# 12. CNC Machine Tools and Control systems

## 12.1 CNC Machining centres

Vertical axis machining centre, and
Horizontal axis machining centre.

### 12.1.1 Vertical axis machining centre


**Fig. 12.1** Present day production vertical axis CNC machining centre Bridgeport VMC 760 (Courtesy Bridgeport Machines Inc., Bridgeport, U.S.A.)

The variations that can be found in the vertical machining centre category are:

a. Travelling column
b. Gantry structure
c. Multiple spindle

**Fig. 12.2** A 5-axis machining operation (Courtesy Yamazaki Mazak Corp., Japan)

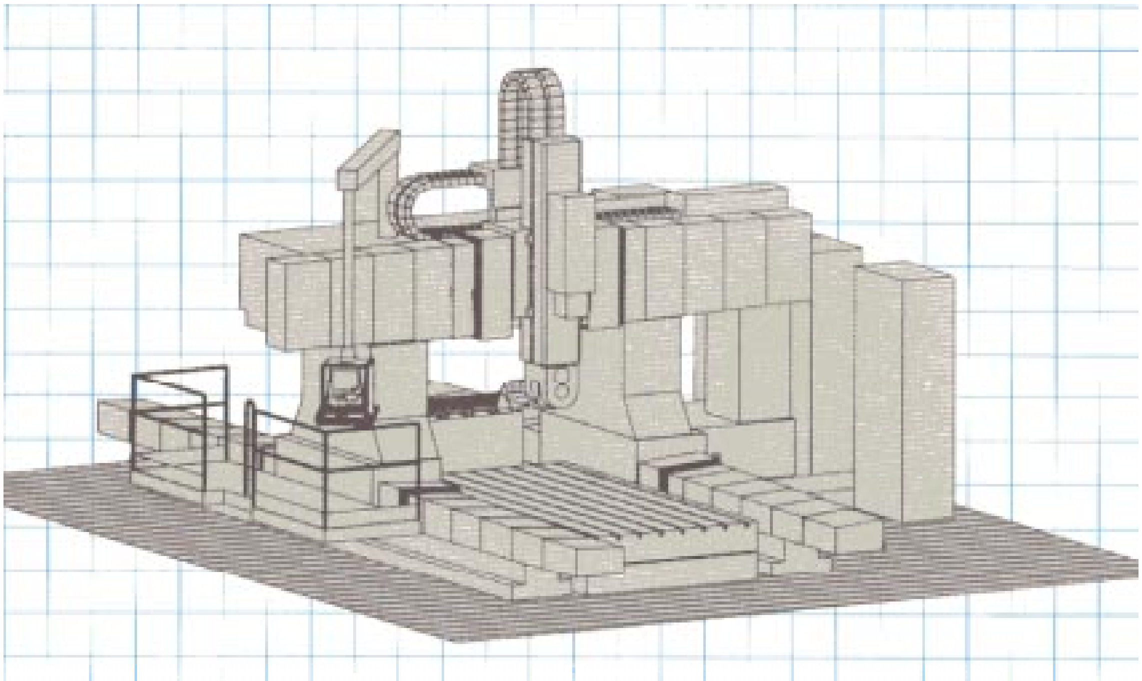


**Fig. 12.3** A schematic representation of a CNC travelling column machining centre (Courtesy Jobs S.p.A., Italy)

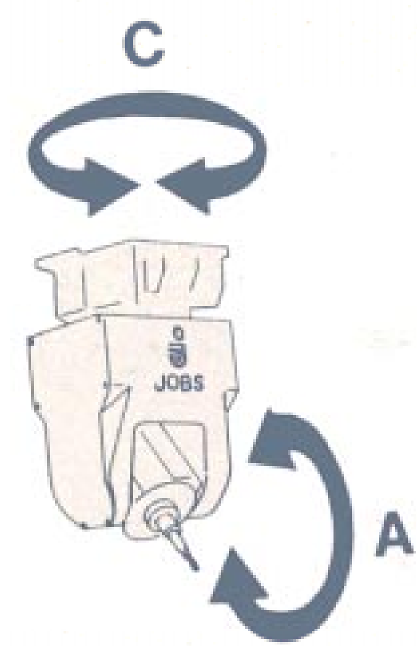



**Fig. 12.4** The possible rotary motions of the tool head of a CNC travelling column machining centre (Courtesy Jobs S.p.A., Italy)

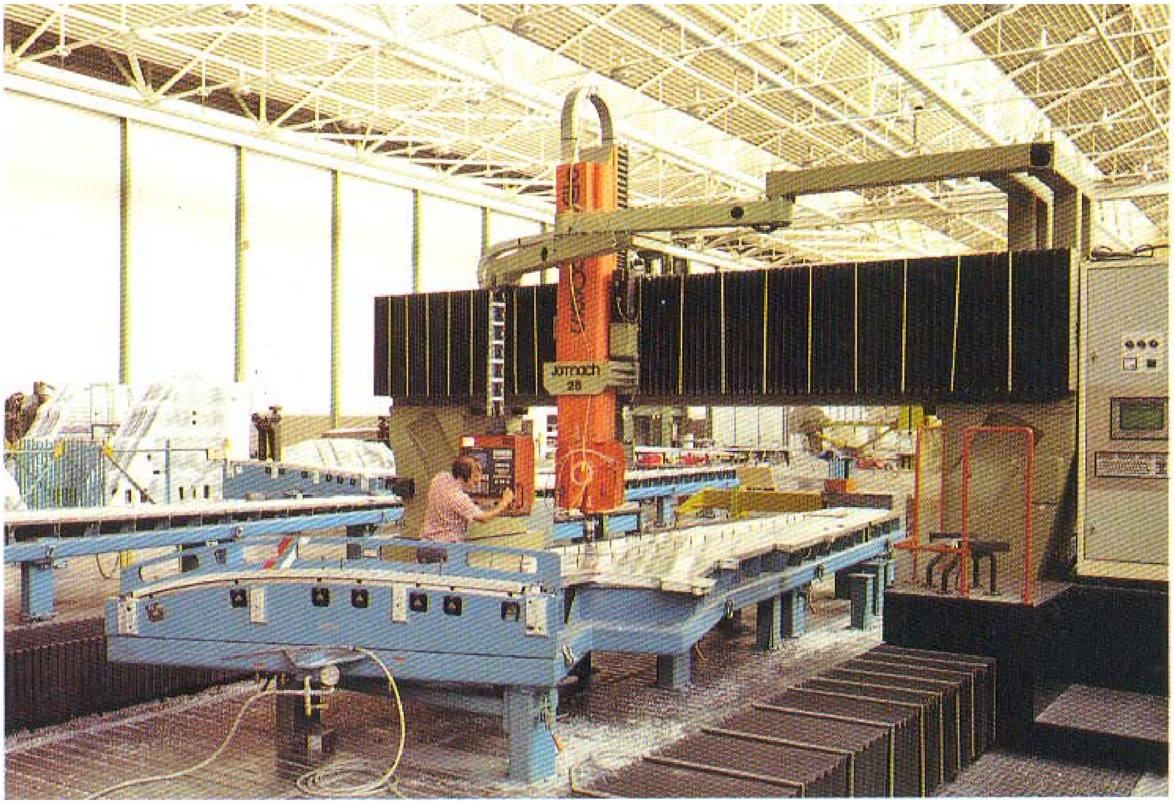


**Fig. 12.5** A 5-axis CNC travelling column machining centre for aerospace machining applications (Courtesy Jobs S.p.A., Italy)

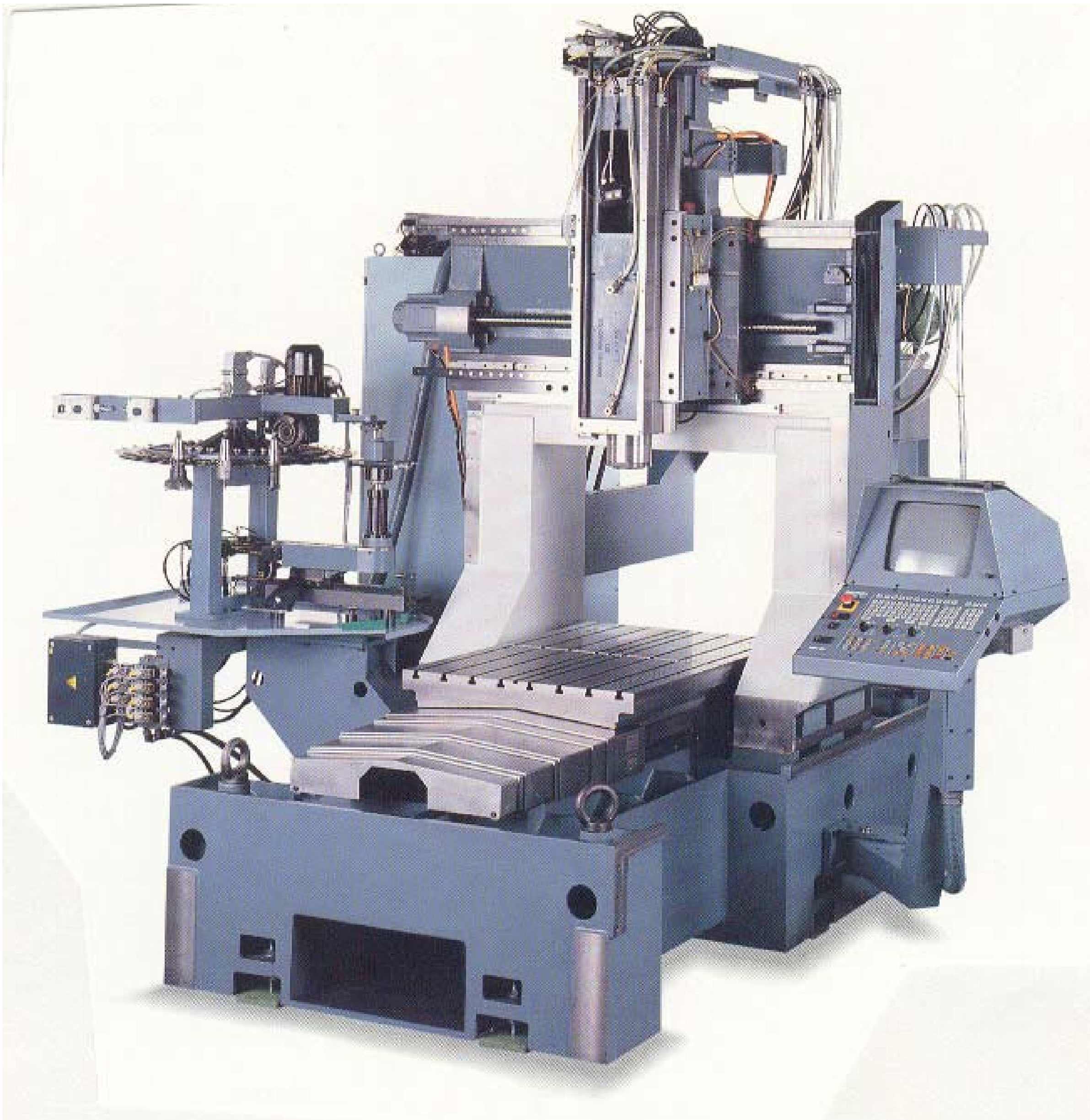


**Fig. 12.6** A gantry type CNC machining centre DMC 65V for high speed machining (Courtesy Deckel Maho Gildemeister, Germany)

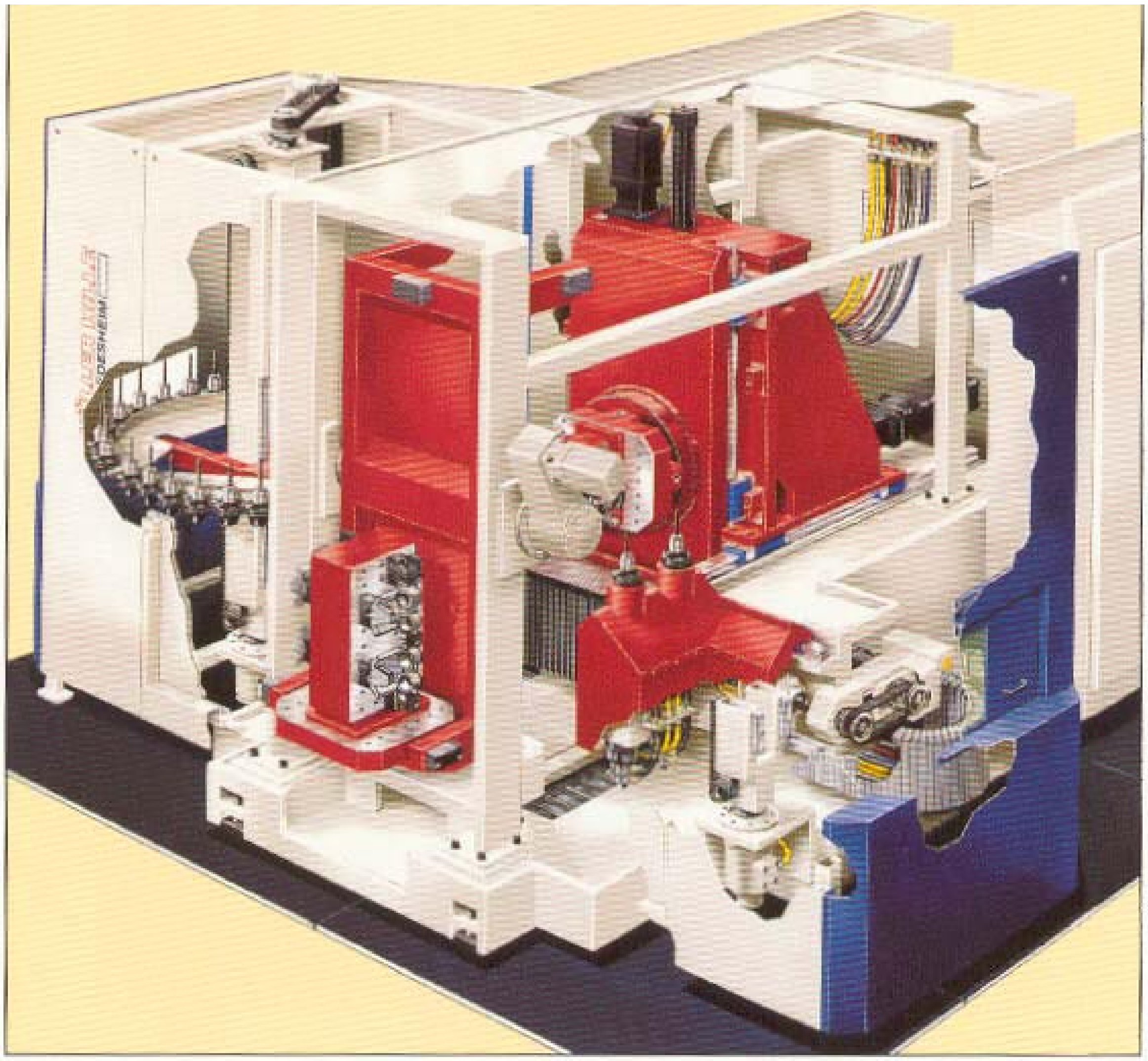


**Fig. 12.7** A 4-spindle CNC machining centre 4CUT for high speed machining (Courtesy Hüller Hille Gmbh, Germany)


**Fig. 12.8** Chiron CNC machining centre FZ 12W for high speed machining with a very fast tool change time (Courtesy Chiron Werke Gmbh, Germany)

