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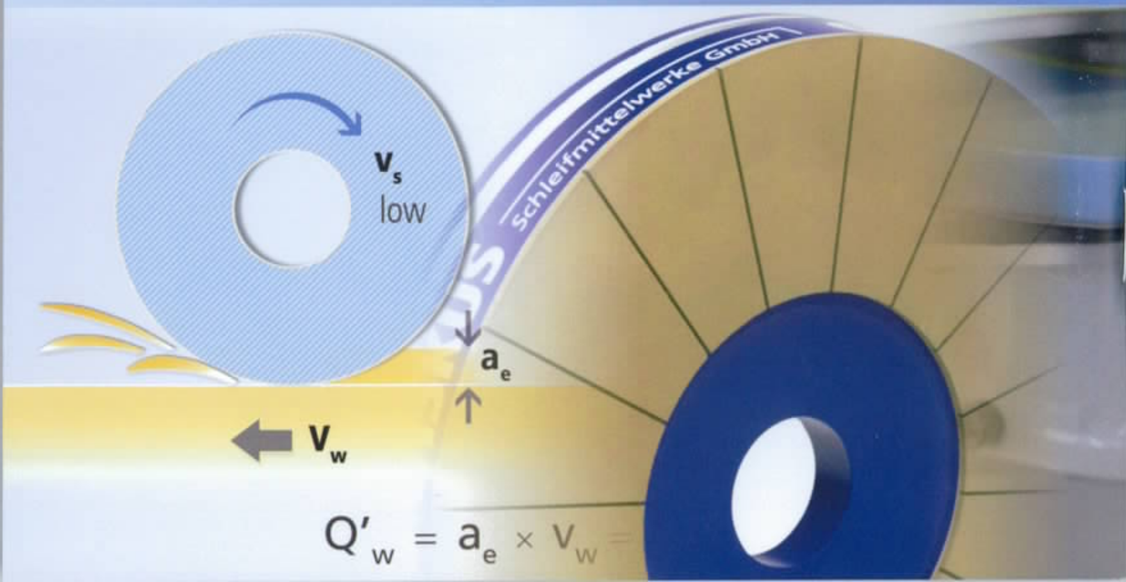


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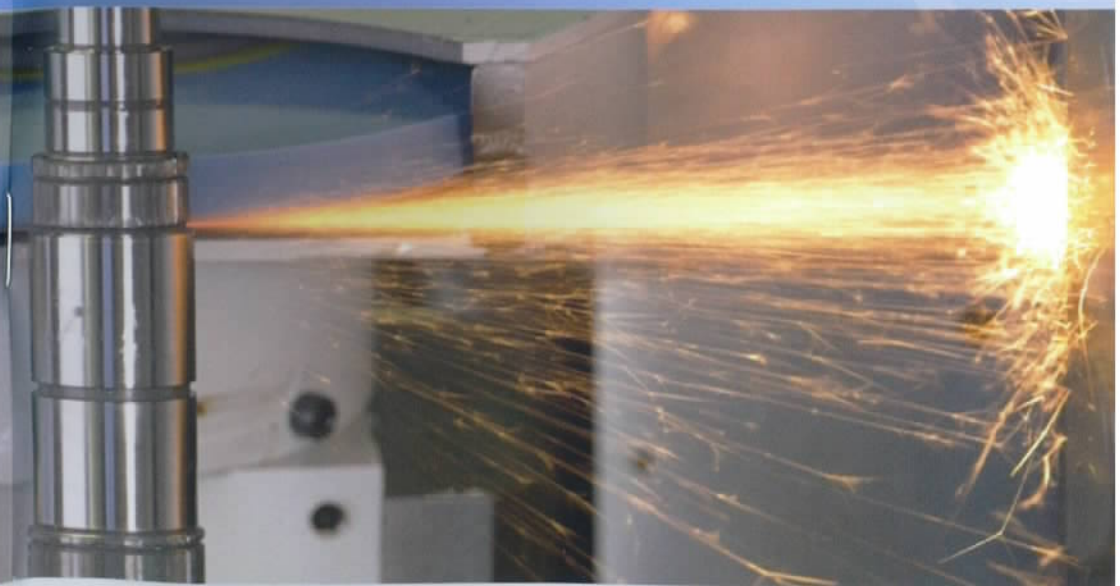
# *Principles of grinding*



# Introduction

This document is intended to provide an overview of the **structure of a grinding tool** and also of the **basic variables of the grinding process**.

Both are closely linked to one another.

The 'grinding' process is subject to principles similar to those known from other machining processes. The 'grinding tool' is made up of abrasive grains and pores and exhibits an irregular distribution of cutting edges.
As opposed to all other operations such as milling or lathing, negative cutting angles occur during grinding, leading to unfavourable chipping conditions.

The correct choice of grinding tool structure and suitable grinding parameters enable efficient, inexpensive machining of a work piece by means of grinding.



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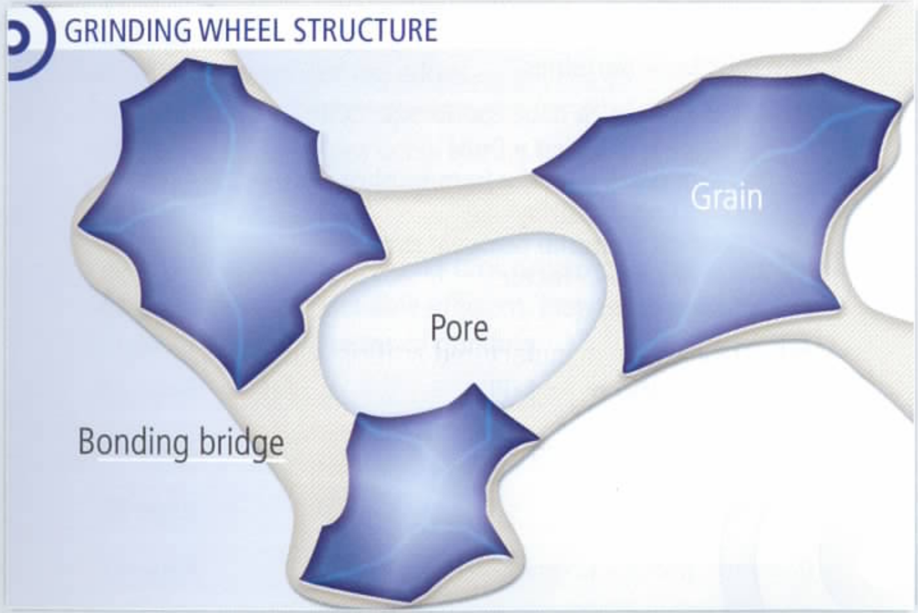
# Static basic variables

## Grinding tool structure

The grinding tool is made up of:

- abrasive grain
- bonding
- pores






## The abrasive grain


The task of the abrasive grain is to form the chip during the grinding process.

