position for either re-use or replacement. The tool-changer arm is withdrawn from the working area of the machine and starts the cutting cycle. A gantry-type of tool-changer with a twin-gripper assembly can be used for high-speed tool-changing where space in the area of the machine is limited.

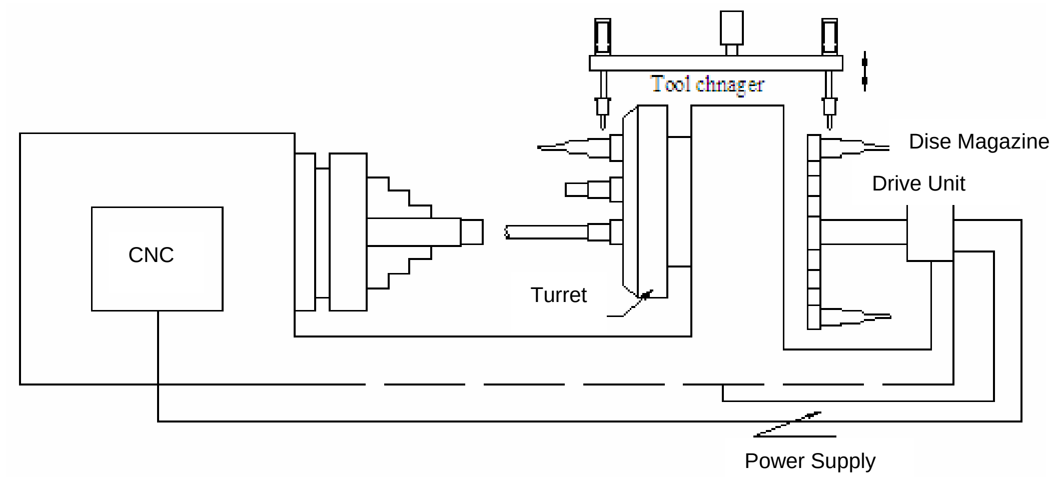


Figure 12.1 : CNC Turning Machine with Integrated Disc Magazine for Automatic Tool Changing

In this design, the gripper assembly also rotates though 90^o to deliver tools to the turret's periphery. The major advantage of using this type of tool-changer is that it can be fitted to a machine tool with very little modification and it keeps the working area free from any mechanisms that might get affected by swarf or hit by the machine tool's moving parts. The disc-type turret magazine mentioned above has "random-access" capability. This means that the tool-changer has completely free access to any tool in the store providing an almost instant delivery to the turret. If company requires even more versatility from the automation of block tooling system, it is also possible to change the disc turret automatically and consequently, the tool-storage capacity approaches to infinity. The advantage of using this universal tool-changing mechanism is that they are designed on the modular principle and can be fitted to any configuration a company requires allowing for higher degree of customization.

The drum-type tool-storage facility is used in conjunction with a gantry-type loading configuration. The rotary drum–type holder permits a continuous supply of cutting units over long periods of unattended machining in the same manner as with the disc turret. When first setting of the machine for a new family of work pieces, the magazine racks can be easily substituted with new one, which holds other types of tools. The cast iron drum consists of the rotating magazine holder assembly and it encloses the interior working parts. This drum is mounted centrally on *z* column and runs freely on two bearing. A locking mechanism is attached to the drum and hinge plates for mounting of either five or ten cutting-unit magazines depending on the magazine holder's capacity. The drum can easily be removed so that the interior working parts are accessible. The tool-actuator mechanism is stationary inside the rotating magazine holder. This mechanism transports the cutting units from or into the magazines. When a particular tool-cutting unit is called, the drum magazine is indexed into position before the tool is energized. Then the actuator will load or unload the gripper. The gripper is attached to transportation mechanism particularly to a gantry robot and is taken to the machine-tool magazine. "Sister tooling" can be used for heavily utilized cutting tools so that the system have a large and versatile cutting capacity on the shop floor particularly if powered tooling is also incorporated into the system as mentioned earlier. Their versatility can be further enhanced if gantry robot is designed to include such features as such trigger probing and the capacity to load and unload the workpiece. This level of sophistication with and work loading coupled to a 'probing ability' is almost the state of art but not quite so completely automated machine tools in which chuck jaws for holding different work holding needs can be offered or a complete chuck-changing facility using a gantry robot is possible as listed by some machine tool builders. When machines with sophisticated specifications are used either as 'stand alone' machines or as parts of flexible manufacturing system, the throughput of work and variety of applications are significantly high. When coupled with a high utilization system having many shifts and pay back period, then time for return on the investment of machine tool is much shorter. The level of investment required to incorporate all of the features described above is considerable and is only possible when a company has an expected volume of work which justifies the cost. An alternative approach which might be suitable for medium to large-batch situations in which the product line is diverse and calls for a certain amount of flexibility in coping with the production demands. Here, the conventional turning-centre turret has quick-change tooling supplied by a chain-type tooling carousel which can carry approximately 20 additional tools that may be utilized. This tooling configuration with automatic tool clamping in the turret is within the reach of most budgets and considerably expands the machine's capabilities for coping with a more diverse range of jobs.

