3.5 AUTOMATIC TOOL EXCHANGE

The assembly groups specified to perform unloading, manipulation, position setting and clamping of tool units in the machining centre without application of human force, skilfulness and management fulfil the automatic tool exchange task. This is the indispensable functional supplement at machining centres necessary to provide their smooth and continuous operation. It consists of a large assortment of design solutions which shall provide the optimum utilization of the machine tool at the given technological operations which define the tooling composition. The automatic exchange and storage of technological accessories belong to this category too.

The automatic tool exchange (Fig. 3.5.1) is connected with the essential technological principle of machining – the main cutting motion is performed by the tool or by the workpiece. The machine type and its size are closely related to this matter. These issues are the cornerstone for many designing principles of the equipment which exchanges the tools the number and size of tools, the magazine location, etc. The tool exchange is realized in two cases: either the worn tool is replaced with a new one, or another tool requires the sequence of technological operations. Specific requirements are put on the design solution of the particular assembly groups as well as on the equipment for the automatic tool exchange. These requirements are especially the following ones [Borský 1991]:

- the minimum tool exchange cycle time which belongs to the secondary time group;
- high functional reliability regarding to the big tool exchange frequency and the high machine price;
- the optimum magazine capacity for the particular field of machine utilization and performed technological operations (effort to perform the complete machining);
- the area-saving solution (the smallest ossible built in surface);
- elimination of the unfavourable impact on the machine working area (the tool exchange equipment must not obstruct at the machining process);
- resistance against the influence of dirt (chips, dust, coolant);
- increased accuracy at the tool position setting in the tool exchange place (this is valid for modern tooling systems);
- tooling variability – it is possible to manipulate with long and heavy tools having the big diameters as well as with light and small tools;
- the combination of more tooling systems at one machine;
- for many application cases it is necessary to perform the exchange of tool holders and tool heads and to exchange tools automatically in them.

The design solution of the magazine is influenced by the machine type which the magazine is determined for, by the tool type (rotary tools, tools for turning operations …), by the number of tools, by the tool clamping way in the machine (this is more extensively described in the section "Tooling systems"), by the tool weight and its orientation in the magazine towards gravity of the Earth, by the tool orientation at the exchange moment and during the tool storage (the tool must be usually turned in angles). Because the demands on minimization of unproductive time are still and still increasing, the tool exchange velocity and many other functional and operation influences or requirements have still and still bigger importance. It is impossible to omit the superordinated restrictions which define how the magazine