Depending on the type of abrasive grain, it has a different number of cutting edges, whereby these are geometrically distributed in an indeterminate fashion. The type of abrasive grain is determined by the material to be machined.

The following types of grain are used for grinding:
**Corundum, silicon carbide, boron nitride and diamond**

Most abrasives are manufactured artificially using industrial processes. Corundum and silicon carbide are referred to as conventional abrasives, whereas CBN and diamond are referred to as superhard abrasives due to their extreme hardness. Diamond possesses the highest hardness of all known materials. Long-chipping materials require the use of corundums or CBN. Very brittle and hard materials are machined using silicon carbide or diamond.

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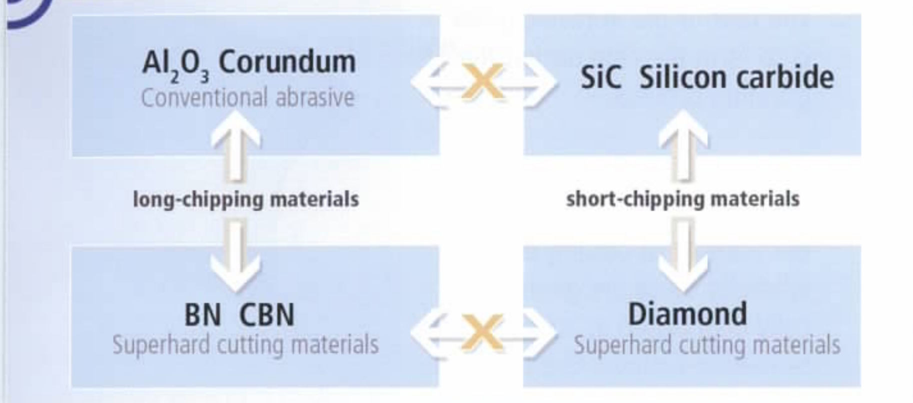
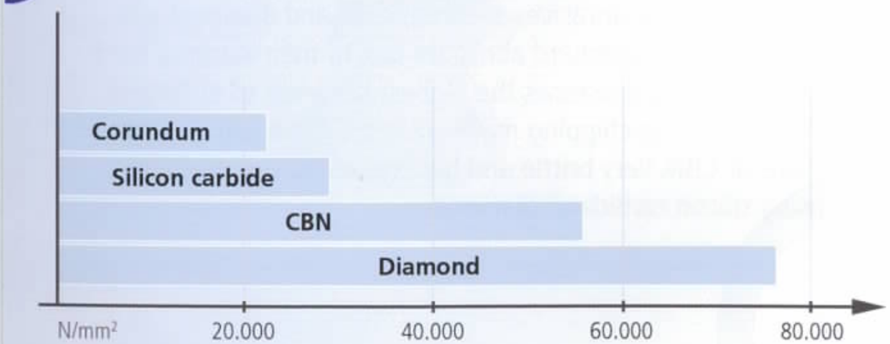
## GRAIN TYPES




The hardness of the different types of grain can be placed in order as follows

**Corundum < silicon carbide < CBN < diamond**

## HARDNESS COMPARISON AFTER KNOOP



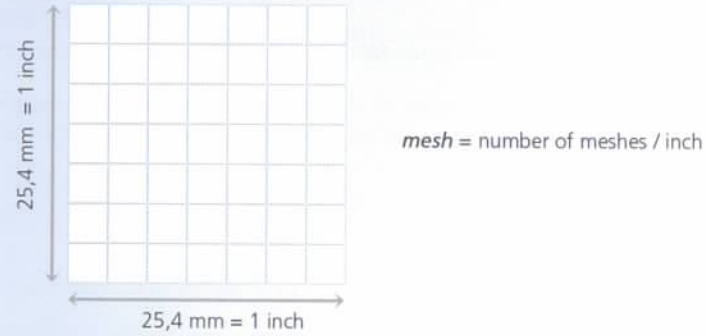



The size of conventional abrasive grains (corundum, silicon carbide) is given in **mesh**.

The grain size in **mesh** is defined as the number of meshes of a sieve per inch (25.4 mm) through which the designated grain just falls, whilst being retained by the next finer sieve.

## GRAIN SIZE

**Conventional grinding grades:** mesh designation




**Superhard abrasives:** Grain size given in µm

*D 126* = Diamond grain size 126 µm
*B 46* = CBN grain size 46 µm

## Guiding values for grinding with conventional grains:

| | | |
|---|---|---|
| **Pre-grinding:** | 36 – 60 mesh | *(coarse)* |
| **Finish grinding:** | 60 – 100 mesh | *(medium)* |
| **Ultra-fine grinding:** | 100 – 320 mesh | *(fine)* |

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## Grain types and properties:

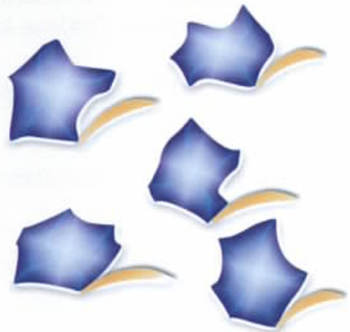
| Grain type | Proportion | Colour | Properties | Area of application |
|---|---|---|---|---|
| **NK** Normal corundum | 95–97 % $Al_2O_3$ | *brown* | high durability | Low alloy steels, in particular for high material removal performance when rough grinding |
| **EK** Precious white corundum | 99,9 % $Al_2O_3$ | *white* | very hard and brittle | Broad range of uses for precision grinding such as tools, round and flat grinding. |
| **HK** Normal corundum with precious corundum | 98 % $Al_2O_3$ | *brown* | high durability, very hard and brittle | Well suited for grinding unhardened and low alloy steels. For precision grinding also. |
| **HKs** Melted semi-precious corundum | 98 % $Al_2O_3$ | | higher durability than precious corundum | Main application areas are precision and tool grinding. |
| **EKd** Precious pink corundum | Over 99 % $Al_2O_3$ 0,2–0,3 $Cr_2O_3$ | *pink* | very hard, higher grain durability than precious corundum | Outstandingly suitable for flat profile grinding and saw-blade sharpening. |
| **FF** Ruby corundum | 98 % $Al_2O_3$ 2 % $Cr_2O_3$ | *ruby red* | very hard, high resistance to wear | Used for precision grinding of high alloy steels. |
| **EKa** Single-crystal corundum | 99,2 % $Al_2O_3$ | *light pink* | very high grain durability | For grinding HSS steels and for tool grinding. |
| **EKT** Chrome-titanium oxide alloyed corundum | 99,35 % $Al_2O_3$ 0,25 % $TiO_2$ | *light pink* | more durable than precious corundum, less hard | Machining of alloyed and thermally sensitive steels. |
| **NAXOS-KSB** Sintered corundum | Micro-crystalline 96 % $Al_2O_3$ | *blue* | extremely durable, 15 % harder than precious corundum | Used for almost all grinding processes if the machine is designed appropriately (rigidity). |
| **SB** Sintered bauxite | NK or NK + $ZrO_2$ | | extremely durable | Exclusively for highly compacted grinding wheels. For high pressure grinding of austenitic steels. |
| **SCg** Silicon carbide, green | 98 % SIC | *green* | extremely hard and brittle | Used for hard metals, non-metallic materials, cast iron (to some extent) and austenitic steels. |
| **SC** Silicon carbide | 97 % SIC | *black* | hard and brittle | For rough grinding of cast materials. |
| **CBN** Boron nitride | 100 % BN | *black* | high hardness, resistance to wear and breakage | Grinding of hard alloys containing carbide. Tool steels, special steels, HSS etc. |
| **Diamond** | 100 % C | *transparent* | highest hardness and durability | Grinding of amorphous, extremely hard materials. Hard metals, concrete, natural stone |