To reiterate earlier statements, whichever the configuration and whatever level of sophistication one requires from a machine tool, it should be apparent that quick-change tooling expands the tooling potential vastly, whilst reducing non-productive cycle times. It should be enthusiastically considered as an alternative to conventional tooling. It may be utilized on other machines for example CNC machines or even conventional machines simply by changing the adaptor. If a company cannot afford the whole system, it should experiment with just a few units to gain experience in their use – bearing in mind, of course, that the full production savings will only result when a whole system is utilized in an effective manner.

The automatic tool changing system is a sophisticated, well-tried and time tested tooling, having large scale industrial usage. Once the tool begins to degenerate (possibly through extraneous circumstances), the productive capability is lost. At the least, there is a need to protect the tool from the little chance of failure by using some form of tool-condition monitoring system.

SAQ 1

(a) What is automatic tool changing mechanism?

(b) Explain automatic tool changing mechanism on turning center.

12.3 CALCULATION OF TOOL NUMBER

Flexible Manufacturing Systems (FMSs) are often viewed as system capable of processing a wide variety of parts in random order. This is achieved by determining by the number of tools of each type that are active in the system at the same time. Very few tools can result in low system utilization and throughput. Too many tools in the system, however, can increase system cost. Proper tool management ensures that the correct tools are utilized on the appropriate machines at the right time so that the desire quantities of work pieces are manufactured.

The utilizations of tools and machines and throughput of each part type are important performance measures that must be managed for efficient production. The Numerical Control (NC) machines used in FMSs are very expensive to purchase, operate and maintain and under-utilization of the machines can be very costly. Part throughput determines the revenue generated by the system. The number of tools of each type active in the system can improve the machine utilization and system throughput. The costs associated with lost machine time and failure to meet production quotas will decrease due to unavailability of tools. But the tooling required by the NC machine is costly. To carry more tools than necessary can increase the cost of operation and maintaining the system and complicate tool storage and transportation. Hence, the number of tool of each type active in the system must be determined to balance these cost.

The tooling cost per unit time can be expressed as :

$$P_T = \sum_{i=1}^{L} P_{Ti}\, N_i\, (1 - \phi_i) \qquad \text{. . . (12.1)}$$

where, P_T = Cost of idle tools,

P_{Ti} = Cost of idle tool of type i,

N_i = Number of tool of type i in the system, and

ϕ_i = utilization of tool type i.

Example 12.1

A production industry consists of a machine having two tool types for three products. The cost of the idle tool (P_T) in two consecutive operations are 348 unit and 342 unit respectively and cost of idle tool of types 1, 2 are 150 unit and 140 unit respectively. Calculate tool number if utilization of tool of types 1, 2 for first operation is 0.4, and 0.6 while for second operation it is 0.7 and 0.4 respectively.