## 12.1.2 Horizontal axis machining centre

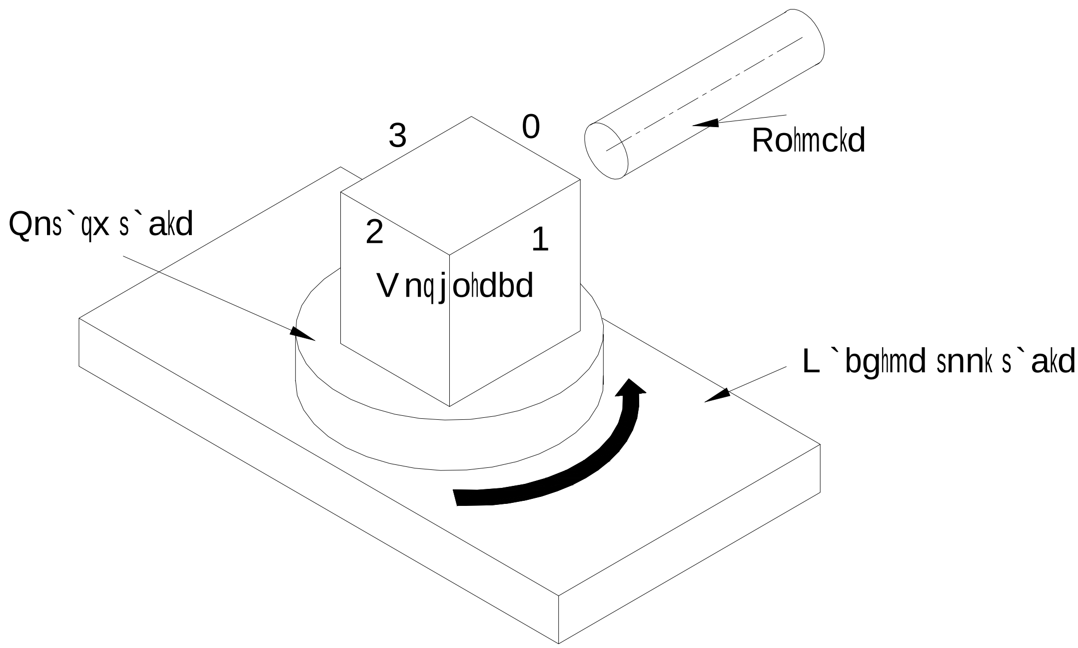



**Fig. 12.9** Rotary table used in HMC for machining all four faces.

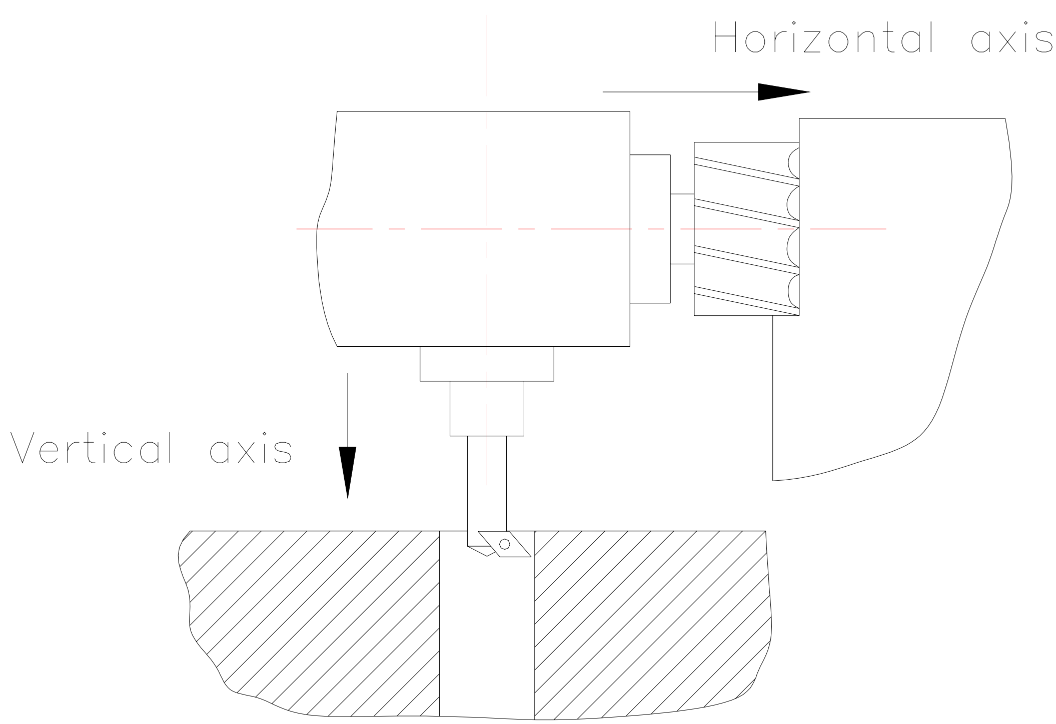



**Fig. 12.10** Spindle swivelling facility in HMC for machining in two different planes (XY as well as XZ).

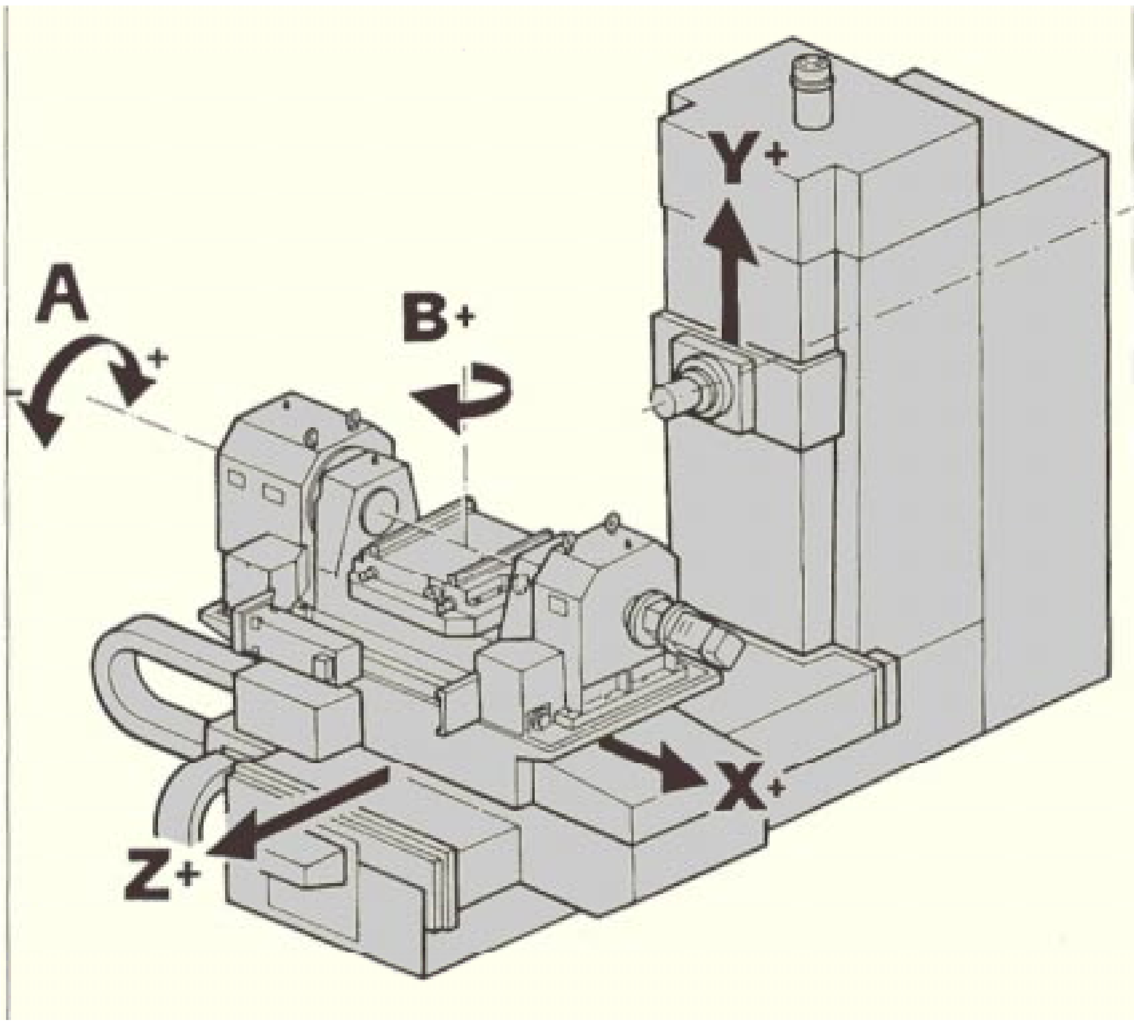



**Fig. 12.11** Horizontal axis machining centre provided with a 2-axis rotary table (Courtesy Dixi Machines SA, Switzerland)

## Pallet changer

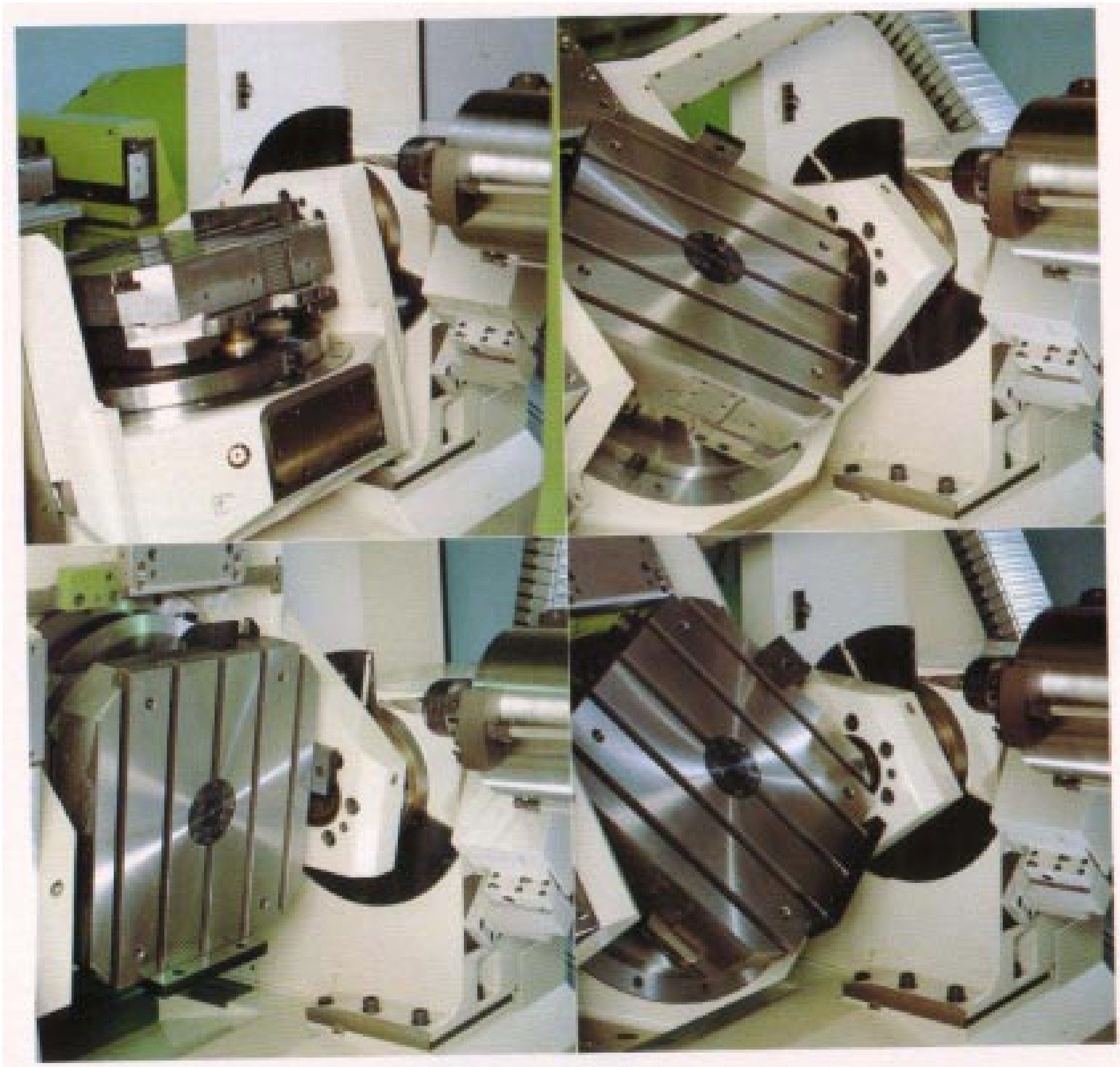
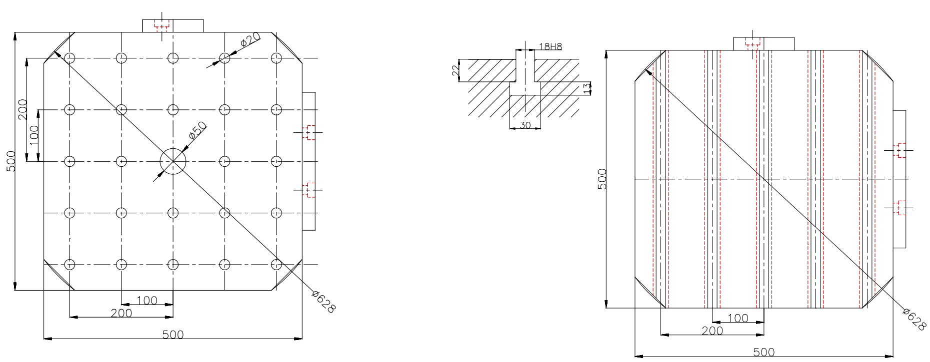


