

5.2 CNC GRINDING MACHINES

The grinding machines belong to the group of machines working mostly with the geometrically non-defined cutting edge. This group includes the grinding machines as well as the honing machines and the lapping machines. The utilization field of these machines is a very large one.

The grinding machines are used especially in the situations, when the precise shape is required (roundness e. g. even under $0,2 \mu\text{m}$) and the workpiece dimensions with the accuracy from 1 to $3 \mu\text{m}$ as well as when it is necessary to reach the high quality of the machined surface ($R_a = 0,8$ to $0,2 \mu\text{m}$) which cannot be reached by another chip machining way (e. g. by turning or by milling). The important property of the machining ways on these machines is also the possibility to machine hardened materials [Borský 1992 a]. Grinding represents the essential operation of the grinding machines. When grinding is performed, the grinding wheel grains act from the technological aspect like small teeth with irregular shapes which are uniformly located on its active surface. The cutting edge shape and the cutting angles depend on the grain location in the grinding wheel. The principle of the cutting relations of the pair "tool – workpiece" is shown in Fig. 5.2.1. The cut chip section is very small and it has the values ranging from $0,0001$ up to $0,002 \text{ mm}^2$.

However, at the current time the new abrasive material kind comes to the market, where – by contrast – the grinding wheel grains are teeth with regular shapes which are uniformly located on the active surface (Fig. 5.2.1). This enables to reach the following advantages:

- significant reduction of the risk that the surface of the ground part will be burnt;
- grinding time reduction (up to 50 % in dependence on the particular application);
- reduction of the costs necessary to dress off the grinding wheel thanks to the longer time when the dressed shape is kept;
- longer service life of the grinding wheel and of the dressing wheel;
- the same grinding performance.

Because the circumferential velocity is many times bigger in comparison with the workpiece motion velocity, it is counted as the cutting speed. Big cutting velocities used at grinding are the cause, why the big quantity of heat and the high temperature of cut chips

are developed. When the grinding grains are worn, the cutting resistance increases. The cutting resistance increases so long until the strength of the connection of grains with the disk binder is overcome. As soon as the cutting resistance passes over this limit, grains are usually broken-out irregularly. Thus, the main cutting motion is performed by the tool (grinding wheel) rotation at the grinding machines – or, it can be provided by the mutual rotation of the tool as well as of the workpiece. The straight feed motion is either performed by the tool towards the

workpiece or by the workpiece towards the machine. The important calculation problem represents at the grinding machines the calculation of the dynamic stability and equilibration as well as the calculation of the thermal machine stability [Borský 1992a].

Curiosities of grinding technology:

- Approximately 90–92 % of output change to heat at grinding, because of the friction, grinding wheel consumption and deformation.
- Friction is generated between the chip and the cutting crystal edge.
- Efficient cooling and efficient lubrication reduce considerably the grinding output.
- Water has twice as big heat capacity as oil and five times bigger heat

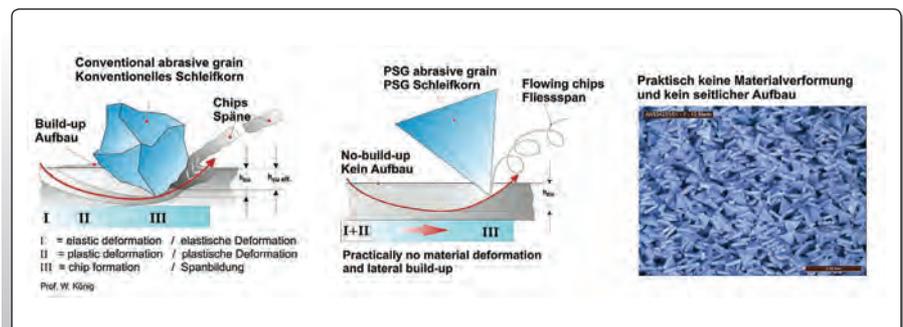


Fig. 5.2.1: Cutting conditions of the pair "tool – workpiece" at grinding [3M]