Solution

Given data :

For first operation : $\Phi_1 = 0.4$, $\Phi_2 = 0.6$, $P = 348$ unit, $P_1 = 150$ unit, $P_2 = 140$ unit

For second operation : $\Phi_1 = 0.7$, $\Phi_2 = 0.4$, $P = 342$ unit, $P_1 = 150$ unit, $P_2 = 140$ unit

Suppose number of tool of type 1 is N_1 and number of tool of type 2 is N_2

Using Eq. (12.1)

For first operation :

$$348 = 150 * N_1 * (1 - 0.4) + 140 * N_2 * (1 - 0.6) \qquad \text{. . . (12.2)}$$

For second operation :

$$342 = 150 * N_1 * (1 - 0.7) + 140 * N_2 * (1 - 0.4) \qquad \text{. . . (12.3)}$$

After solving Eqs. (12.2) and (12.3), it is found that

$$N_1 = 2 \text{ and } N_2 = 3.$$

SAQ 2

Explain the method of calculating tool number.

12.4 PERFORMANCE OF TOOL MANAGEMENT SYSTEM

12.4.1 Tool Management

A comprehensive cutting tool management system is critical for a successful operation of a flexible manufacturing system. Tool management can be defined as the capability of having the correct tools on the appropriate machines at the right time while maintaining acceptable utilization of manufacturing resources. One of the primary objectives of tool management is to ensure that tooling is never cause for delays in the production schedule.

The following statistics indicate the need and importance of cutting tool management :

- 30 to 60 % of a shop's tooling inventory is somewhere on the shop floor, with most of it placed in the toolboxes.
- 16 % of production demand cannot be met because the tooling is not available.
- 40 to 80 % of production supervision time is spent to search the appropriate materials and cutting tools.
- In some plants, operators spend 20% of their time to search cutting tools.
- A metalworking firm's annual budget for tooling, jigs, fixtures, consumable supplies, and spare parts is 7 to 12 times larger than its entire capital-equipment budget.

In a typical machining system, actual cutting time is between 5 to 20 % of average machine utilization time. Non-productive areas where machine utilization levels can be increased include tool setting, tool changing, and part loading.

Incorporation of automatic tool handling and management system result in the following benefits :

- Machine productivity is increased because tool change is automated and takes place while the machine is operating.
- Reduced costs are associated with lower tooling inventory, since each machine has access to common tool storage. Tooling represents a major investment both in the initial start up of a system, and in the ongoing operation of the system. By installing a cutting-tool management system, saving can be greater than 20 % as compared to purchase of new tooling.
- Emergency tool purchases and the purchase of incorrect tools are eliminated.
- Product delivery time is improved because tool shortages are never responsible for delays in the production schedule.

12.4.2 The Hardware Components of the Tool Handling and Management System

Tool magazine and Automatic Tool Changer

A tool magazine and automatic tool changer are located on a machine. The operation of a tool changer is shown in Figure 12.2.