**Fig. 12.12** Various planes possible by the 2-axis rotary table with a HMC (Courtesy Yamazaki Mazak Corp., Japan)




a b

**Fig. 12.13** Typical pallet designs used with HMC, a) Pallet with holes; b) pallet with T-slots

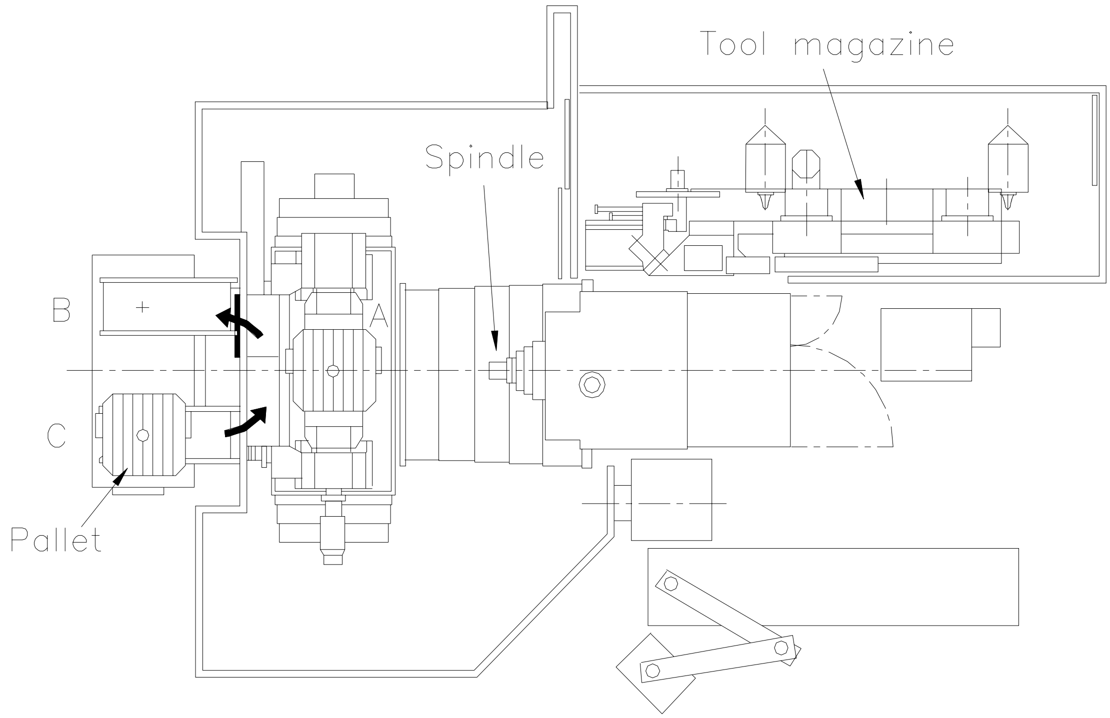



**Fig. 12.14** A typical horizontal machining centre with an automatic pallet changer.

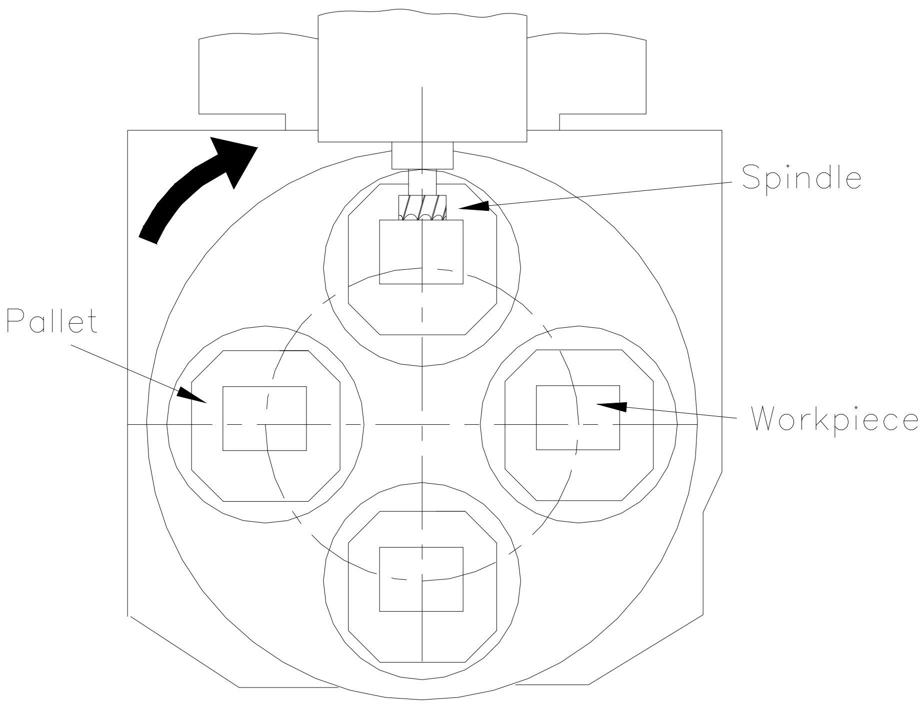



**Fig. 12.15** A typical pallet changer with a rotary style pallet changer.

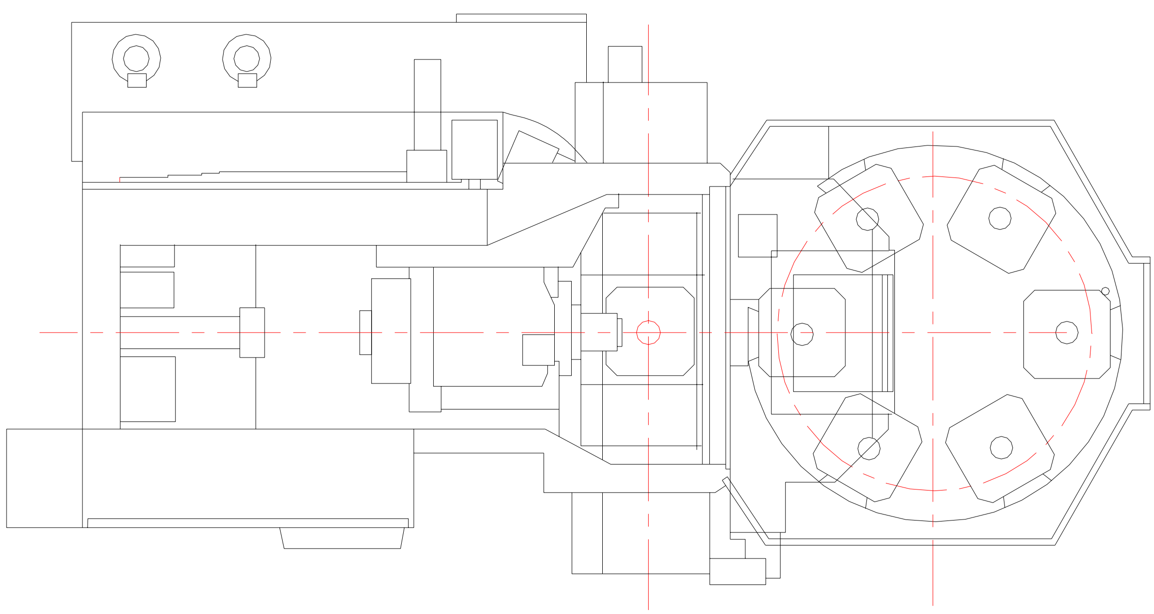


**Fig. 12.16** A typical pallet changer with a shuttle pallet changer combined with a 6 pallet carousal.

## 12.2 CNC Turning Centres

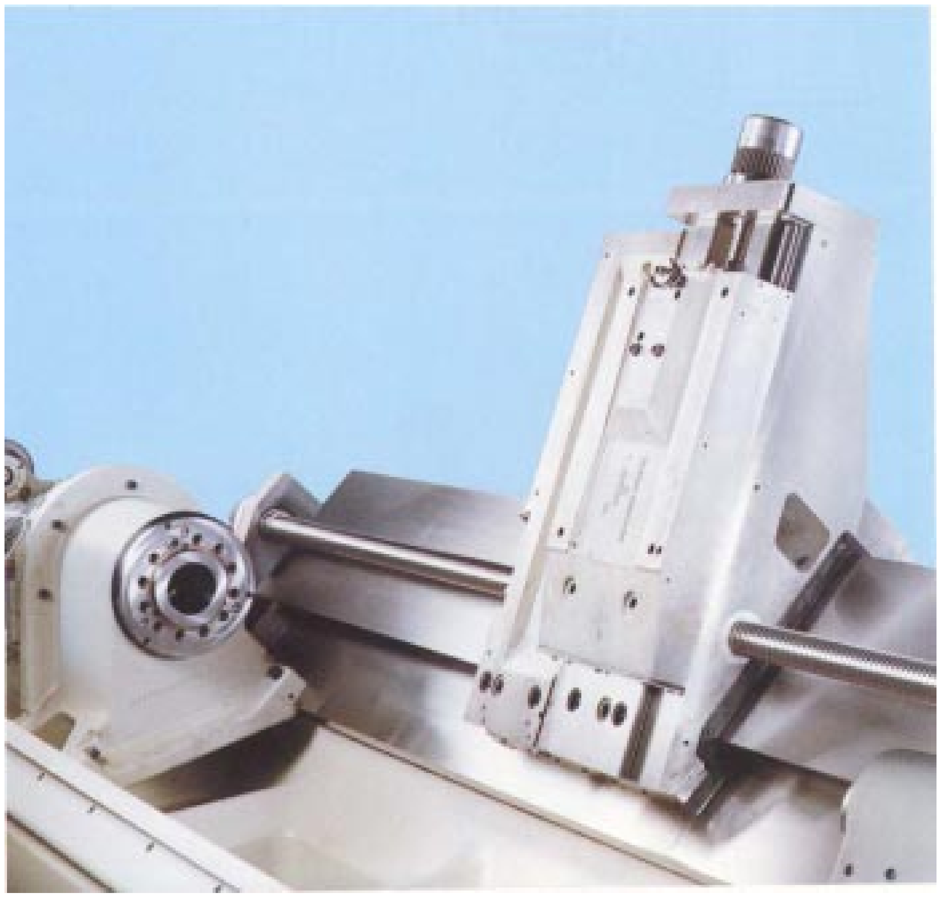


**Fig. 12.17** The slant bed of a CNC turning centre (Courtesy Boehringer werkzeugmaschinen GmbH, Germany)

The major categories of CNC turning centres can be classified as under:

a. Turn mill centres (X, Z, C)
b. Multiple axis turning centres (X, Z, C, Y)
c. Vertical turning centres
d. Twin turret turning centres
e. Multiple spindle turning centres
f. Integrated material handling