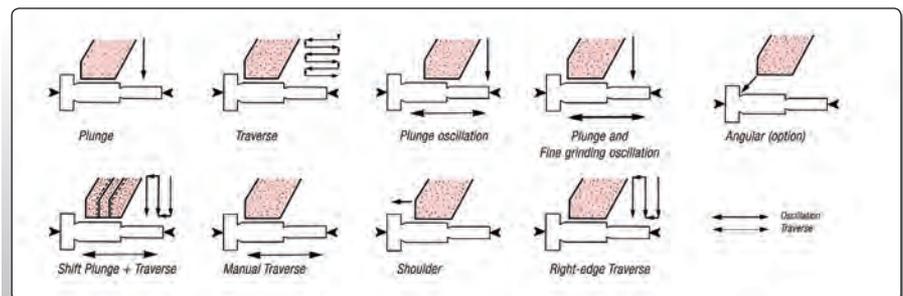


Fig. 5.2.2: Working cycle example at grinding [Okuma]

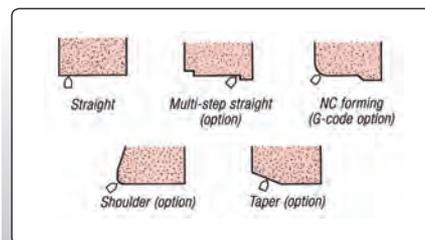


Fig. 5.2.3: Dressing cycles at grinding wheels [Okuma]

conductivity, but it cannot be used for the high-speed grinding process (boiling point of $100 \text{ }^\circ\text{C}$). Low-viscosity oils have boiling temperature of $240 \text{ }^\circ\text{C}$.

- The machining surface having a better quality can be reached by oil cooling. Oil also lubricates all functional motion machine elements, no corrosion occurs.
- Because oil is inflammable, the machines must be equipped with the inspection

equipment, if oil is used at machining – with the fire-fighting and anti-explosion equipment.

At the beginning the application of NC technology to the grinding machines met with specific problems of grinding procedures. The first utilization of the hardware numerical control technology in practice, especially at production cylindrical grinding machines was noticed at the 9th EWA European machinery show in Brussels in 1965. The quick expansion to all kinds of grinding machines happened only with the arrival of the CNC software (free-programmable) numerical control systems based on computers with utilization of microprocessors and semiconductor memories. The current numerically controlled grinding machines are equipped not only with the CNC path contouring control but also with the simple NC control of one axis or even with the mere position indication. The CNC control expansion at the grinding machines was also conditioned by the increase of CNC control reliability and especially by simplified programming, which made the CNC control available for a common operator. The measuring increment reduction up to $0,1 \mu\text{m}$ is not insignificant for the development of the numerically controlled grinding machines either [Borský 1992a].

The first numerically controlled grinding machines adopted the concept of traditional grinding machines with the grinding wheel axis which is parallel with the workpiece axis and with the perpendicular in-feed motion. However, this way appeared to be the unsuitable one at often grinding of front surfaces of the particular diameter steps on the workpieces. It was necessary to correct the diameter and face grinding wheel dressing. The inclined grinding wheel setting towards the workpiece appeared