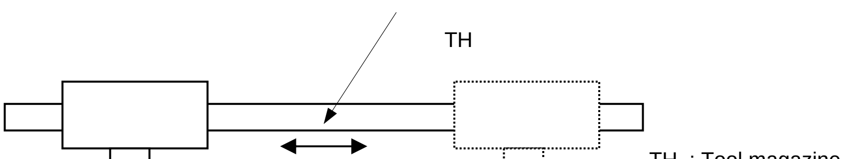


Figure 12.2 : Tool Changer

Tool Storage and Support System

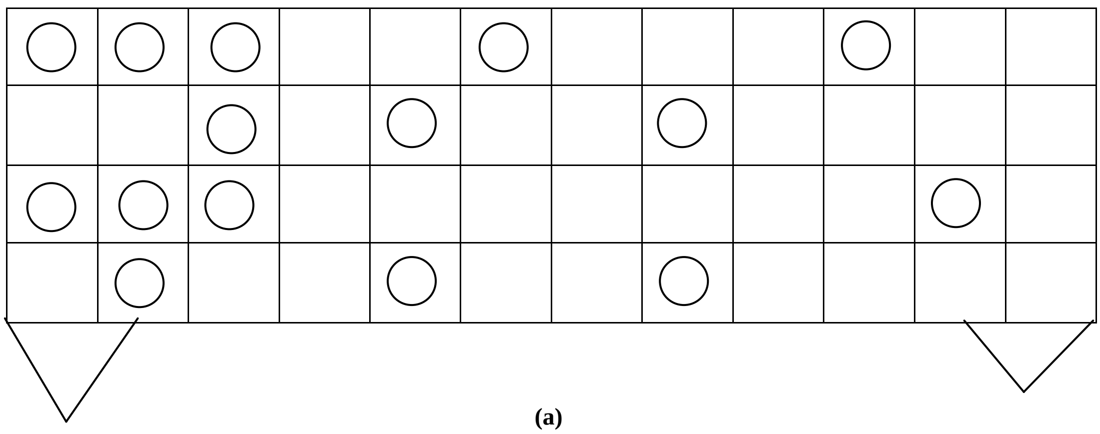
The primary objective of the tool storage and support system is to prepare the tools for the production in a timely fashion. The functions performed in the tool storage system are :

(a) Tool identification,

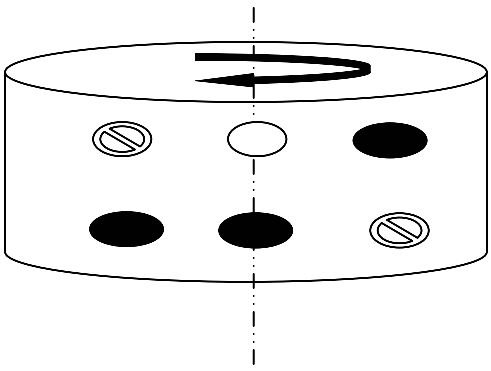
(b) Tool storage, and

(c) Tool presenting.

Other support functions performed in the tool storage and support system include buildup of tool assemblies returned from the machine and tear down of tool assemblies.



(a)



(b)

Figure 12.3 : Tool Stockers (a) Rack Stockers; and (b) Disk Stockers

Two types of commonly used tool stockers are shown in Figure 12.3(a) the rack stocker and disk stockers in Figure 12.3(b). They can be automated in a way similar to an automated storage and retrieval system.

Tool Handling System

The tool handling system transfers tools from the tool storage and support system to the individual tool magazines on each machine. One tool handling system can service several machines, depending on the tool changeover requirements. A typical tool handling system uses an automated guided vehicle to transfer tools from the tool room to the tool magazines on each machine. An automatic tool handling system between the tool room and individual machines allows tools to be changed while the machines are running. This reduces setup time and increases machine utilization. Figure 12.4 Shows an AGV-mounted robot loading a tool magazine with tools.