**Coarse grains produce larger chips, small grains produce finer chips**

It is better to select coarse grains for removing large quantities of material and/or for easily-chipped and/or long-chipping materials.

Fine grains are required in order to achieve greater precision and surface quality and/or sharp edges and/or for materials that are difficult to chip.

## SELECTION OF GRAIN SIZE ⟷ GRINDING TASK



**Coarse grain** (e.g. 36 mesh)

Greater removal of material

- Material easier to chip
- Longer chipping material

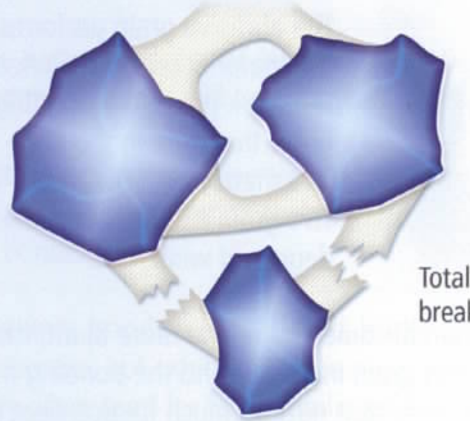
**Fine grain** (e.g. 100 mesh)

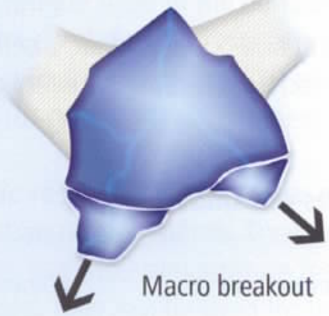
Greater accuracy

- Better surface
- Material harder to chip
- Obtaining sharp edges



## TYPES OF GRAIN WEAR




## Bonding


The abrasive grain performs the material removal work on the work piece. The bonding holds the grain in the abrasive matrix until the abrasive grain exhibits a certain degree of wear.

In other words, the grain becomes more and more blunt, the grinding pressure on this grain increases and the bonding finally releases the grain so that not too much friction heat is generated as a result of the grain becoming blunt.

If the ratio of grains, bonding and pores is ideal, a self-sharpening effect is produced, which is desirable for every grinding operation.

**The most important types of bonding are:**

| | | |
|---|---|---|
| **Ceramic bonding** | Abbreviation V | *(Ceramic)* |
| **Synthetic resin bonding** | Abbreviation B | *(Bakelite)* |
| **Metallic bonding** | Abbreviation M | *(Metal)* |
| **Rubber bonding** | Abbreviation R | *(Rubber)* |
| **Fibre reinforced** | Abbreviation BF | *(Bakelite fibre reinforced)* |
| **Galvanic bonding** | Abbreviation G | *(Galvanic)* |



The bonding properties differ widely, which must be taken into account for the various areas of application.

The basic properties of ceramic, synthetic resin and metal bonds will be described in detail here.

Both the physical properties and the grinding properties of the finished grinding tools can be influenced by the type of bonding.

**Ceramic bonds** are hard, rigid, brittle and have low damping properties, but exhibit high temperature resistance. They are very often used for form grinding. Ceramic bonds can achieve high material removal performances. Bond wear occurs as a result of fatigue tears in the bond bridge. Ceramic grinding wheels are used above all in many precision applications such as outer cylindrical grinding (OD grinding), inner cylindrical grinding (ID grinding) and flat/deep grinding.

**Synthetic resin bonds** are softer, more elastic and more durable than ceramic bonds. They possess higher damping properties, but their temperature resistance is unfortunately very limited. They can be used for both rough grinding (high material removal) and smooth polishing (good surfaces and low roughnesses). These properties make the use of synthetic resin grinding wheels particularly suitable for methods such as centreless grinding, flat/planar grinding and outer cylindrical grinding (OD grinding). Good surfaces and material removal performances are achieved here. However, synthetic resin-bound fibre-reinforced abrasives are also used for cutting and rough grinding operations in the free-handed sector.

As opposed to the previously described materials, **metal bonds** are good conductors of heat. They are also very hard, exhibit low damping and are very resistant to heat. These bonds are used in combination with CBN and diamond. Besides use in the precision field (e.g. glass grinding), these bonding systems are used primarily in the machining of concrete and natural stone.

### TYPES OF BONDING

| *Properties:* | Synthetic resin | Ceramic | Metal |
|---|---|---|---|
| Hardness | ↓ | ↑ | ↑ |
| Dimension stability | ↓ | ↑ | ↑ |
| Durability | ↑ | ↓ | ↑ |
| Damping properties | ↑ | ↓ | ↓ |
| Profile | form-following | formative | formative |



# Further grinding tool factors

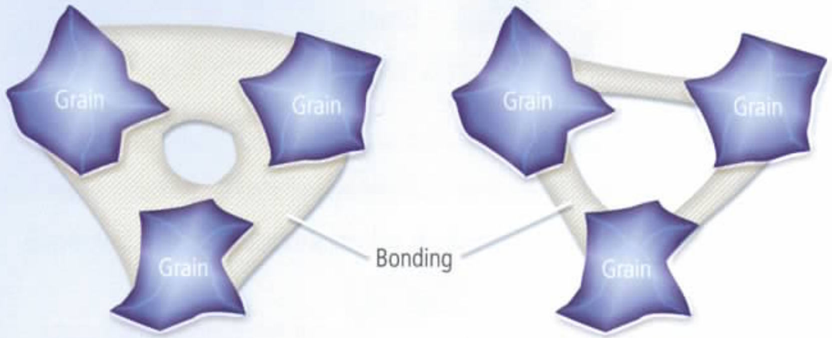
## Hardness

When we talk about of the hardness of a grinding tool, we do not mean the hardness of the abrasive grain, but rather the volume of bonding in the abrasive matrix. A large bonding volume bonds the grain tight and the grinding tools exhibit high hardness; they cut less easily, but in return their service life is higher. Accordingly, grinding tools with a low bonding proportion are softer and cut more easily, but their service life is conversely lower.