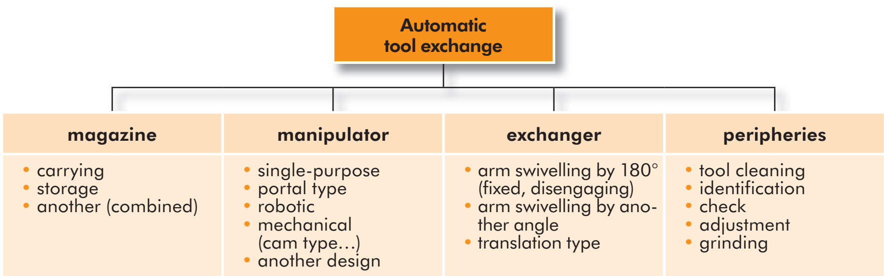

Fig. 3.5.1: Morphology of the automatic tool exchange and its types

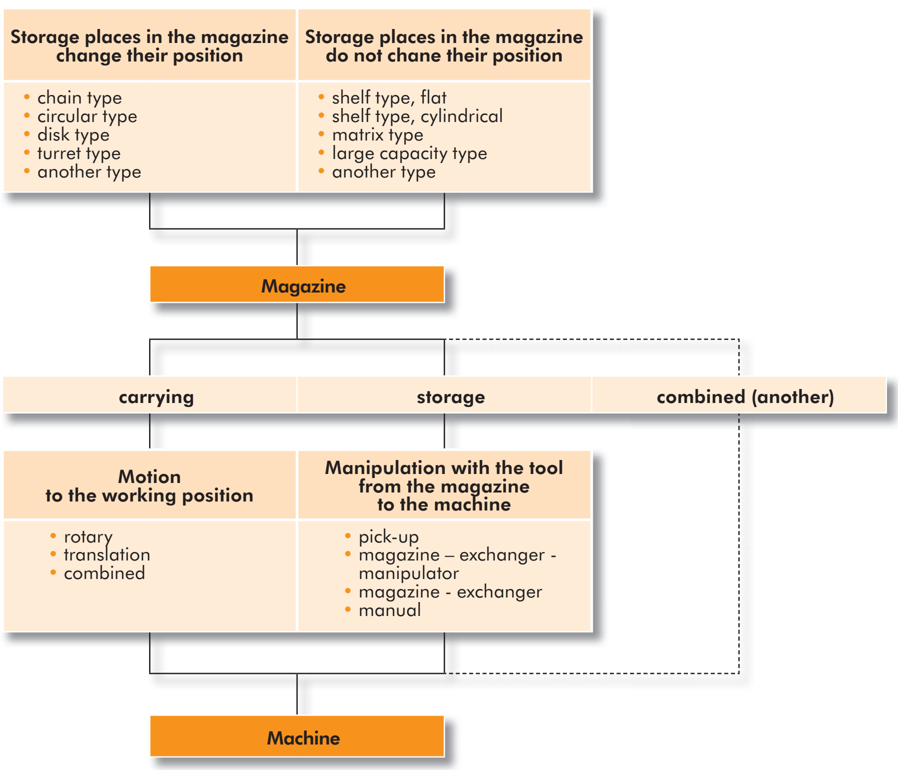

Fig. 3.5.2: Morphology of the automatic tool exchange and its types

shall look like considering the operation safety. This concerns mainly prevention of the operator's entrance to the magazine area (this matter is described in more details in the section about the protective guards) and the machine operation state at the tool exchange performed by the operator or by means of the exchange equipment.

The overview of the tool magazine types related to the machine and the tool exchange way is shown in Fig. 3.5.2. The carrying magazines transfer the cutting forces from the tool to the machine frame (Fig. 3.5.3). They are most often constituted by the turret. The tools which are clamped into the turrets can be non driven ones (turning tools are typical at this case) or driven (rotary tools for drilling and similar operations).

The immovable – non driven tools in the turret have their significance in the case of a moving workpiece. These are turning tools. drills for axial drilling and e. g. taps. The typical utilization is mainly at CNC lathes in various types (Fig. 3.5.14 see thereinafter) and at automatic lathes. The turrets in the disk type (Fig. 3.5.4) can be situated in the machine with the vertical axis of rotation as well as with the horizontal axis of rotation. The orientation of axis of turret rotation regarding to the axis of rotation of the workpiece can be parallel, perpendicular or less often inclined (most often under the angle of 45 degrees). The turret is created in dependence on the number of tools using the regular "n side" prism. The tool clamping shank axis is perpendicular to the axis of rotation of the turret or parallel with it (Fig. 3.5.7). When the turret is rotated to the working position, the required tool is ready to start the cutting operation.

The turrets with driven tools are highly sophisticated devices – the design unites. They can be also supplied as the functional assembly groups, where it is only necessary to lead energy and control signals. Fig 3.5.5 shows an example of the design of the turret in the disk type with the integrated drive in the Y axis. The motor M2 is determined to do this task, the motor M1 is determined to rotate the turret and at the same time it serves as the rotary tool drive. Whether the tool or the disk is rotated, this depends on the position of toothed wheels. The position of the movable wheels is checked by the sensors S4 and S5. The disk fixation in the working position is provided by the Hirth rim. The tool shanks can have various type executions. Fig. 3.5.6