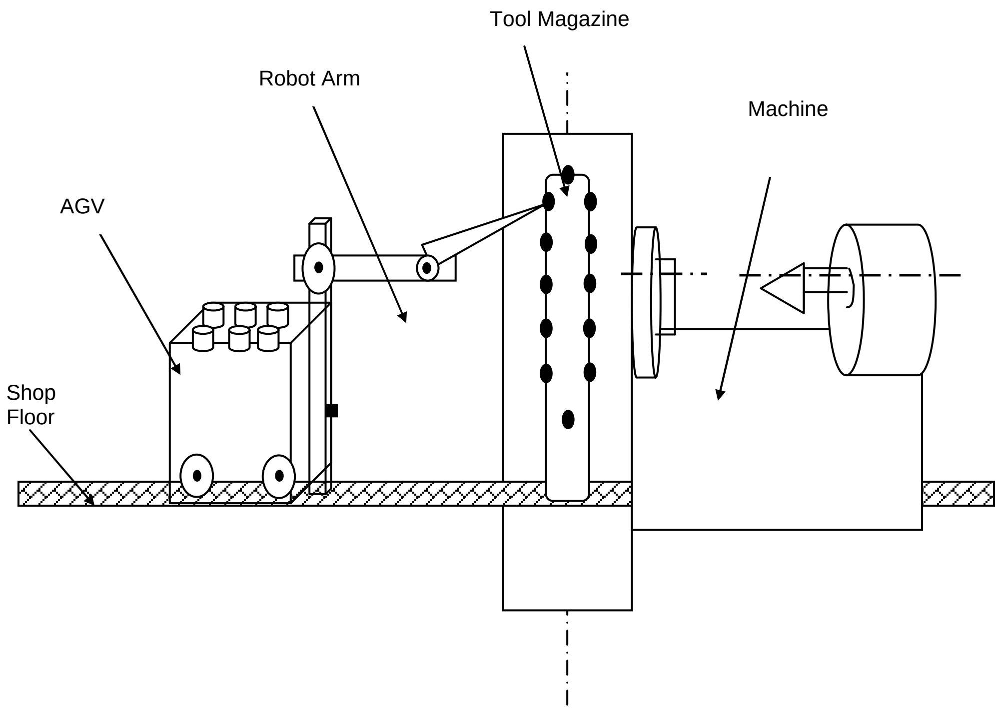


Figure 12.4 : Loading of Tool Magazine

Tool Fault Detection System

A tool fault detection system is required for a successful operation of a tool management system. Tool fault detection can be classified into tool wear monitoring and tool breakage detection. In view of the risk to the machine and part, breakage detection is more important than tool wear monitoring. A breakage detection system protects the machine, tool holder, and machined part from damage through tool breakage or collision. It also permits unattended operation of the machining center over prolonged time.

A practical approach to the tool wear problem is to replace tools after a predetermined number of hours of machining. In this way, the need for tool wear monitoring is eliminated and the occurrence of tool breakage is minimized. Fault detection is a function handled at each machine and monitored by the machine control system. CNC machine with automatic tool changers should have tool breakage detection capability for efficient operation. When a tool fails prematurely, a replacement tool may have to be obtained from the tool room. The ability to respond to these situations is an important issue in the tool management system.

SAQ 3

(a) What are the various components of tool handling and management system?

(b) Explain tool storage and support system.

(c) Describe Tool handling system.

(d) Explain tool fault detection system.

12.5 TOOL STORAGE POLICIES

Different tool policies are used in order to efficiently manage tools. Without the loss of generality, four different tool policies are analyzed based on a manufacturing cell that includes three machine tended by an AGV. Each machine is equipped with a permanent tool magazine of capacity mc = 60.

Tool Storage Policy 1

The tool magazine of each of three identical machines is loaded with six different tools as shown in Figure 12.5

This tool storage police have some advantages and disadvantages.

Advantages

- A backup set of tool is available.
- A backup machine is available.
- The tool handling system is simple.

Disadvantages

- More than one set of identical tools is required.
- Identical NC program are stored in more than one machine.
- Tool magazine capacity requirement is high.

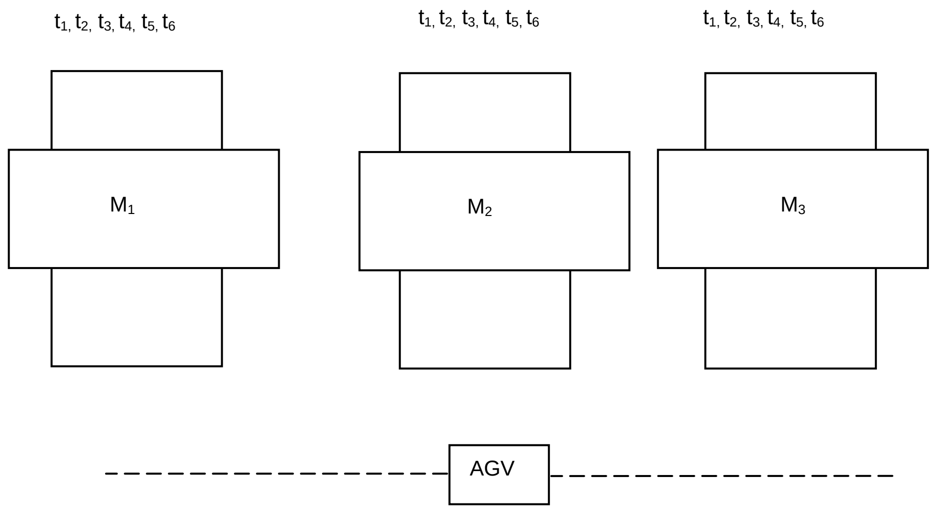


Figure 12.5 : Tool Storage Policy 1

Tool Storage Policy 2

Each tool magazine is loaded with two different types of tools. Additionally, each of these tools is duplicated as shows in Figure 12.6.