### HARDNESS

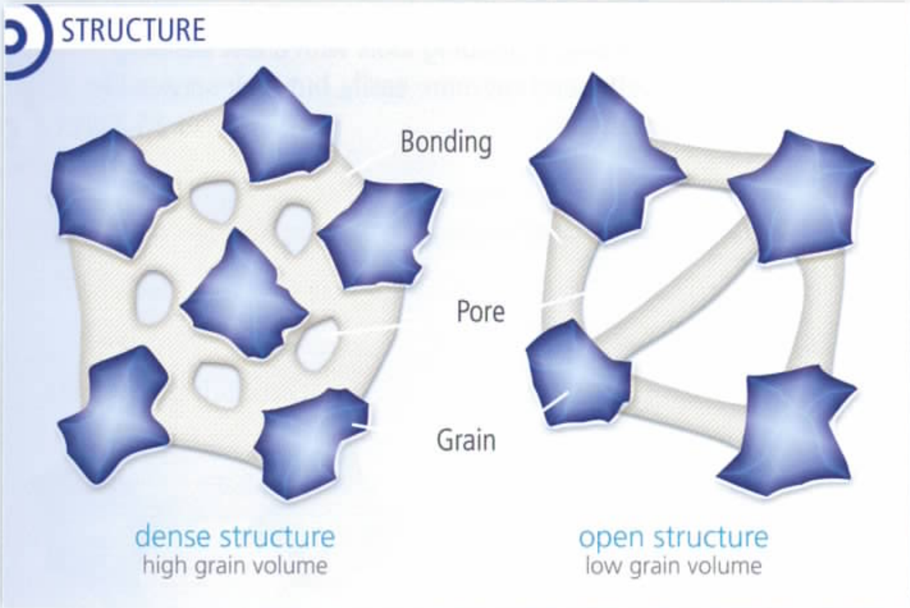
**Hard:** large amount of bonding

**Soft:** small amount of bonding



## Structure

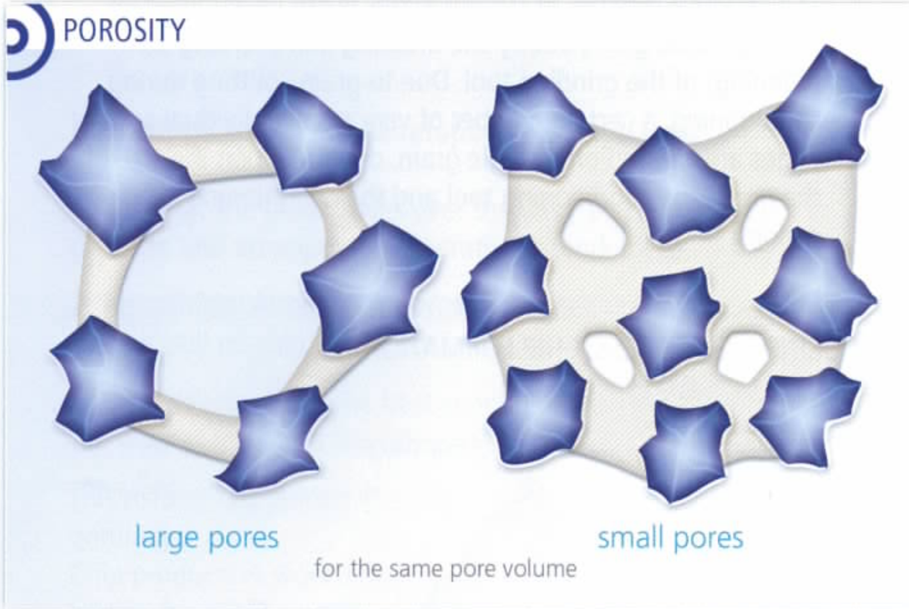
The structure of a grinding tool denotes the proportion of grains by volume in an abrasive matrix. In dense structures (structures 1–5) the distance between two grains is small; in open structures (structures 6–10) the grain-to-grain distance is increased.






## Porosity

Porosity denotes the pore space between the abrasive grains that is not filled with bonding. The pore space serves to removing chips from and supply cooling lubricant to the grinding zone. The same pore volume may be made up of single very large pores, or very many, evenly-distributed pores.




Expected interdependencies for a changing matrix:

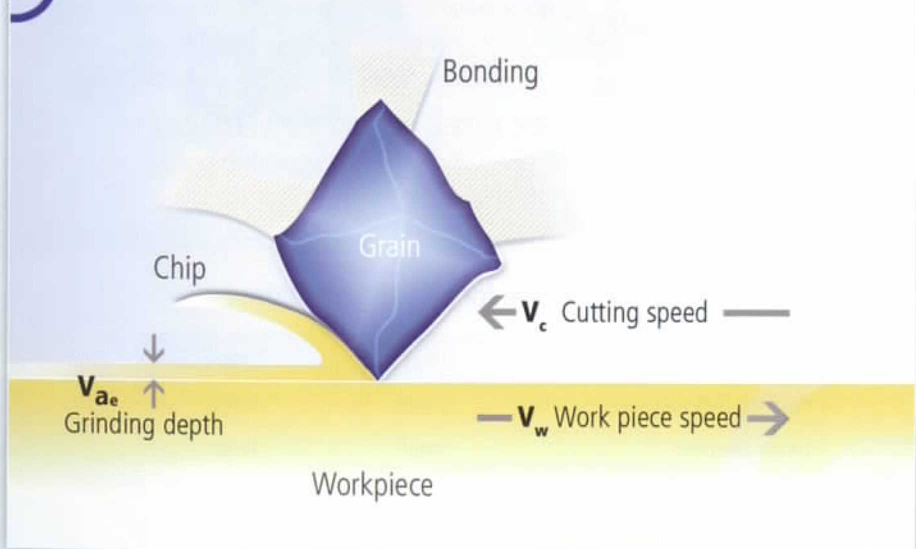
| | Dense | Open |
|---|---|---|
| Porosity/pore space | small | large |
| Grain spacing | small | large |
| Effective hardness | hard | soft |
| Individual grain load | low | high |
| Heat generation | large | small |
| Edge stability | high | lower |

# Dynamic basic variables

According to standard, the following definition is given for the grinding process as a manufacturing method:

Grinding is a chipping method with an undefined number of cutting edges.
The effective number of cutting edges is not determined by the individual grain, but by the dressing and profiling (conditioning) of the grinding tool. Due to grain splitting during conditioning, a certain number of very small individual cutting edges are created on a single grain, depending on the size of the grain, the conditioning tool and the conditioning specifications.

GRINDING PROCESS: CHIP FORMATION






The chip production process is decisive for the efficiency and productivity of the grinding process. The machinability of the work piece and the required processing quality determine the type, size and volume of the grains, as well as the degree of hardness and the matrix of the grinding tool. The number of active cutting edges produces the material chip removal.

The generation of heat plays a large part in every grinding process.