### 12.2.1 Turn mill centres (X, Z, C)

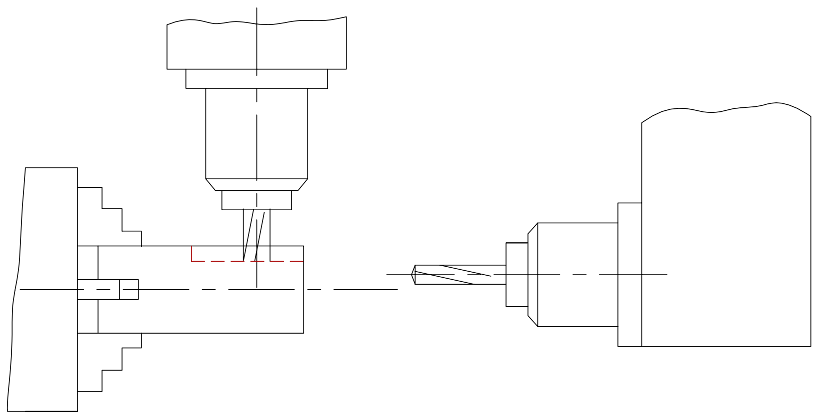


**Fig. 12.18** Machining of a key way or drill a hole away from the centre of the workpiece.

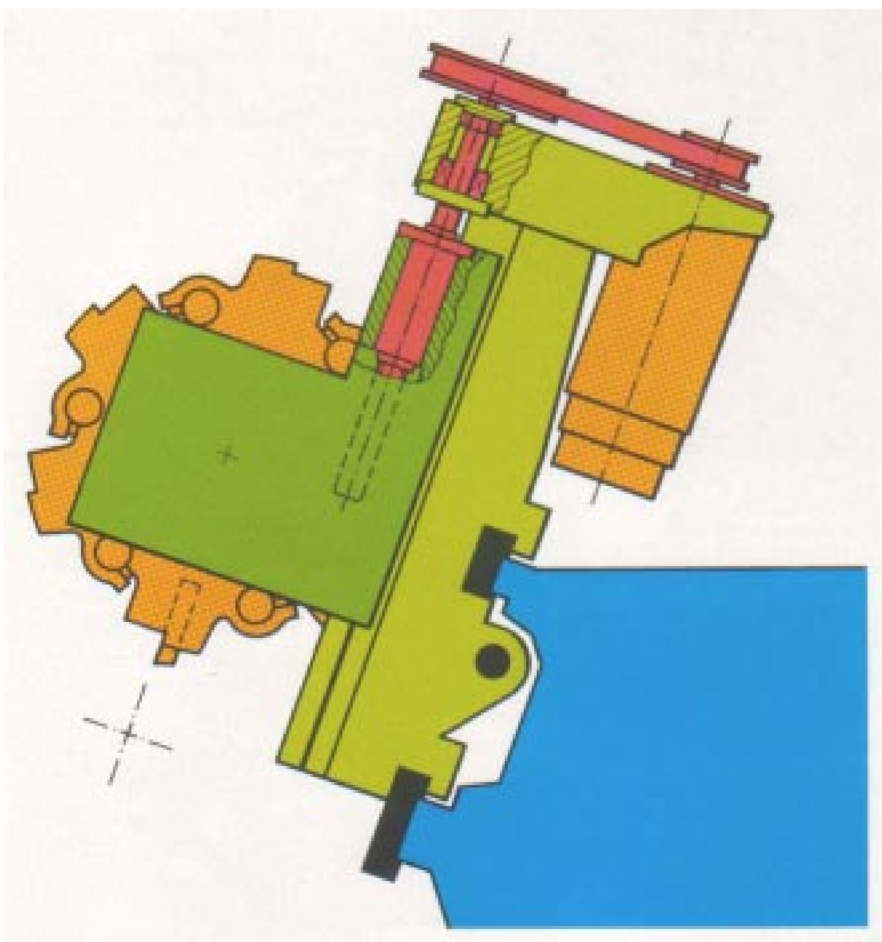


**Fig. 12.19** The drive for tooling in the turret of a CNC turn mill centre (Courtesy George Fischer, Switzerland).

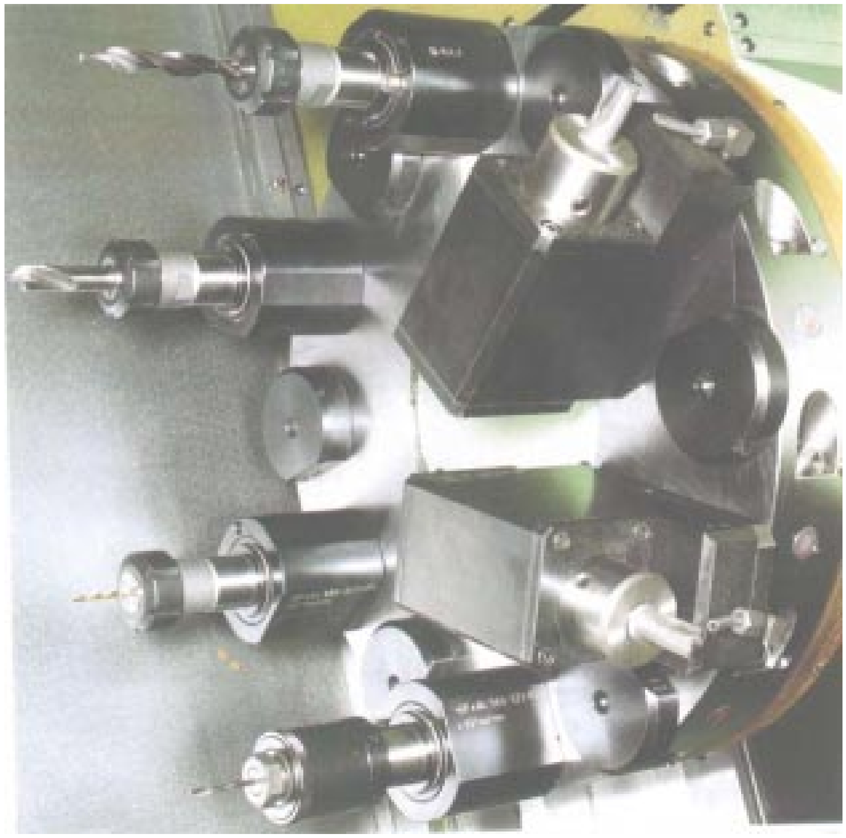


**Fig. 12.20** A tool turret with driven tooling to be used in CNC turn mill centre. (Courtesy George Fischer, Switzerland).

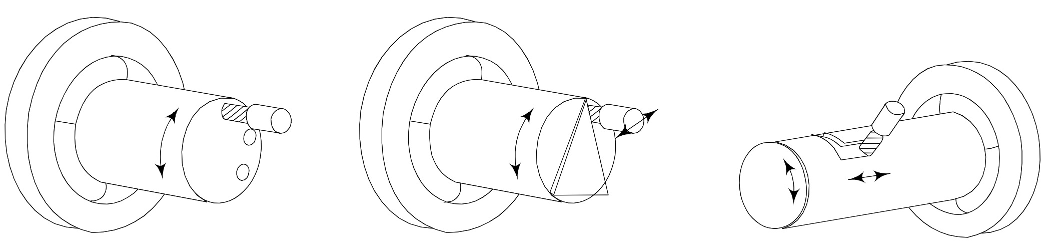


**Fig. 12.21** Typical shapes of component that can be machined by the combination of X, Z and C-axis movements.

## 12.2.2 Multiple axis turning centres

## Twin turret turning centres

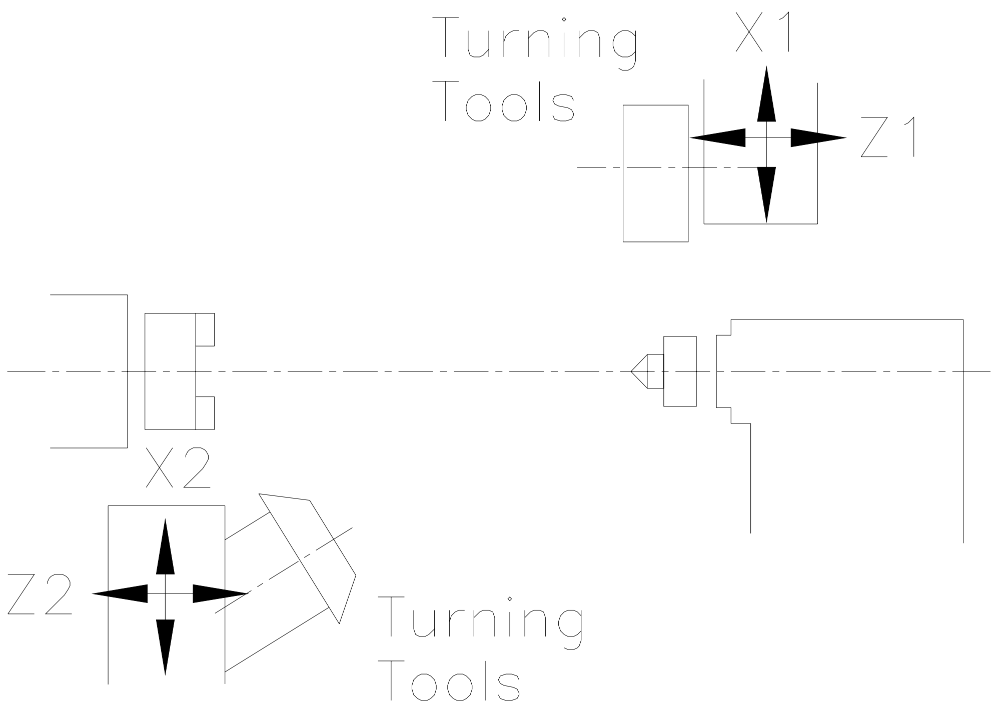



**Fig. 12.22** CNC Turning centre with twin turrets.

## Multiple spindle turning centres

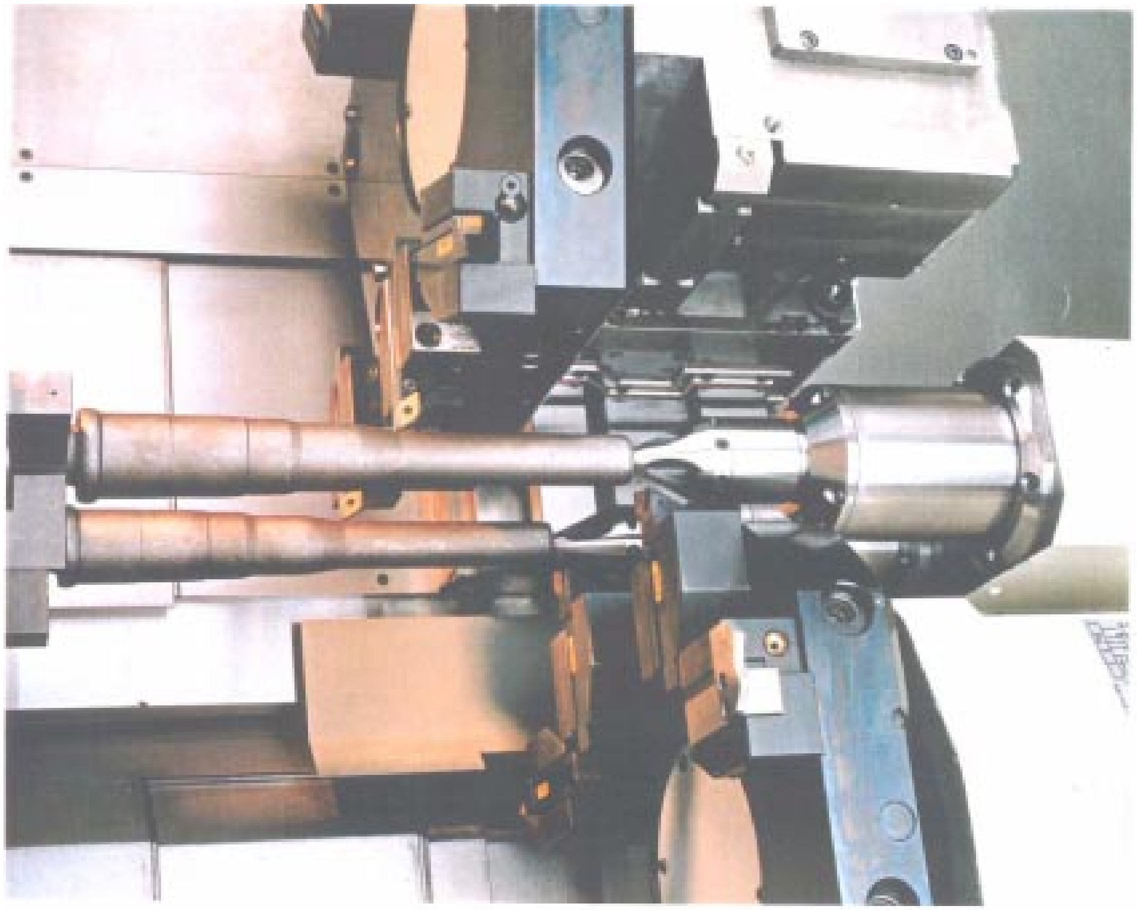


**Fig. 12.23** Twin spindle CNC Turning centre (Courtesy Georg Fischer, Switzerland).


**Fig. 12.24** Twin spindle CNC Turning centre Mazak Dual Turn 20 (Courtesy Yamazaki Mazak Corp., Japan).


**Fig. 12.25** CNC turn Mill centre with Y-axis, Yamazaki Integrex 30 (Courtesy Yamazaki mazak Corp., Japan).

- Turret with turning tools
- Turret with driven tools
- Turret with Y-axis movement
- Programmable tailstock
- Tool changer for the Y-axis turret
- C-axis movement.

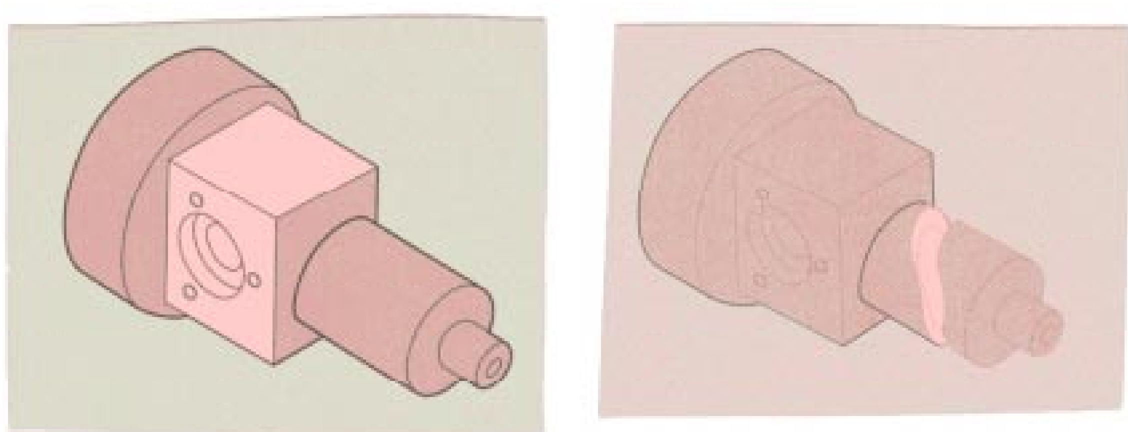


**Fig. 12.26** The types of machining that can be done using a CNC turn Mill centre with Y-axis (Courtesy Yamazaki mazak Corp., Japan).