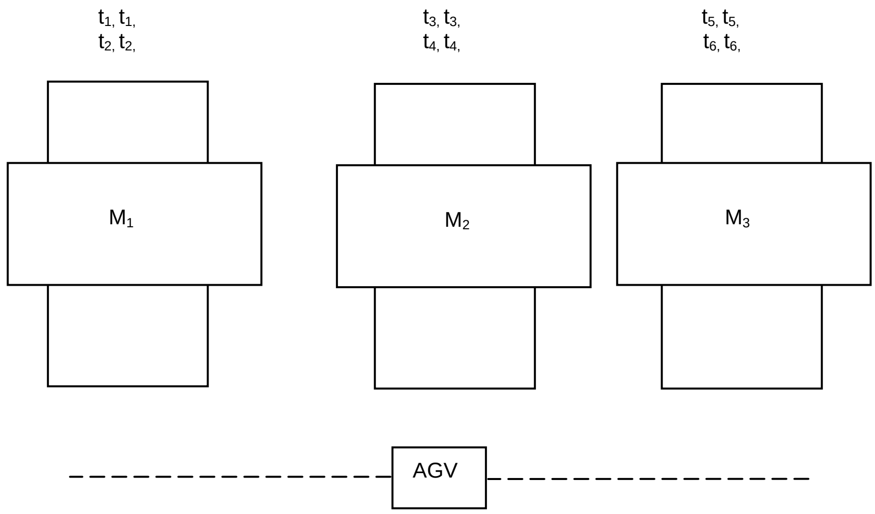


Figure 12.6 : Tool Storage Policy 2

Advantage

- A backup set of tool is available.
- Each NC program is stored in one machine.
- There is a simple tool handling system.

Disadvantage

- More than one set of identical tool is required.
- A backup machine is not available.
- There is a high requirement for tool magazine capacity.

Tool Storage Policy 3

The tool magazine of each machine is loaded with only one tool of each type as shown in Figure 12.7. All spare tools are stored with a number of other tools in the tool storage and handling system.