### The chipping process develops in three phases:

**1. Gliding:** The grain glides over the work piece, builds up pressure and attempts to penetrate the work piece.

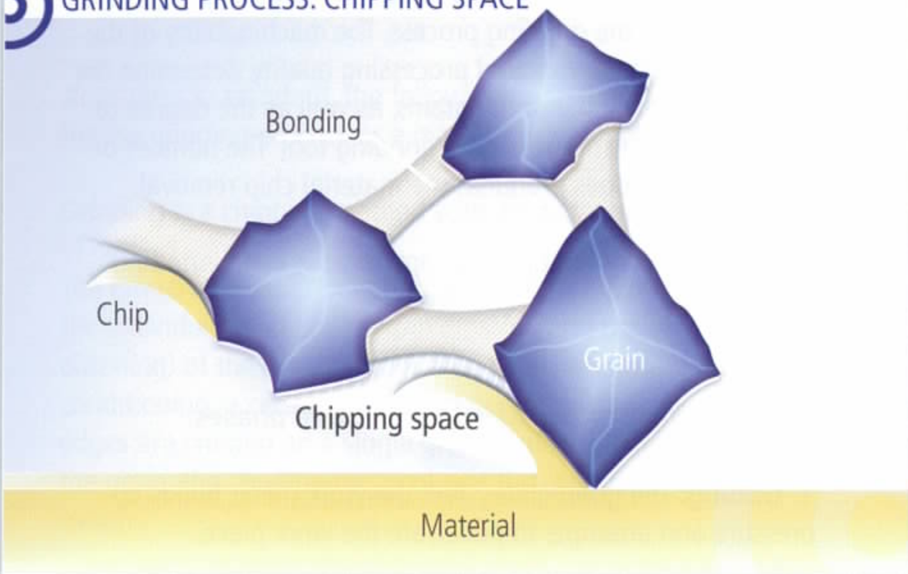
**2. Ploughing:** Although a furrow is created during ploughing, there is still no chip produced.

**3. Chip production:** The heat is only transported away from the work piece when the chip is produced.

This means: The quicker the chip is produced, the cooler the grinding.
Chip production should therefore take place with as little friction heat as possible.

The size of the chip produced can be influenced by selectively altering the process parameters.

## GRINDING PROCESS: CHIPPING SPACE




**The rule of thumb is:**
**As far as possible, only change one parameter!**

### Process parameters:

| | |
|---|---|
| Cutting speed | $v_c$ [m/s] |
| Work piece speed | $v_w$ [mm/min] or [m/min] |
| Grinding depth | $a_e$ [μ or mm] |
| Peripheral speed | $v_s$ [m/s] |

### Variables derived from this:

| | |
|---|---|
| Grinding ratio (service life) | G |
| Specific material removal rate | $Q'_w$ [mm³/mm · s] |
| Speed ratio | q |

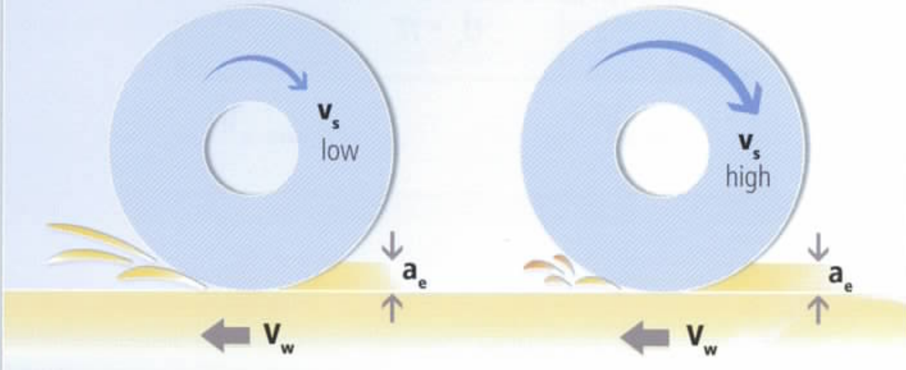


## Peripheral speed $v_s$ [m/s]

The peripheral speed is a very important variable. The chip size for a prescribed grinding tool specification can be changed by altering the peripheral speed. If the peripheral speed is increased whilst leaving the other process parameters unchanged, the chip size will decrease; if the peripheral speed is reduced, the chip size will increase.

Reduction of the chip size also reduces the forces acting on the grain; the splintering tendency of the individual grain is reduced and the service life of the grinding tool is prolonged. If the chip size falls below a certain value, the friction constituent of the grinding process increases drastically. The grinding tool generates very high temperatures and, under certain circumstances, burning (the hardness of the work piece is changed at the affected spot and it becomes brittle).

## CHANGE OF PERIPHERAL SPEED




$$Q'_w = a_e \times v_w = \text{constant}$$

An increase in the chip size also increases the forces acting on the grain during chipping. The splintering tendency is increased, grain tips break off faster and new, sharp edges are available for the grinding process. The grinding tool cuts more easily and grinds cooler, however this advantage is offset by increased grinding tool wear.

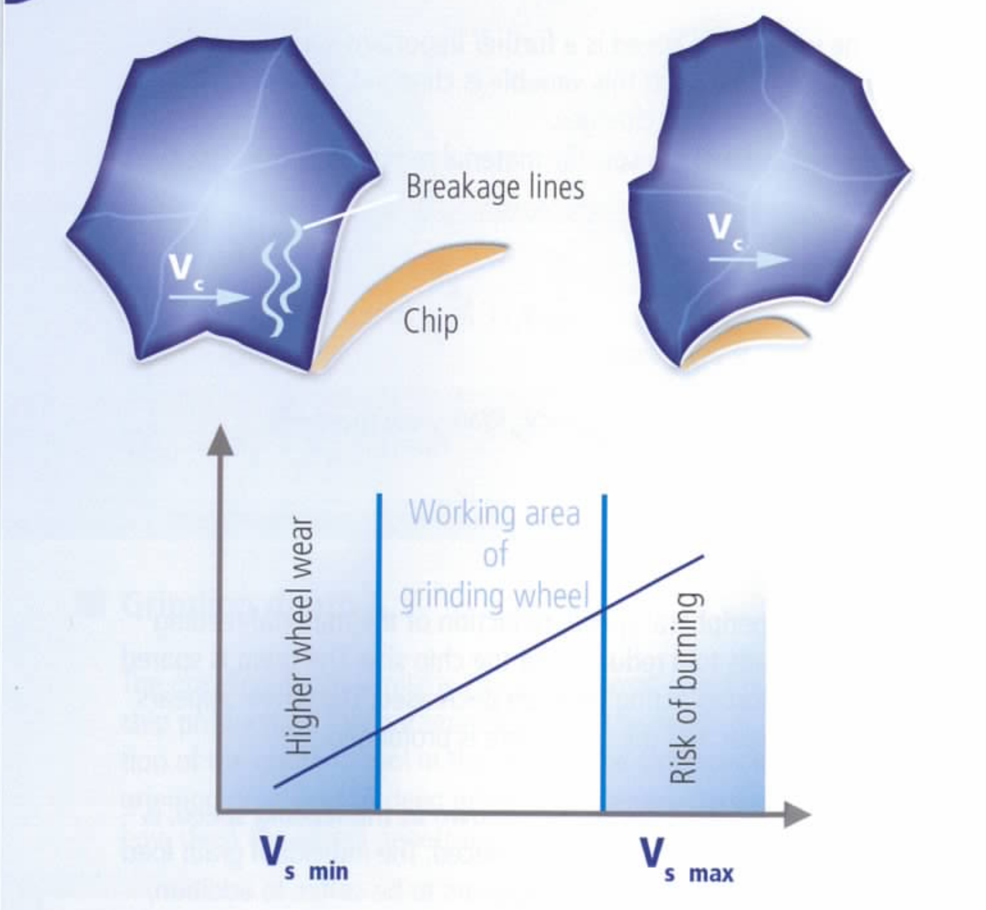
Since on the machine side usually only the rotary speed is known and not the peripheral speed, the formula below can be used to convert:

$$v_s = \frac{n_s \cdot d_s \cdot \pi}{1000 \cdot 60}$$

$$n_s = \frac{v_s \cdot 60 \cdot 1000}{d_s \cdot \pi}$$

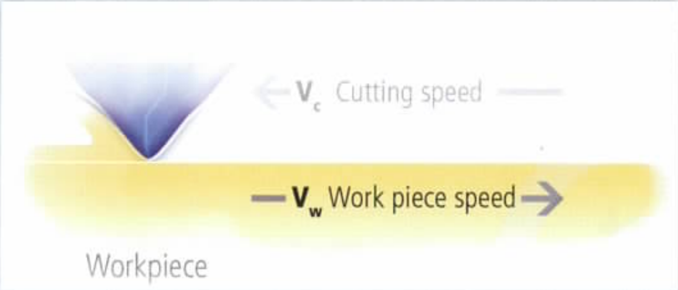


## PERIPHERAL SPEED



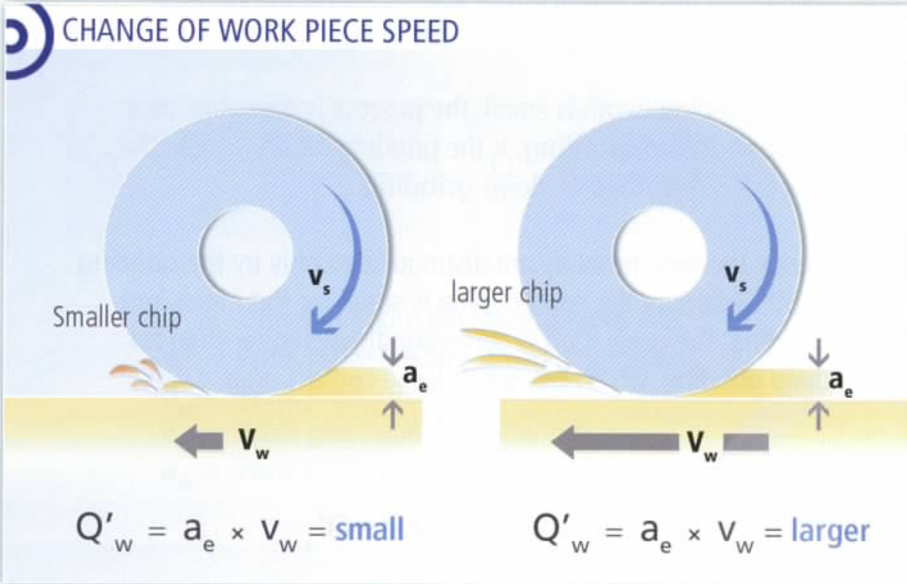
## Work piece speed $v_w$ [mm/min] or [m/min]

The work piece speed is a further important variable in the grinding process. If this variable is changed, the material removal rate also changes.
(See chapter $Q'_w$ = specific material removal rate)




Like the peripheral speed, reduction of the material feeding speed leads to a reduction of the chip size. The grain is spared and the forces acting on it are decreased. The wheel appears to be harder and the service life is prolonged.

If the work piece speed, also known as the feeding speed, is increased, larger chips are produced. The individual grain load is increased and the wheel appears to be softer. In addition, the friction work and the process temperature are decreased.




## Grinding depth $a_e$

The grinding depth similarly has a very great effect on the chip production. This parameter defines the depth of penetration of the grinding tool in the work piece. One speaks of flat grinding processes or deep grinding processes, depending on how deep the wheel penetrates into the work piece.

Increasing the grinding depth $a_e$ produces a softer effect. If $a_e$ is reduced, the grinding tool appears to be harder.

If the grinding depth is small, the process is described as a **flat pendulum grinding**, if the grinding depth is high, the process is described as **deep grinding**.

Hence the two methods are distinguished only by the grinding depth, whereby the contact area is small for flat pendulum grinding. The grain load is correspondingly higher than for deep grinding, which exhibits a large contact area.

## Specific material removal rate $Q'_w$

The specific material removal rate is defined as the volume of material removed from a work piece per $mm^3$ work piece. This calculation variable allows a comparison to be made of different grinding operations. At the same time this variable shows the efficiency of a grinding operation. Small values are achieved in smooth polishing operations, large values in rough grinding operations.

Increasing $Q'_w$ increases the productivity of the grinding process However, this can only be optimised if environmental variables are taken into account (available machine power, rigidity of the machine, rigidity of the holder, component, grinding tool used). High $Q'_w$ values can cause the service life of the grinding tool to be shortened.



$$Q'_w = \frac{a_e \cdot v_w}{60}$$

$$Q'_w = \frac{d_w \cdot \pi \cdot a_e \cdot n_w}{60} \qquad Q'_w = \frac{d_w \cdot \pi \cdot v_f}{60}$$

$a_e$ = Grinding depth per revolution in mm
$v_f$ = Work piece feeding speed in mm/min
$d_w$ = Work piece diameter in mm
$v_w$ = Work piece speed in mm/min
$n_w$ = Work piece rotational speed in rpm

| Area of application | Description | Formulas (metric units) | Unit of measurement |
|---|---|---|---|
| Coarse grinding operation | material removal rate | $Z_m = \frac{\Delta m}{t_c}$ | Kg/h |
| Cutting operation | Grinding area | $Z_m = \frac{A_w}{t_c}$ | $cm^2/s$ |
| • metal | Cutting rate | | $cm^2/s$ |

$Z_m$ = Material removal rate [kg/h]
$A_W$ = Area [$cm^2$]
$t_c$ = Cutting time [sec.]
$Z_A$ = Grinding area
m = Mass [kg]

## Service life G-factor

The service life of a grinding tool describes the time period from the start of use of the grinding wheel until it is used up. The G-factor is used for the calculation. It is determined by the following formula:

$$G = \frac{V_w}{V_s}$$

$\mathbf{v_w}$ = total amount of material removed in mm³

$\mathbf{v_s}$ = wheel wear in mm³

High G-factors are achieved by CBN and diamond, as well as in fine and ultra-fine grinding operations.