### 12.2.3 Vertical turning centres

**Fig. 12.27** CNC Vertical turning centre, Yamazaki (Courtesy Yamazaki Mazak Corp., Japan).

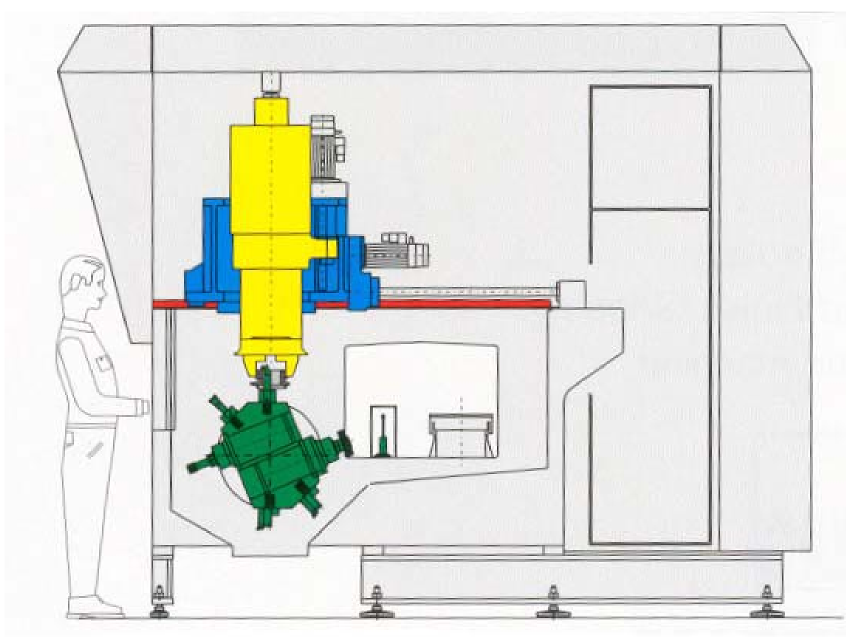


**Fig. 12.28** CNC Vertical turning centre with inverted arrangement EMAG VSC 250HDS, (Courtesy EMAG Maschinenfabrik, Germany).

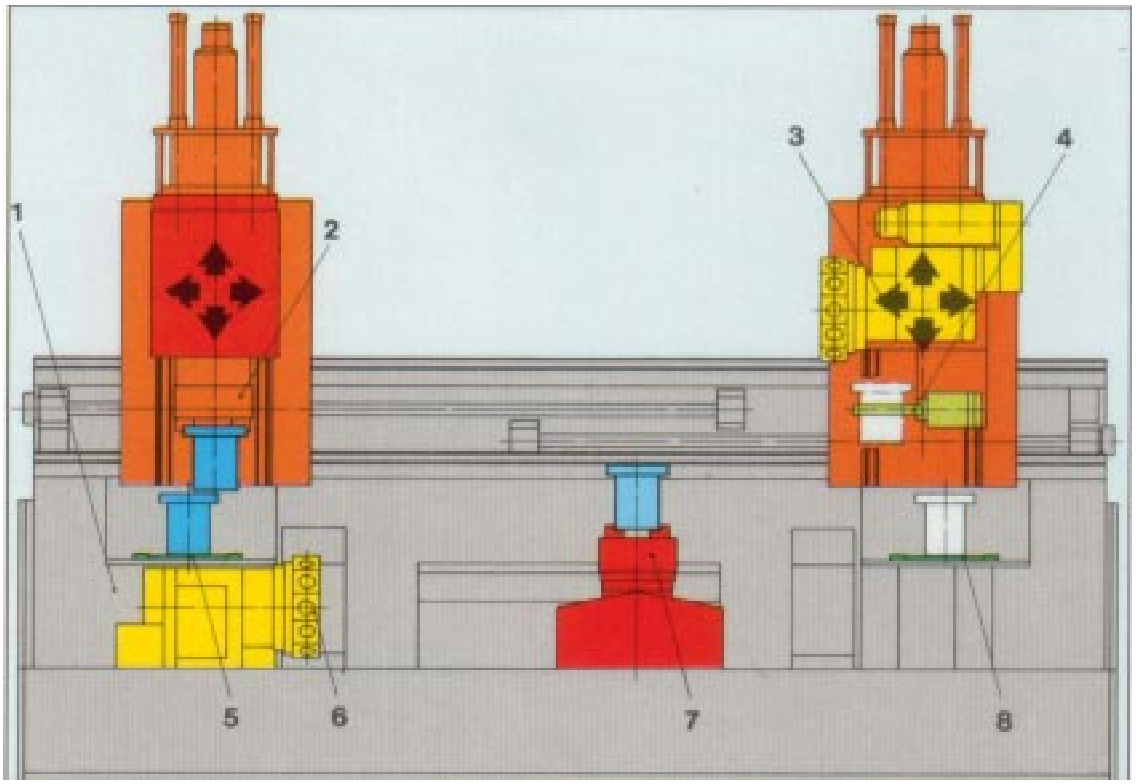



**Fig. 12.29** CNC Vertical pickup turning centre Hüller Hille DVTH300, 1 - DV-Transfer, 2 - Movable spindle, 3-Turret head on cross slide, 4-unloading gripper on cross slide, 5-Workpiece supply, 6-Stationary turret head, 7 - Stationary spindle, 8-Workpiece removal. (Courtesy Hüller Hille, Germany).

These machines are further developed by EMAG to what it calls as 'Multi Functional Vertical production Centres' shown in Fig. 12.30 which can do any of the following operations:

- Turning
- Drilling
- Milling
- Grinding
- Gear cutting
- Balancing
- Gauging

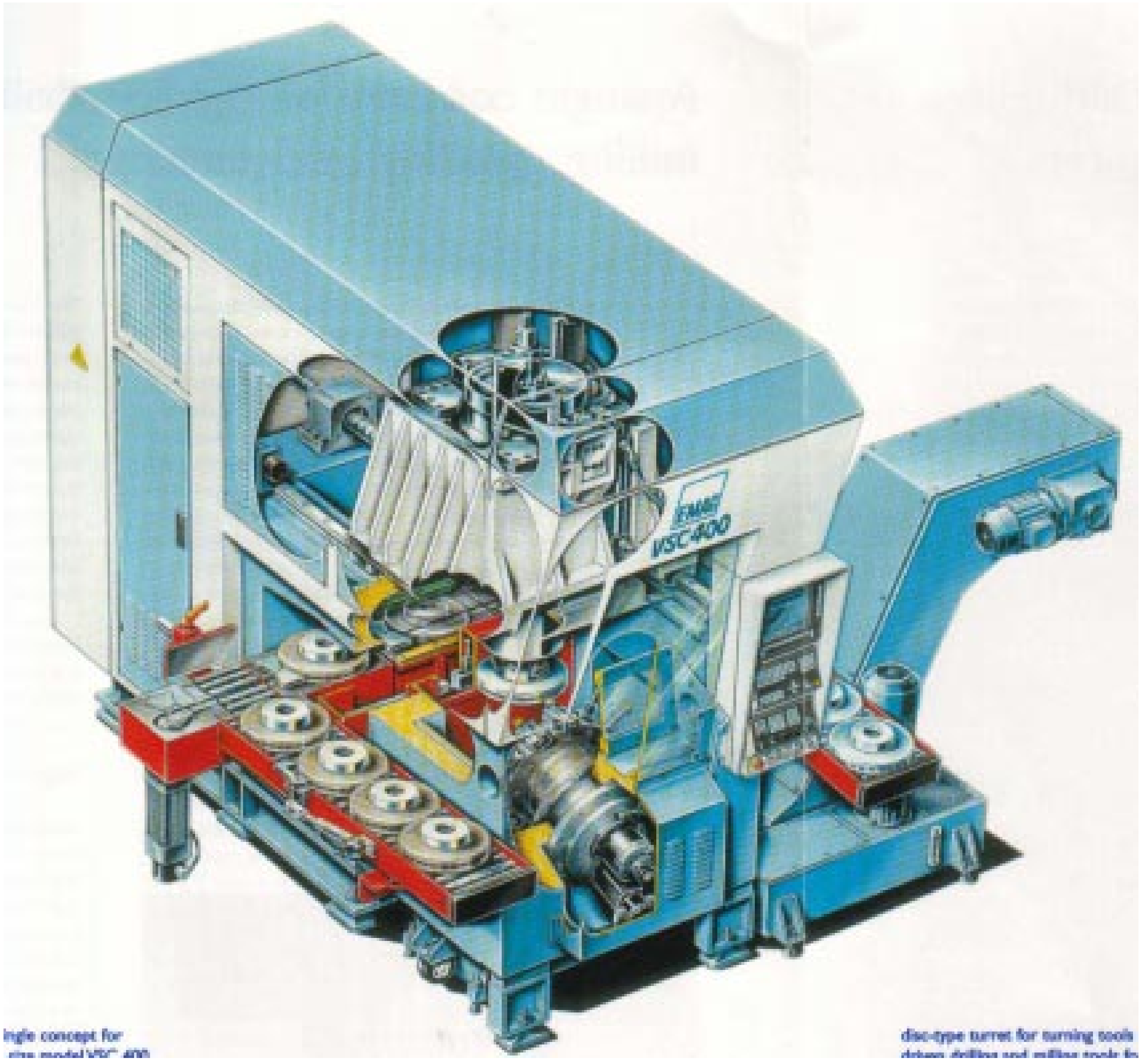
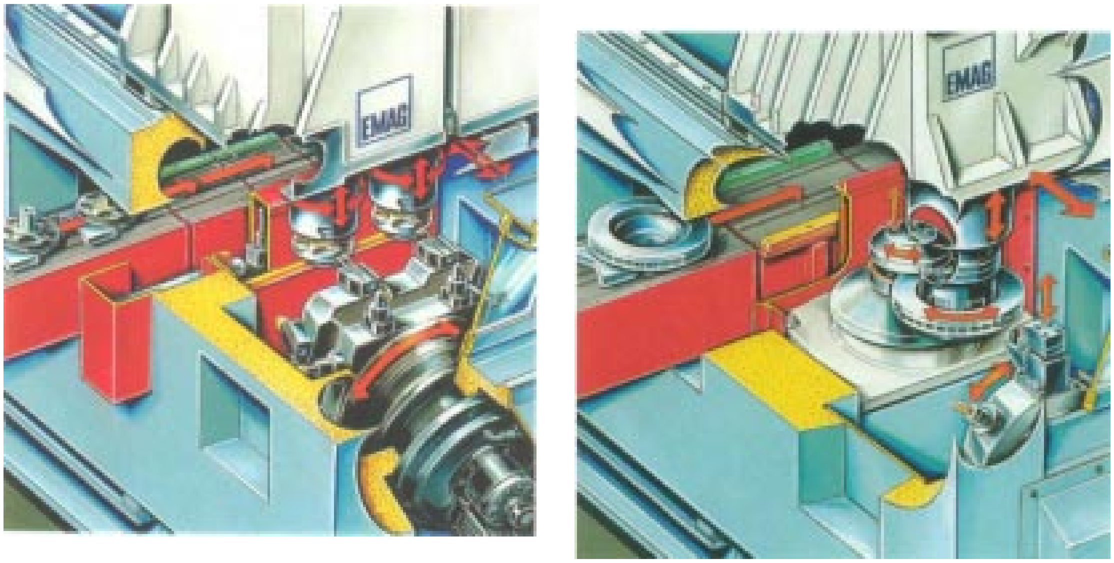



**Fig. 12.30** Multi-functional Production centre EMAG VSC 400, (Courtesy EMAG Maschinenfabrik, Germany).



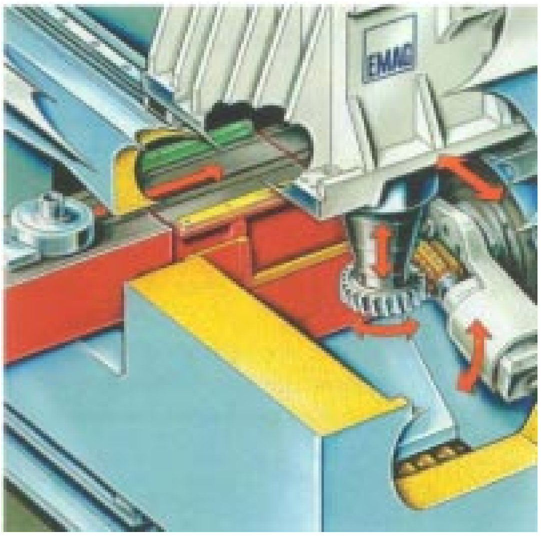

a) Twin spindles to machine two workpieces simultaneously

b) Turning and grinding in the same setup

**Fig. 12.31** Some options for the multi-functional Production centre EMAG VSC 400, (Courtesy EMAG Maschinenfabrik, Germany).