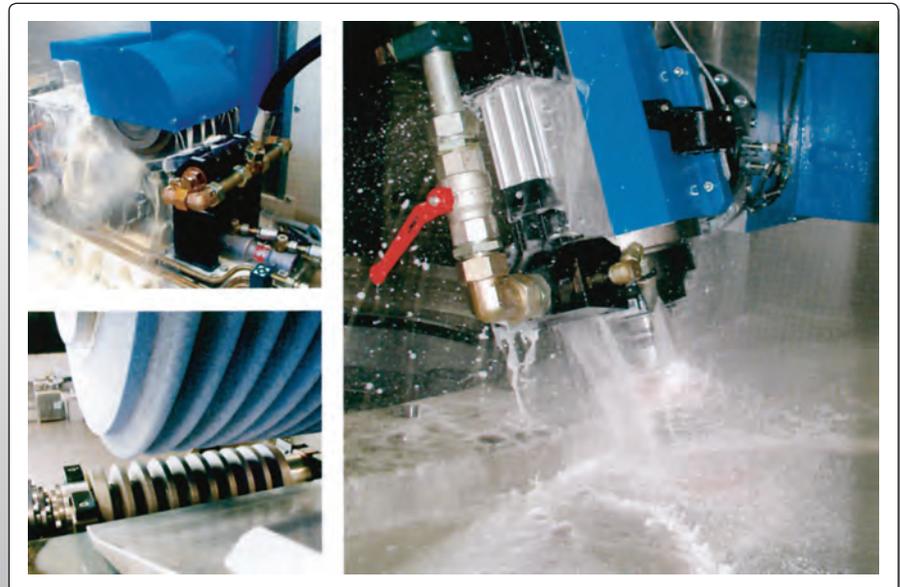


Fig. 5.2.4: Cutting lubricant supply to the grinding wheel [Mägerle]

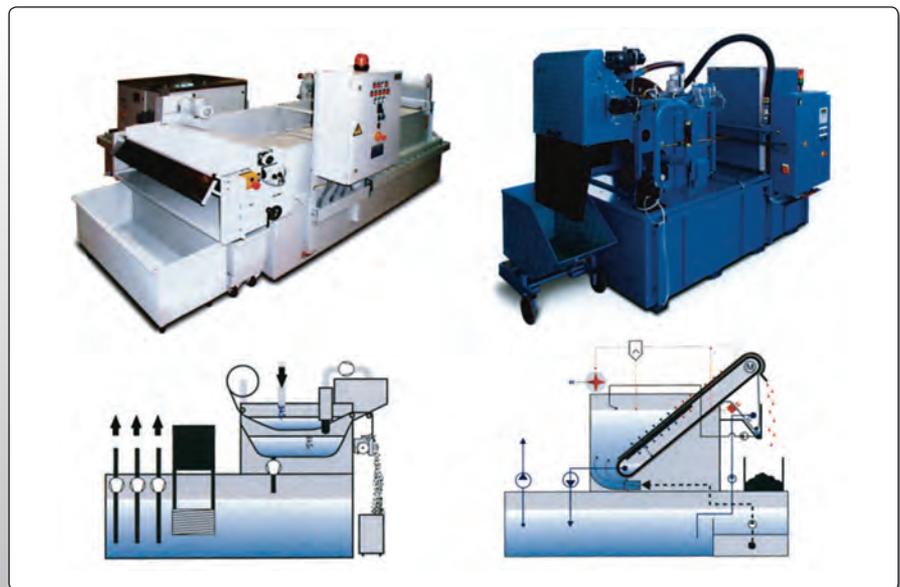


Fig. 5.2.5: Hydrostatic and vacuum filter [Mägerle]

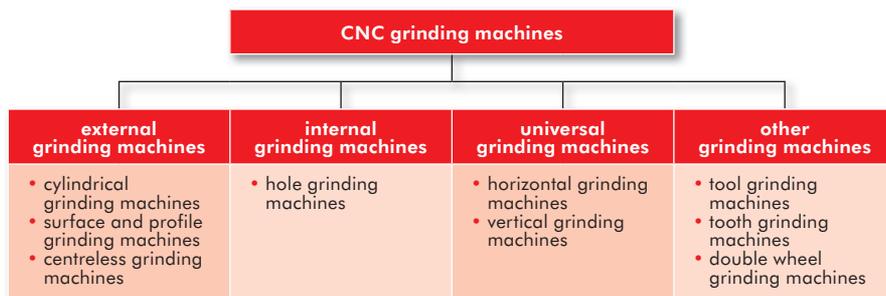


Fig. 5.2.6: Division of the CNC grinding machines

to be the more suitable one. In this case the grinding wheel in-feed motion to the workpiece can be either perpendicular to the wheel axis or perpendicular to the workpiece axis. The compensation after grinding wheel dressing is more complicated in the first case. The transition rounding-off on the workpieces had to be the same ones as the grinding wheel rounding-off at the straight line control. Its

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inclined setting at the contouring control of the X-axis and of the Z-axis enables to grind also the rounding-off having the bigger radius than the rounding-off radius is at the grinding wheel. In order to provide the exact length dimensions of the particular steps, the numerically controlled cylindrical grinding machines are usually equipped with the device for the longitudinal workpiece setting

[Borský 1992 a]. The working cycle is shown in Fig. 5.2.2. and in addition to the grinding cycles, it is also possible to grind using the straight recess or the inclined recess.