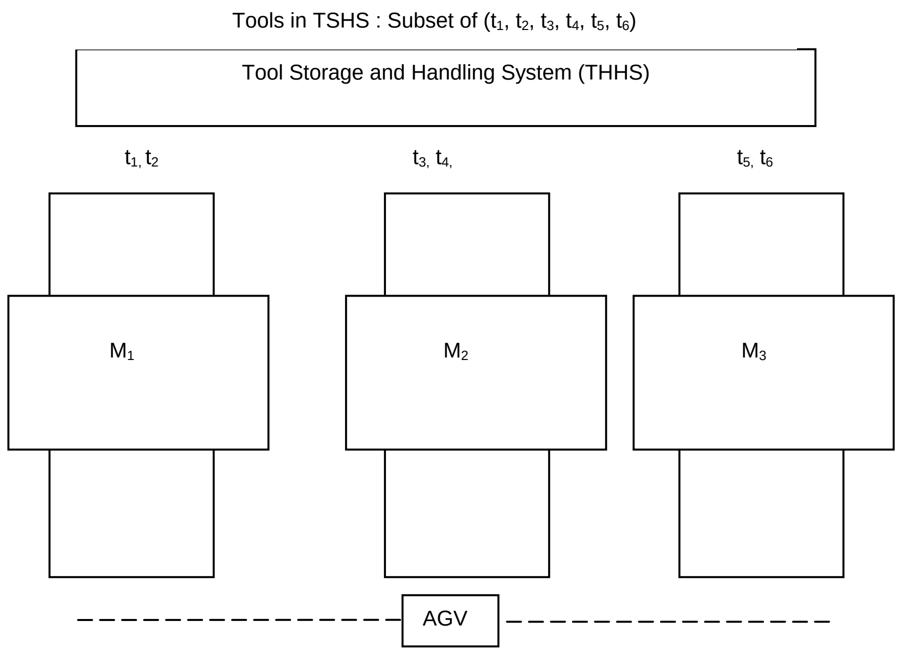


Figure 12.7 : Tool Storage Policy 3

Advantage

- A backup set of tool is available.
- Each NC program is stored in only one machine.
- There is a low requirement for tool magazine capacity.
- A backup machine can be created by changing tools in a tool magazine.
- The number of identical sets of tools might be reduced in comparison to the number of tools in storage polices 1 and 2.

Disadvantage

- Relatively complex tool storage and handling system is required.

Tool Storage Policy 4

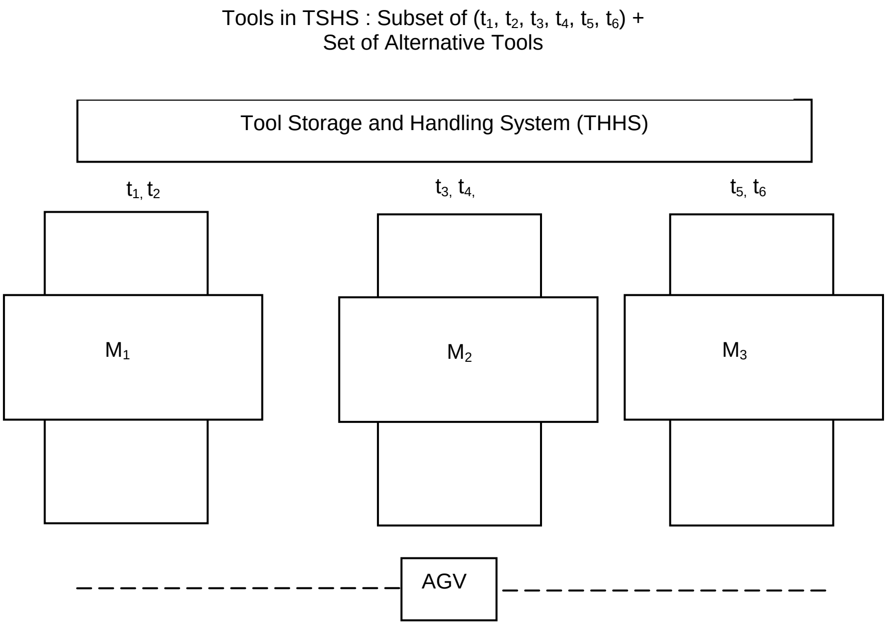


Figure 12.8 : Tool Storage Policy 4

In all the three tool storage policies discussed, the assumption was made that at least two identical sets of tools were available in a given planning horizon. However, this assumption very often does not hold in industrial practice due to :

- The high cost of tools.
- Delays in tool maintenance

Figure 12.8 illustrated a tool storage policy that reduces the number of tools stored in the tool storage and handling system.

In this storage policy, the following two subsets of tools are stored in the tool storage system :

- Tool prone to breakdowns
- Tools providing alternative part routes

Typically, not more than one copy of the tools falling into one of the preceding two tool categories is stored in the tool storage and handling system.

SAQ 4

(a) Explain various tool storage policies?

(b) State advantages and disadvantages of tool storage policy 2?

(b) Explain tool storage policy 4 in detail.

12.6 SUMMARY

Automatic tool changer is often used to improve tool carrying capacity of CNC machine. CNC machine with automatic tool changer increases the machine tool's productivity time reduces the times for changing worn tools. The utilizations of tools and machines and throughput of each part type are three important performance measures that must be managed for efficient production. Hence it is necessary to calculate effective number of tool required for machining. Tool management consists of tool magazine and automatic tool changer, Tool storage and support system, tool handling system, tool fault detection system. The success of tool management depends mainly upon various tool storage policies.

12.7 KEY WORDS

ATC **:** It is automatic tool changer, used for automatic tool storage and tool changing.