These machines can be provided with specific tooling to suit the individual components. Some of the typical options available are:

- Disc-type turret for stationary turning and driven drilling and milling tools.
- Heavy duty drilling turret; can also be equipped with turning tools.
- CNC heavy duty drilling turrets with Y-axis for double drilling.
- Combination of the standard disc-type turret for stationary turning tools and a high-performance milling spindle
- Workpiece specific multi-spindle drilling heads (Fig. 12.32b)
- HSC-High Speed drilling and milling spindles for process and workpiece specific machining
- Automatic tool changer for drilling and milling tools
- Grinding spindles and turning tools in one turret for turning and grinding especially of hardened components in one clamping set-up (Fig. 12.31b)




a) High speed gear hobbing without coolant

b) Multiple spindle drilling head

**Fig. 12.32** Some options for the multi-functional production centre EMAG VSC 400, (Courtesy EMAG Maschinenfabrik, Germany).

## 12.3 High Speed machine tools

**Table 12.3:** Comparison of conventional and HSM parameters

| **Parameters** | **Conventional** | **High speed machining** |
|---|---|---|
| Spindle speeds, rpm | 4,000 | 8,000 ~ 50,000 |
| Axis feed rates, mm/min | 10,000 | 2,500 ~ 60,000 |
| Rapid feed rates, mm/min | 20,000 | 20,000 ~ 60,000 |
| Accelerations, g | -- | 0.5 ~ 2.0 |

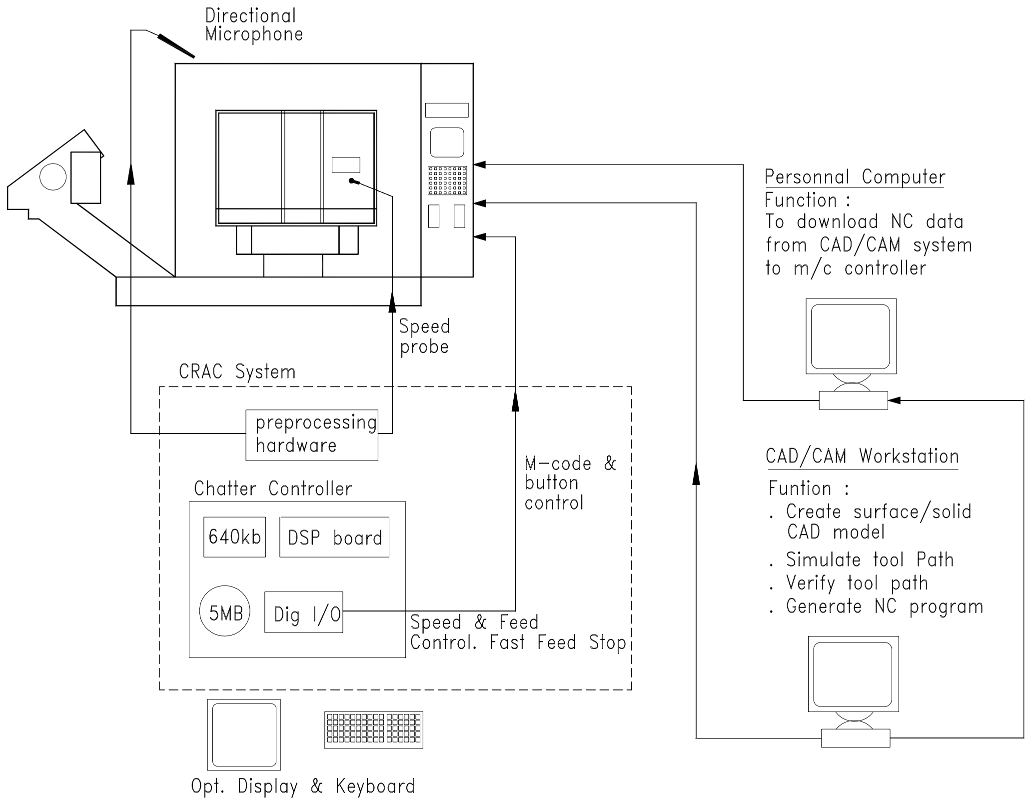



**Fig. 12.33** Chatter Recognition and Control (CRAC) system used for optimising the metal cutting process parameters in HSM.

## 12.4 Machine Control Unit

- Larger part program storage running to MB rather than kB or single blocks in the previous controllers.
- Part program graphical proving and editing.
- Part program generation using conversational part programming methods such as FAPT TURN.
- Tool life management function, which includes larger number of tool offset registers as well as monitoring the life of the individual tools used.
- Background part programming methods.
- Drip feeding of part programs when they are very large in cases such as finish machining of 3D contours of dies and moulds.

- Enhanced part programming facilities such as
  - Complex interpolations such as parabolic and helical
  - Additional canned cycles (other than the drilling series G 80 to 89)
  - Repetitive part programming using functions such as DO loops,
  - Use of subroutines and macros
  - Probes for inspection programs
  - Use of parameters in part programming
  - Help for operator instructions
  - Special geometric calculation facilities
- Better interfaces to outside world (serial as well as parallel communications)
- Diagnostic facilities with the possibility of direct linking with the service centres using modems.
- Enhanced DNC functions with links to factory networks
- Use of standard operating systems such as Windows 95/98 with the associated use of the controller for other functions.
- Better shop floor control by the use of two-way linking through the PLC with the outside world.
- Enhanced machine control such as adaptive control, lead screw pitch error compensation, thermal compensation, etc.
- Enhanced machine control for high speed machining by having a look-ahead facility.
- Multiple axis machining with more axes simultaneously.

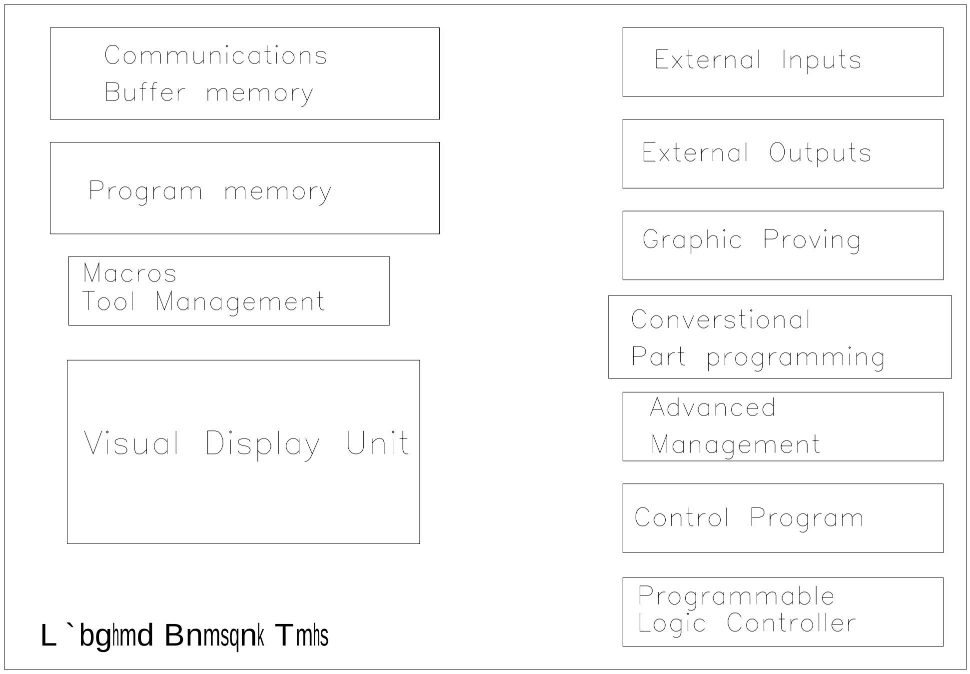



**Fig. 12.34** Organisation of the modern Machine Control Unit functions.

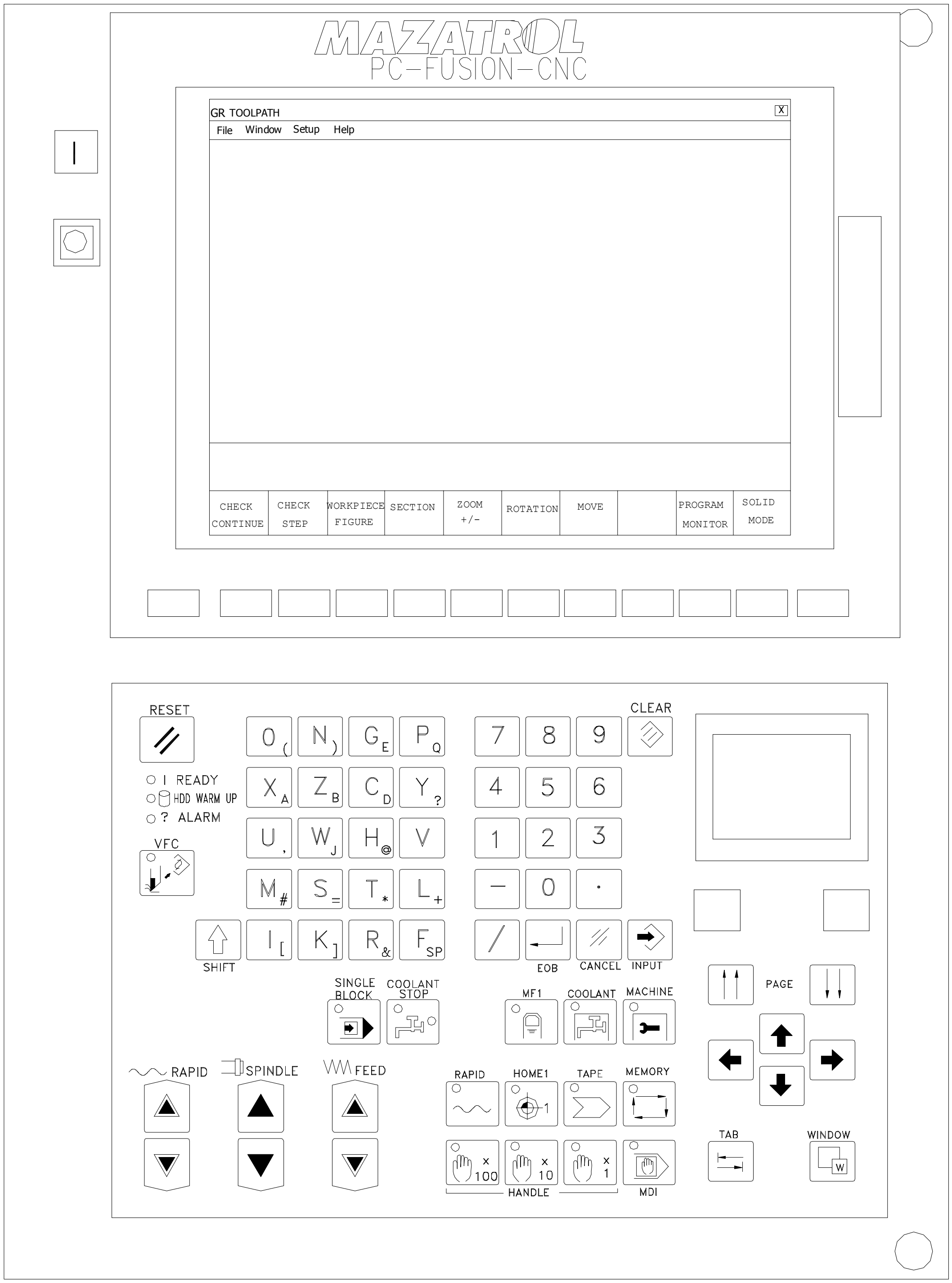



**Fig. 12.35** Present generation Machine Control Unit showing the various options present on the front panel Yamazaki Mazak Mazatrol PC Fusion CNC.

∉# Ellipse

- Spiral
- Helical
- Irregular pocket / area clearance
- Rectangular profile (in/outside)
- Circular profile (in/outside)
- Mold rotation (any axis)
- Rectangular plunge pocket
- Circular plunge pocket
- Draft angle pocket
- Rough turning
- Rough facing
- Grooving (ID/OD)
- Face grooving