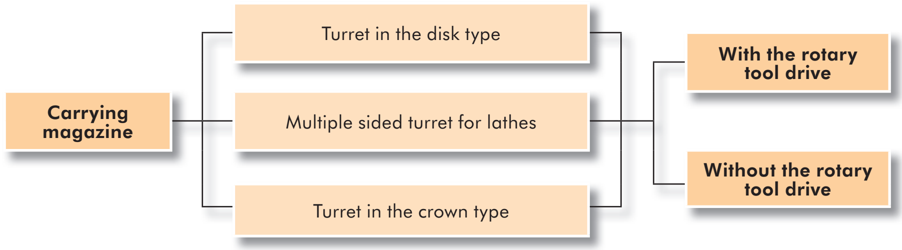

Fig. 3.5.3: Types of turrets

Series	Blue	Orange	Direct Drive	Red
	Medium-scale mass production	Large-scale mass production	Medium-scale mass production	Large-scale mass production
Service life	●●	●●●●	●●●●●	●●●●
Crash resistance	●●	●●●●	●●●●●	●●●●
Turret drive	AC-Motor	Synchronmotor	Synchronmotor	Servomotor
Locking system	elektromechanical	hydraulic	hydraulic	hydraulic
Indexing speed	●●	●●●●	●●●●	●●●●
Suitability for back-turning	●	●●●	●●●●	●●●●
Tool drive	axial - AC-Servomotor, 2- motor-system	axial/radial, AC-Servomotor, 2-motor-system	axial /radial - Direct Drive 1-/2-motor-system	axial/radial - no seperate motor, 1-motor-system

Fig. 3.5.4: Types of disk turrets [Sauter]

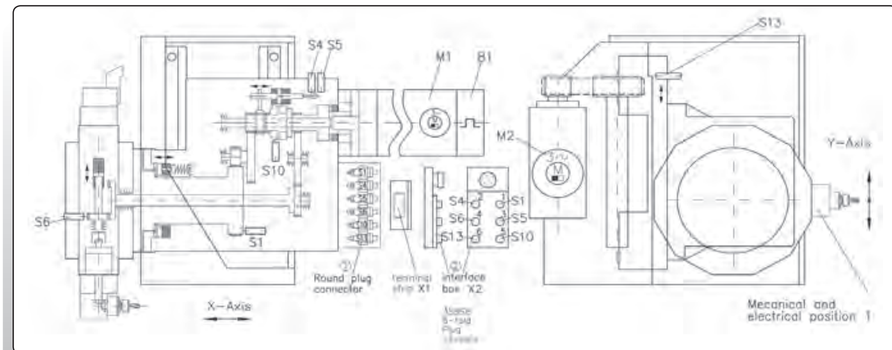

Fig. 3.5.5: Example of the design of the turret drive [Sauter]

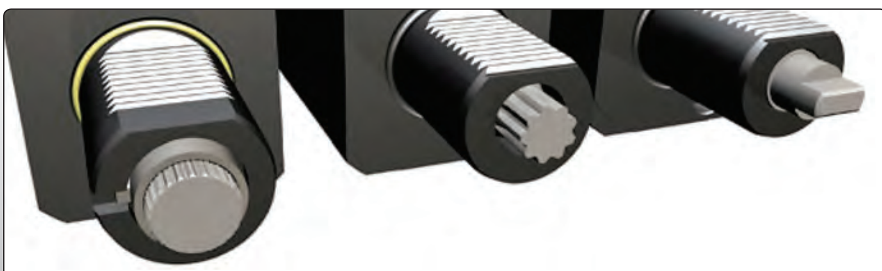

Fig. 3.5.6: Tool shanks and types of clutches driving the rotary tools [Sauter]

shows the examples of shanks which were normalized. In order to rotate the tool in the tool head, the connection with the drive shaft must be made. Its position is checked by the sensor S6. At the older tool shank DIN1809 it is not necessary to move the drive spindle, because the transit groove is in the drive shaft. Therefore, it is enough to perform the oriented tool stop before the start of the wheel rotation. This older way simplifies the design solution of the turret but it is suitable to transfer smaller torques in comparison to shanks according to DIN 5480 and DIN 5492. The example of utilization of the turret in the disk type is shown in Fig. 3.5.7. Each turret can move independently in the X axis and in the Y axis.

Fig. 3.5.8 on the left shows the example of the unit built structure of the turret. On the right it shows the way how to increase the tool capacity of the turret. Different tools are in one disk position. If the workpiece does not collide with the tool which does not machine, it is possible to extend technological possibilities of the machine in this way. The tools located next to each other can be identical ones and multiple spindle machining is utilized in this case, which increases productivity (Fig. 3.5.8 on the right). The multiple sided turret is the specific example of the carrying magazine for heavy lathes. Fig. 3.5.9 shows the example of the tetrahedral turret with tool clamping by means of the dovetail.