High $Q'_w$ values may lower the G-factor under certain circumstances. Process trade-offs are often unavoidable here.

### Further service life calculations:

Coarse grinding: [kg material removed/kg grinding wheel wear]

Cutting:

$$G = \frac{A_{\text{Work piece}}}{A_{\text{Grinding wheel}}}$$

**A** = Area



## Speed ratio q

The speed ratio is a dimensionless ratio. It states how often the abrasive grain moves over the same spot on the work piece.

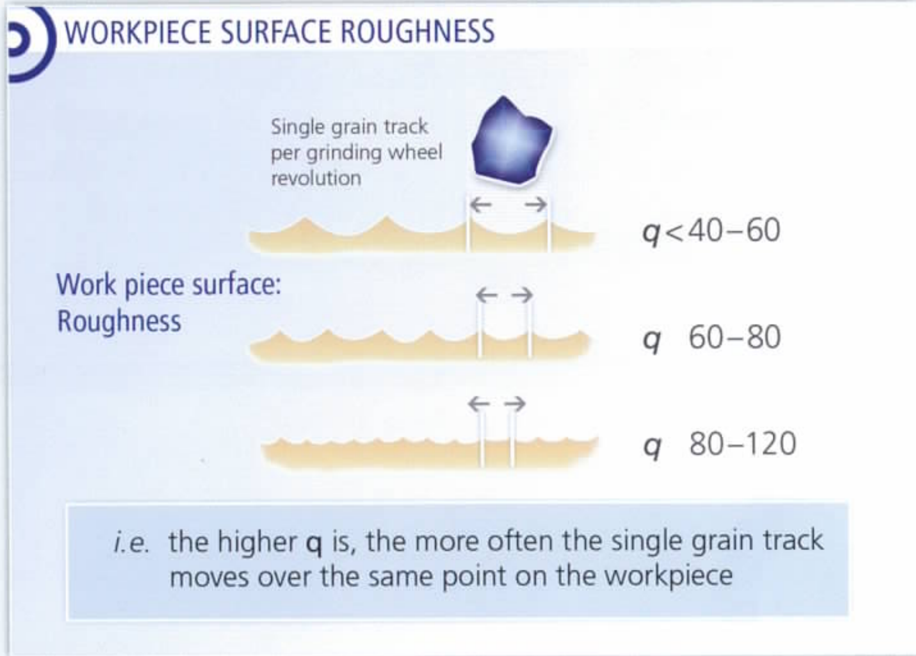
$$q = \frac{V_s}{V_w}$$

$\mathbf{v_s}$ = peripheral speed in m/s

$\mathbf{v_w}$ = work piece feeding speed in mm/min or m/min

### Common values for the speed ratio:

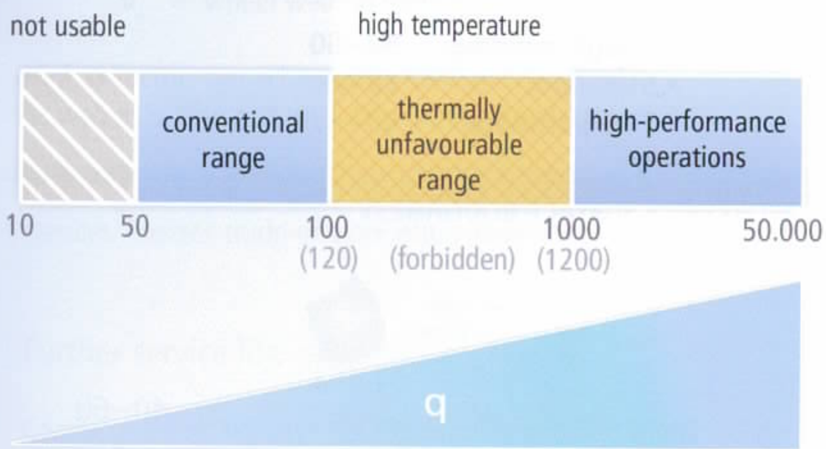
- **Rough grinding:** **50–60**
- **Standard:** **60–80**
- **Fine polishing:** **90–120**



The range of q values between 120 and 1000 is thermally critical. This range is **NOT** suitable for grinding operations and must be avoided at all costs. (There are a few exceptions).

Values above 1000 are attained primarily in high performance grinding, where high $v_s$-values (> 80 m/s) occur as process variables.

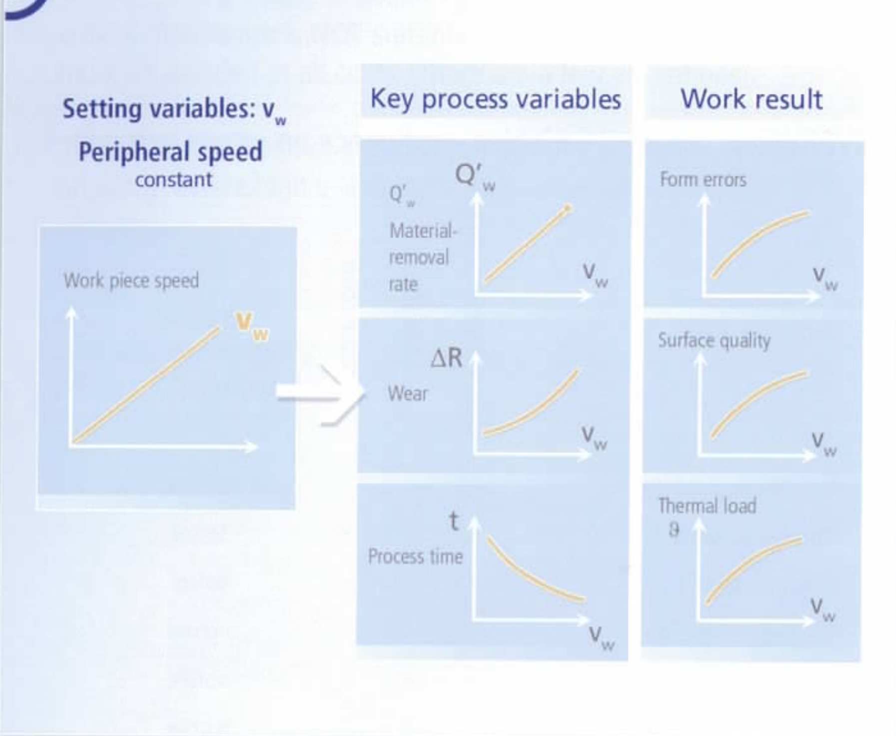
## SPEED RATIO RANGE




## OVERVIEW: Process variables – influence on wheel behaviour

| *Setting variable* | *Material removal rate* | *Chip size* | *Grain load* | *Effective wheel hardness* |
|---|---|---|---|---|
| Peripheral speed **(+)** | + | - | - | harder |
| Peripheral speed **(-)** | ~ | + | + | softer |
| Feeding speed **(+)** | + | + | + | softer |
| Feeding speed **(-)** | - | - | - | harder |
| Grinding depth **(+)** | + | + | + | softer |
| Grinding depth **(-)** | - | - | - | harder |
| Wheel diameter **(+)** | | | - | harder |
| Wheel diameter **(-)** | | | + | softer |
| Cooling lubricant oil | | | - | harder |
| Emulsion | | | + | softer |