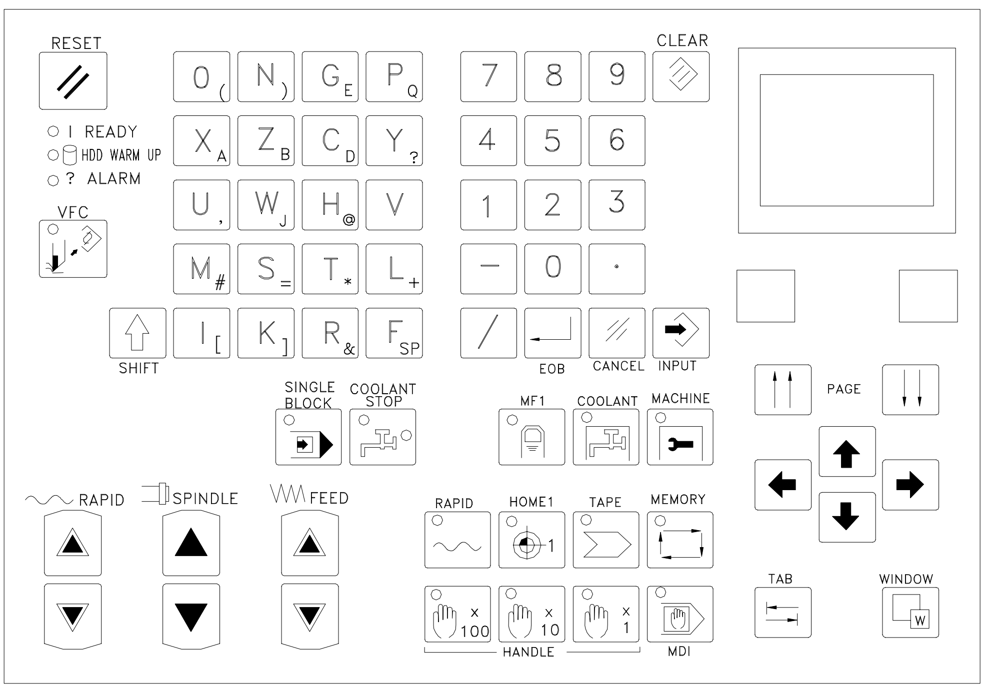



**Fig. 12.36** Organisation of the keypad of a Machine Control Unit in traditional lines (Yamazaki Mazatrol).

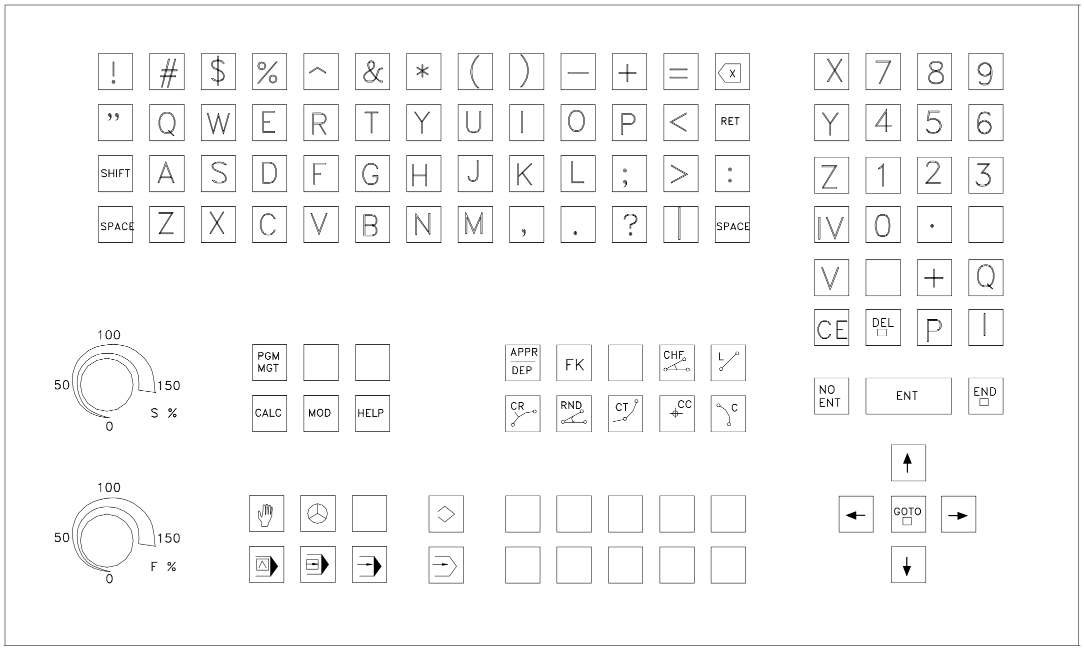



**Fig. 12.37** Organisation of the keypad of a Machine Control Unit with QWERTY format as used in personal computer (Heidenhain).

## 12.5 Support systems

### Chip removal

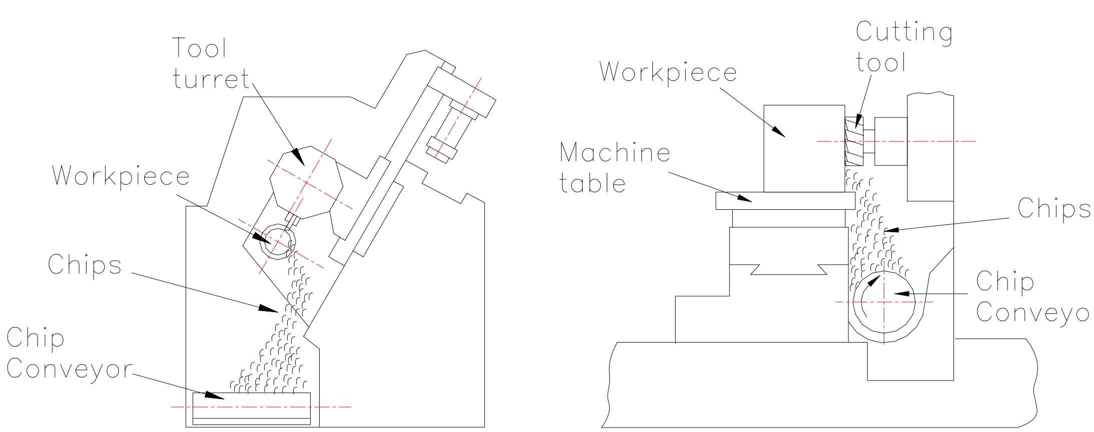



**Fig. 12.38** Chip conveyors used in CNC machine tools.

### Work support in turning centres

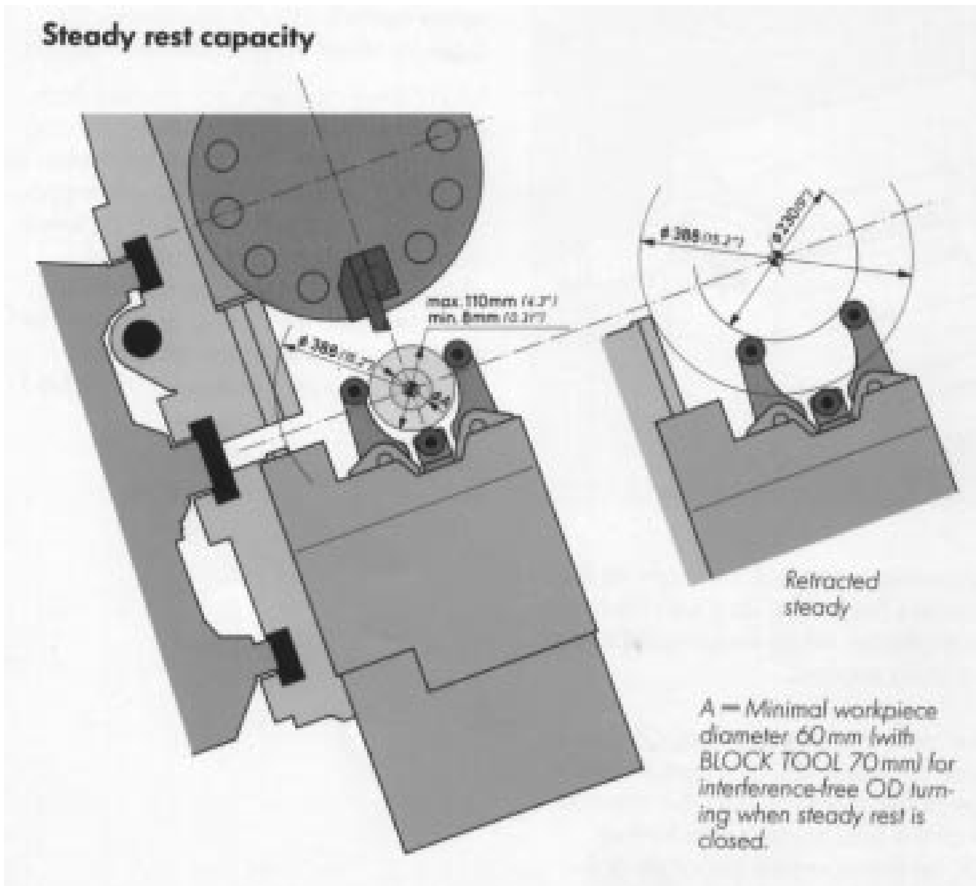



**Fig. 12.39** Programmable steady rest used in CNC turning centres (Courtesy Georg Fischer, Switzerland)

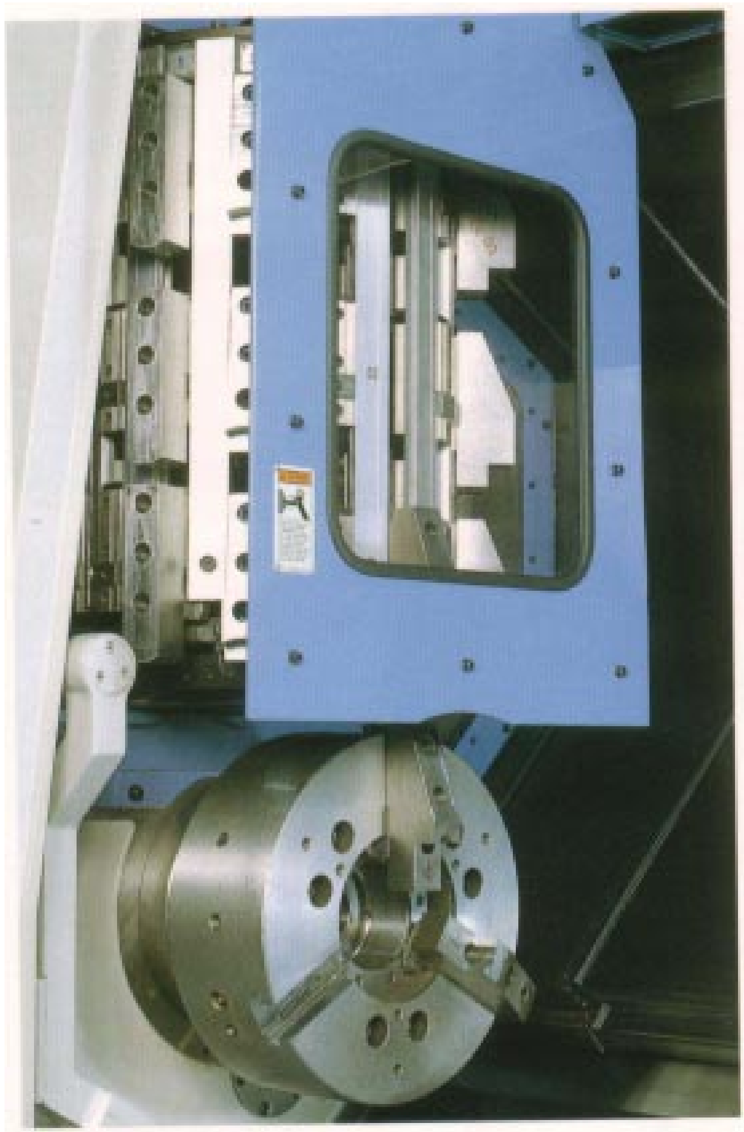


**Fig. 12.40** Automatic chuck jaw changer for CNC Turning centres (Courtesy Yamazaki Mazak Corp., Japan)

**Chuck jaw changer**

## 12.6 Touch Trigger Probes

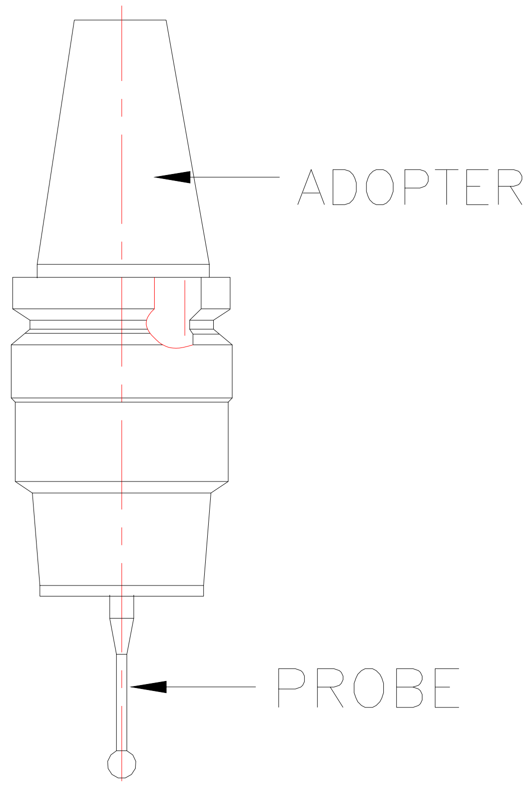



**Fig. 12.41** Touch trigger probe used for inspection on a CNC Machine tool

*Direct hard wired connection*

*Inductive transmission*

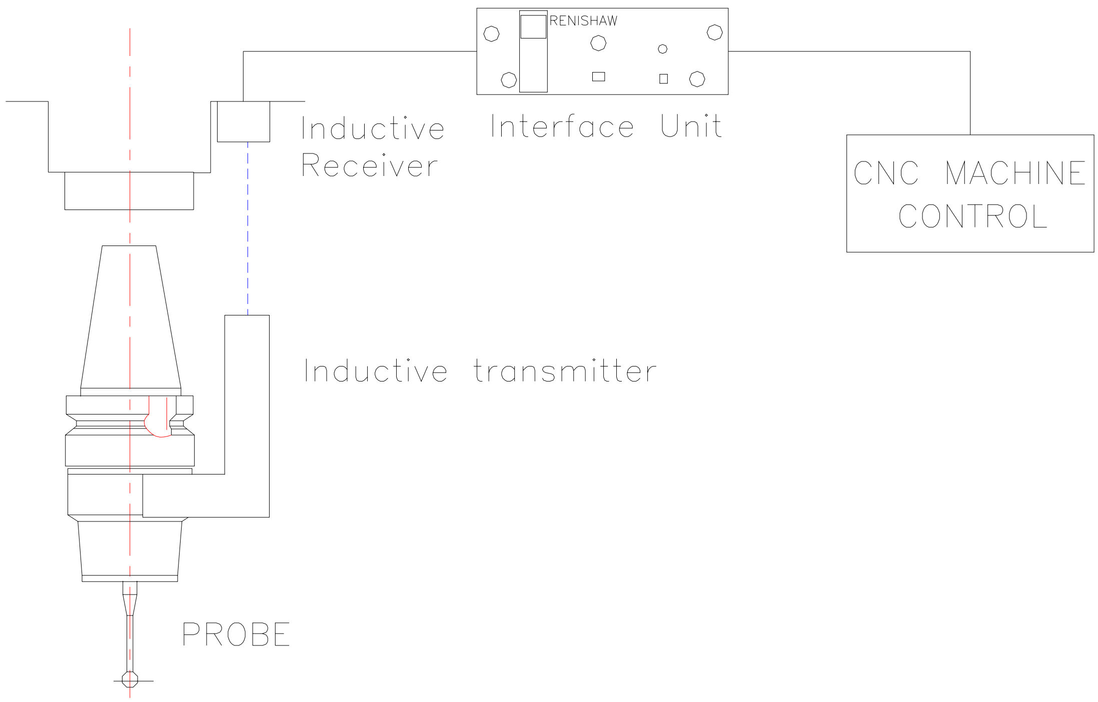



**Fig. 12.42** Inductive transmission systems used in machining centres.

*Optical transmission*

These probes can be used for a number of applications.