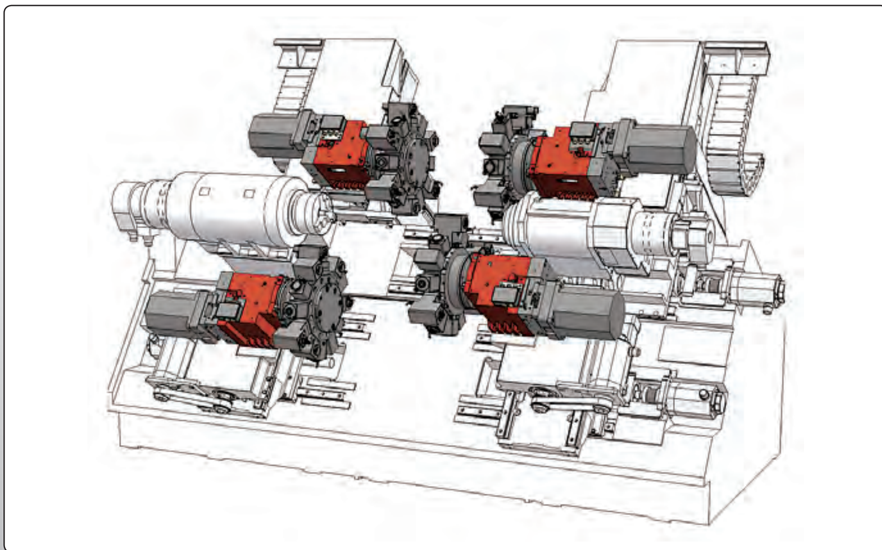

Fig. 3.5.7: Application of disk turrets to the machine [Sauter]

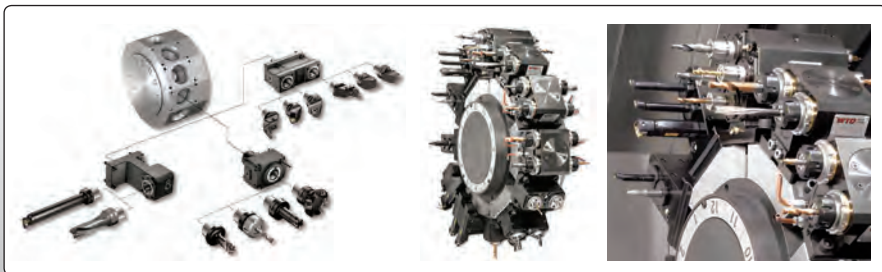

Fig. 3.5.8: Unit built structure of the turret and doubled tools in the turret [WTO]

The concept of the turret in the crown type is utilized at production machines determined for manufacture of the big quantity of parts. The turret in the crown type is determined mainly for rotary tools (Fig. 3.5.10), even in the case when the tool for rotary operations does not move and the main cutting motion is performed by the workpiece (e. g. axial drilling). The tools are inclined to the axis of rotation of the turret and the turret body has the shape of the multiple sided pyramid. The turret designer can design that the covering surface of the turret has the cone shape or the hemisphere shape, but the clamping and contact surfaces of the tools define the n sided pyramid. The tool inclination angle is given by the number of tools and by the internal design. The axis of turret rotation must be inclined by the same angle towards one of the workpiece axes. Of course, other turret inclinations towards the workpiece are also possible and they have their justification at

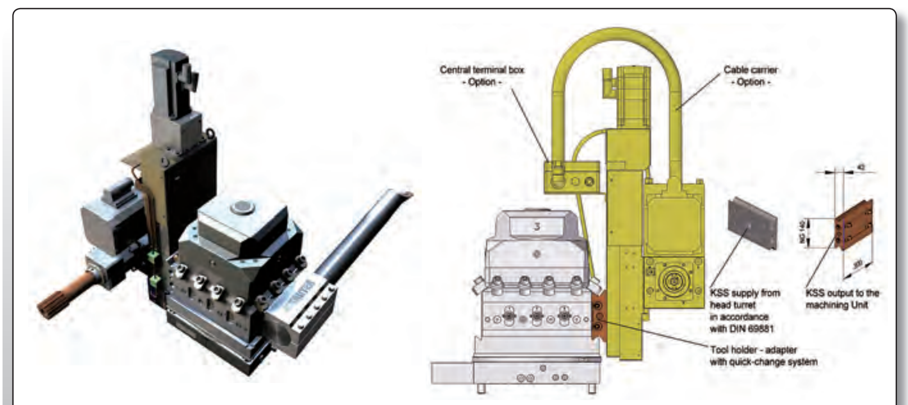

Fig. 3.5.9: Turret for heavy lathes [Sauter]

Fig. 3.5.10: Example of the turret in the crown type used at the machine [Sauter]