The grinding machines can be equipped with many compensations, like the dressing compensation, the dressing wheel consumption compensation and the grinding wheel consumption compensation. The typical dressing cycles are shown in Fig. 5.2.3.

As it was already said, cooling and lubrication have the considerable significance at the grinding machines during the cutting process. Coolant has the task to remove arising heat from the cutting process contact zone (from the workpiece and from the grinding wheel). Moreover, it shall provide cleaning of the grinding wheel, to provide chip removal and lubrication of the surface, where the material is removed. So that these requirements can be fulfilled, dimensioning of the cooling circuit must comply with the performed operations [Borský 1992a]. The layout of the coolant supplies to the material removal place has the very important role (Fig. 5.2.4).

The supplied coolant flow shall be tangential and it shall strike against the rotating

wheel before its entering the contact zone. The cleaning of grinding wheels can be considerably improved by the suitable arrangement of the nozzles cleaning in the radial layout or in the tangential layout. It is recommended to use higher pressure values to increase the cleaning effect.

In order to reach the correct cooling circuit function, it is necessary to provide the high-quality and efficient coolant filtration.

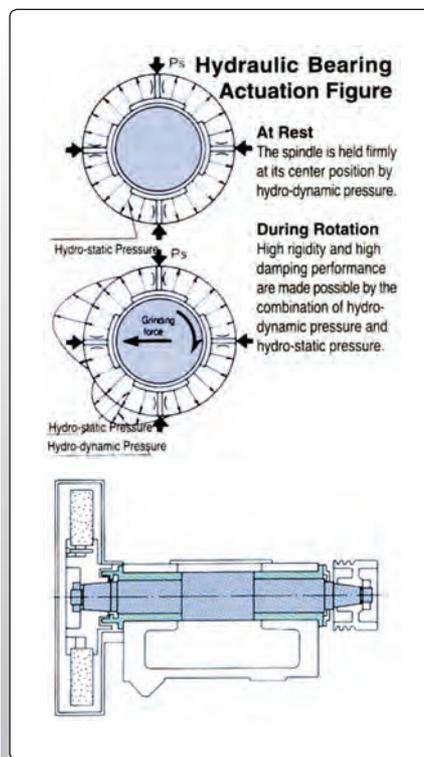


Fig. 5.2.7: Special bearing of the grinding spindle [Palmary]

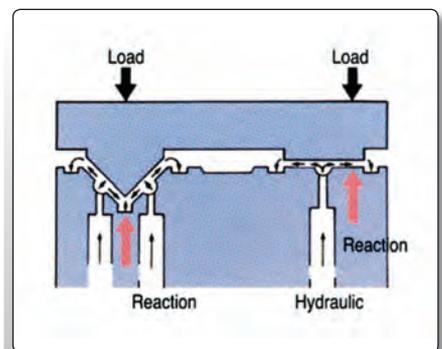


Fig. 5.2.8: Hydrostatic table guiding at the cylindrical grinding machine [Palmary]

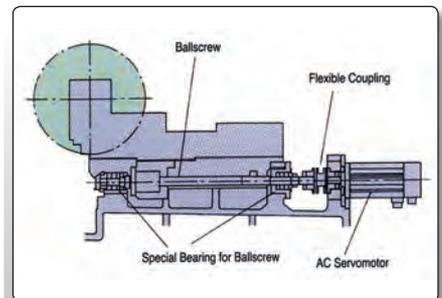


Fig. 5.2.9: Feed-in mechanism of the grinding wheel [Palmary]



Fig. 5.2.10: Cylindrical grinding machine EGP [e-tech]