- Datuming of the workpiece
- Workpiece dimension measurement
- Tool offset measurement
- Tool breakage monitoring
- Digitizing

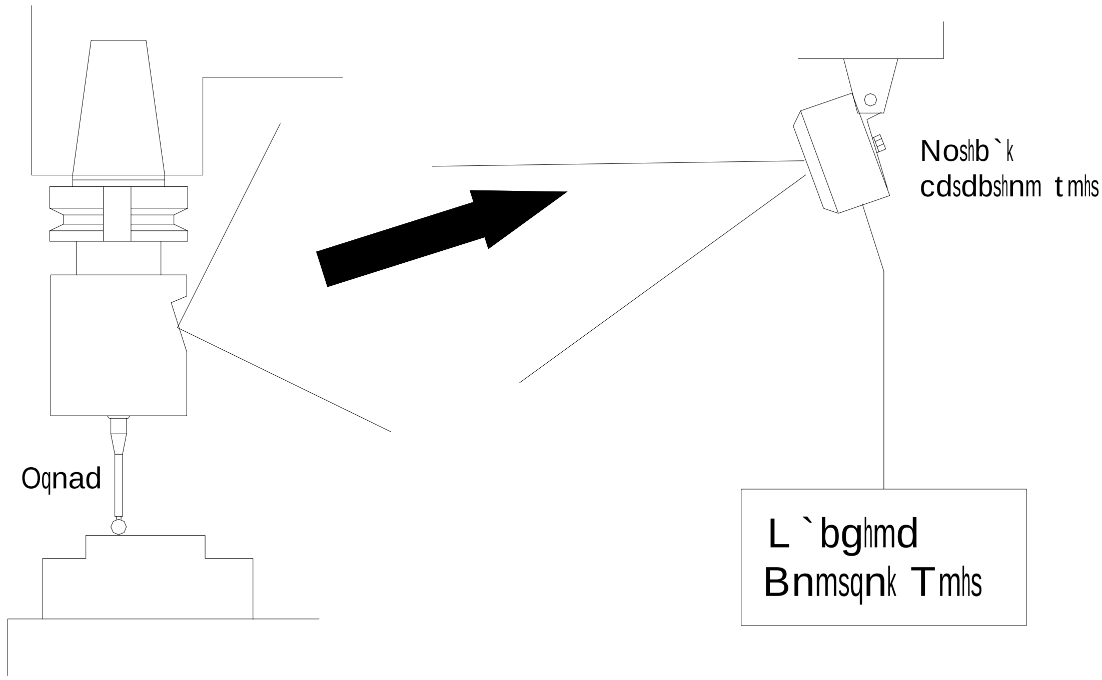



**Fig. 12.43** Optical transmission systems used in machining centres.

**Datuming of the workpiece**

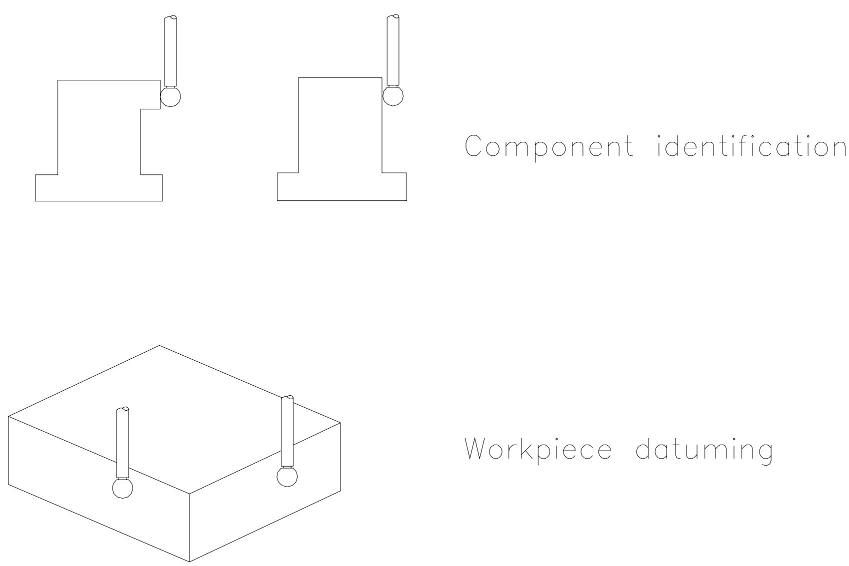



**Fig. 12.44** Probing examples for workpiece setup on the machine tool table.

## Workpiece dimension measurement

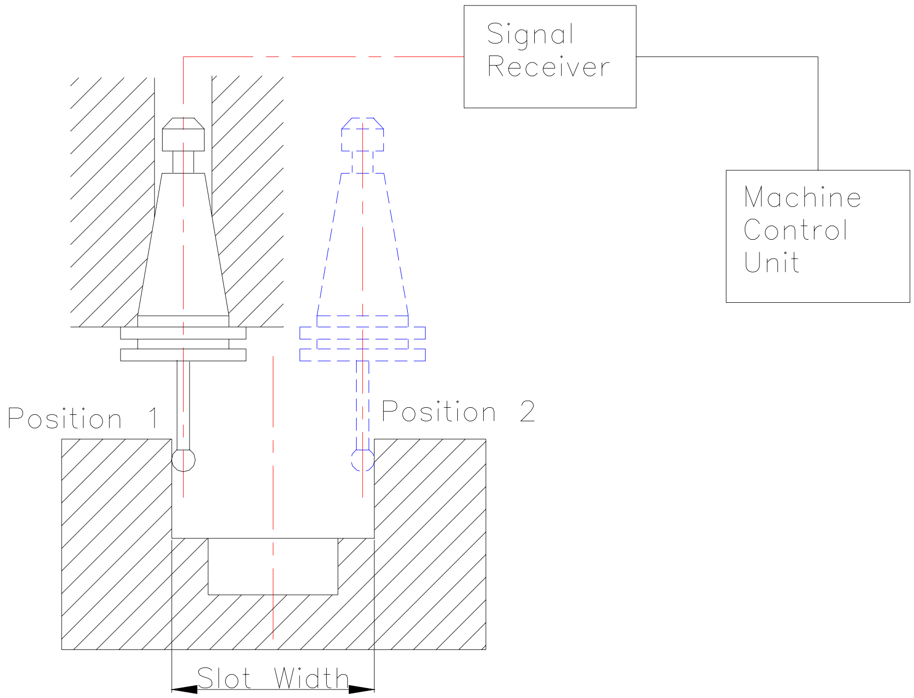



**Fig. 12.45** Use of probe for measuring the width of a slot.

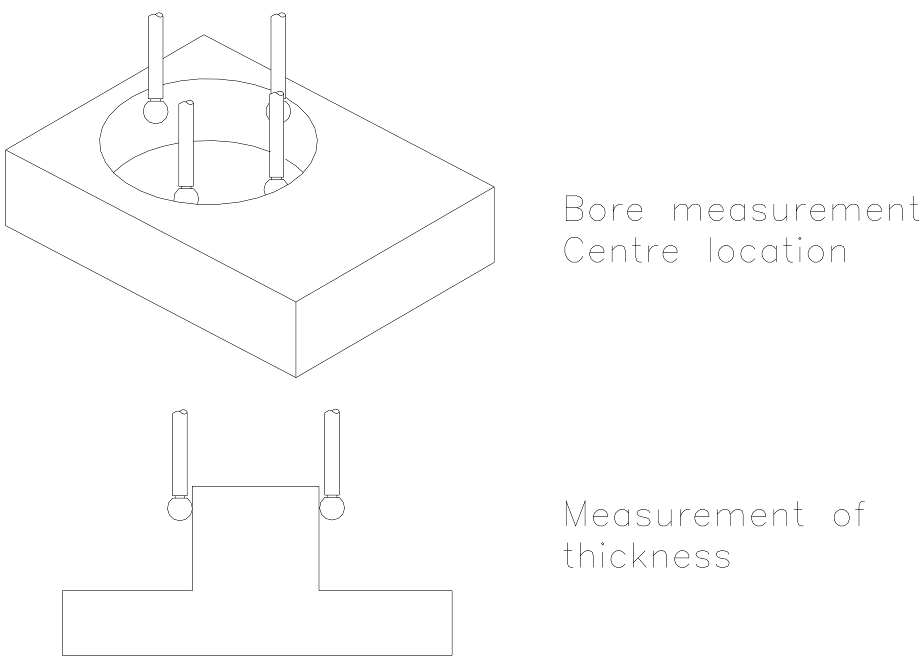



**Fig. 12.46** Probing examples a) Inspection of a bore for diameter and centre position and b) Inspection of a web thickness

*Tool probing*

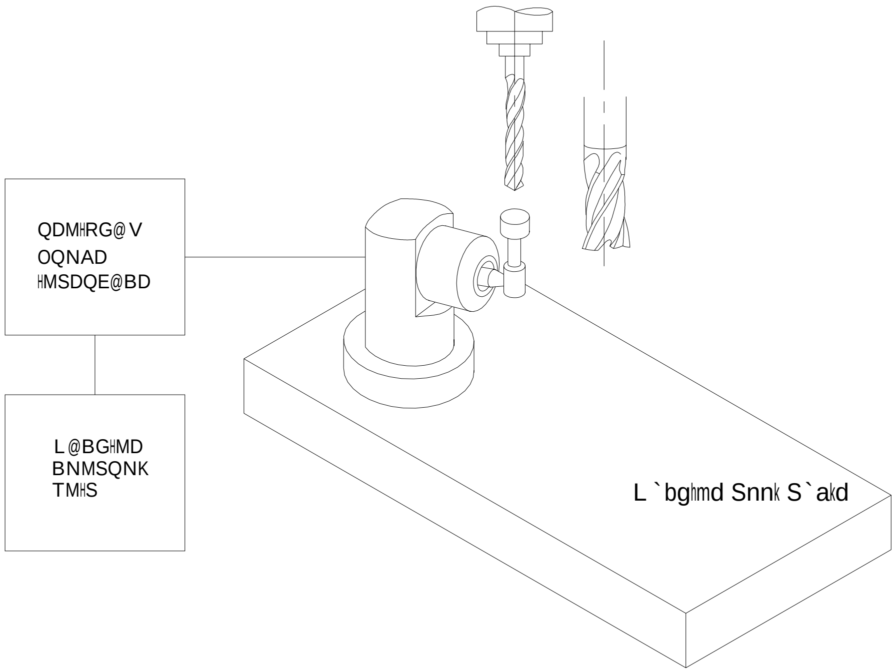



**Fig. 12.47** Probe type used for tool offset determination in machining centres

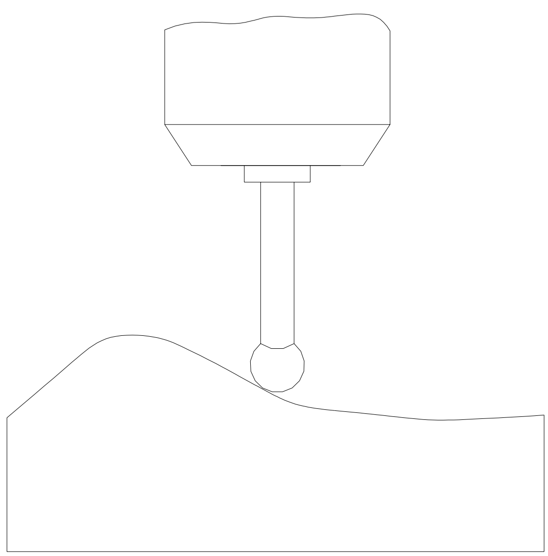


**Fig. 12.48** Probe used for digitising a profile.

## Digitising

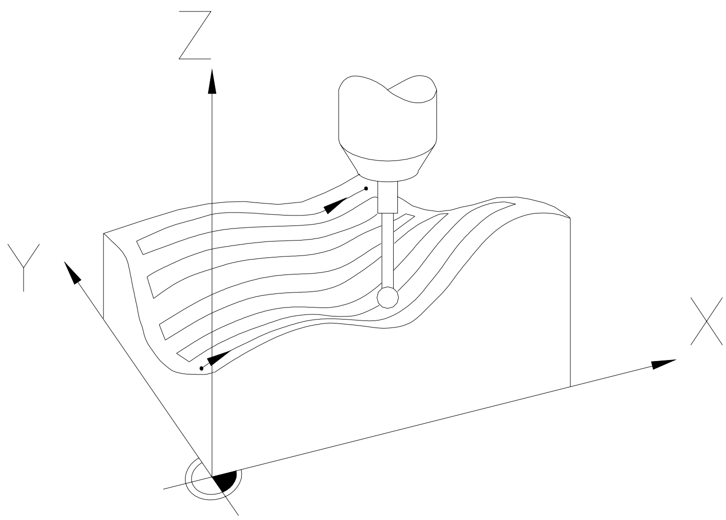



**Fig. 12.49** Probe used for digitising a surface.