## INFLUENCE OF THE WORK PIECE SPEED



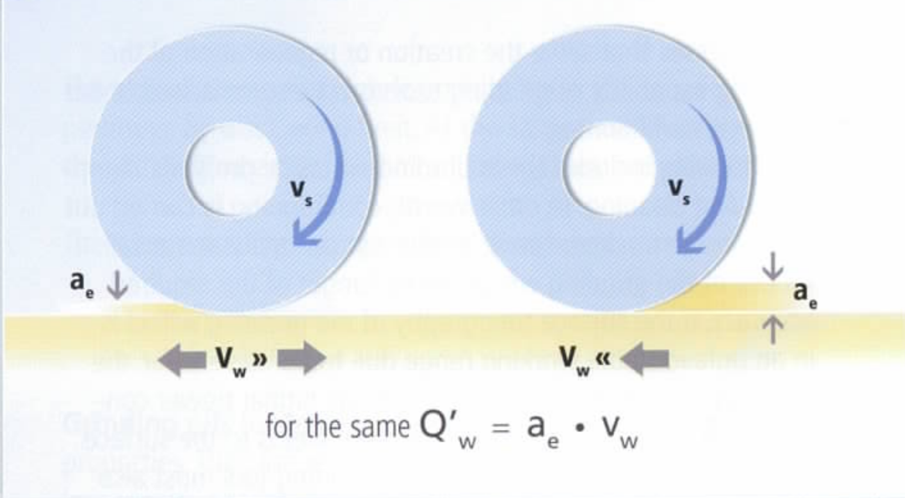

# Grinding methods

Different grinding methods have different values for peripheral speed, grinding depth and feeding speed.

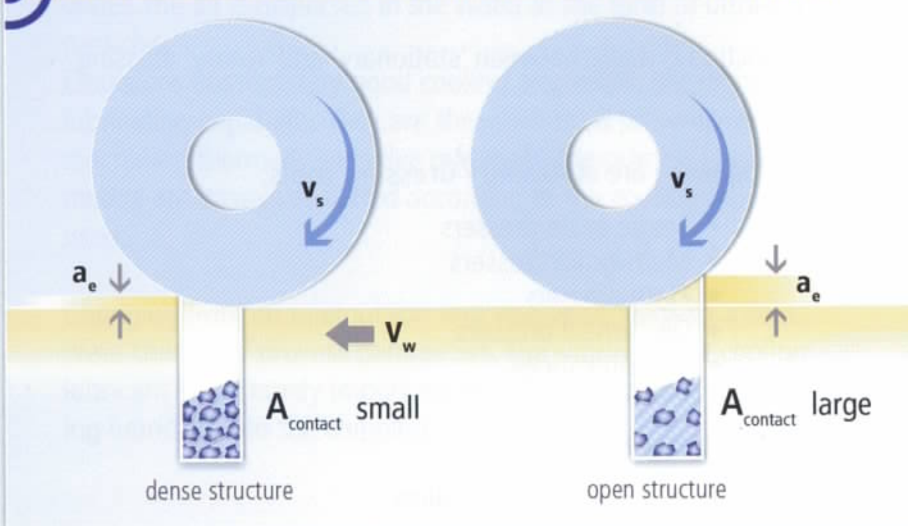
The following grinding methods exist:

- Flat/deep grinding
- Outer cylindrical grinding (OD grinding)
- Inner cylindrical grinding (ID grinding)
- Centreless grinding
- Honing
- Cutting

## DIFFERENCE – PENDULUM GRINDING / DEEP GRINDING




## CONTACT SURFACE – PENDULUM GRINDING / DEEP GRINDING



## Dressing / conditioning

All processes that serve the creation or regeneration of the grinding capability of grinding tools can be summarised under the term 'conditioning'.
Conditioning includes the subordinated tasks: profiling, sharpening and cleaning. In other words, conditioning is carried out when the form, dimensions, profile, concentricity and axial runout of the grinding wheel are no longer of the required accuracy. If the surface topography of the grinding wheel is in an unfavourable working range due to abrasive wear, the grinding tool tends to pinch and exhibits higher power consumption. Material from the work piece welds to the surface of the grinding tool. In this case the grinding tool must also be conditioned or dressed. Dressing must always take place under controlled conditions in order to obtain a reproducible result.

Distinction is made between 'stationary' and 'rotary' dressing tools.

The following are **stationary dressing tools**:

- Single-grain dressers
- Multi-grain dressers
- Plate dressers
- Disc wheel dressers
- Dressing sticks

**Rotary dressing tools are:**

- Diamond dressing rollers
- Drum dressers



## Cooling lubricant

The task of the cooling lubricant is to lower the process temperatures by dissipating heat. At the same time, the surface of the grinding wheel is freed of adhering chips and cleaned.

There are basically two types of cooling lubricant:

- Grinding oils
- Emulsions

**Grinding oils** lubricate very well but have poor cooling properties. They are used primarily with materials which are less sensitive to heating up.

**Emulsionen** consist of a mixture of 2 – 6 % oil and 94 – 98 % water. The oil is dispersed in the water in the form of ultra-fine particles.
Emulsions possess very good cooling properties, but limited lubricating capability. They are therefore used primarily when machining thermally sensitive materials. The process parameters are always designed according to the cooling lubricant used.

Changing from oil to emulsion and vice versa leads to a complete change of process parameters. The supply of the cooling lubricant is extremely important in order to transport the cooling lubricant into the chipping zone.

The basic rule of thumb is that the nozzle is directed tangentially to the surface and the outlet speed of the cooling lubricant should be adjusted to the peripheral speed of the grinding wheel.
This is the case when the jet of cooling lubricant is partly taken with the grinding wheel.

Too low and too high cooling lubricant speeds produce a considerably poorer cooling effect.

COOLING LUBRICANT


Cooling lubricant jet taken with the wheel when wheel and lubricant have the same speed



# Common process errors

## Burning, grinding cracks

### Description of the error:

Burning: Discolouration of the ground surface
Grinding cracks: Very fine lines on the ground surface

### Possible causes:

- Overheating during the grinding process/ insufficient supply of cooling lubricant
- Blunt grinding wheel
- Blunt dressing tool

### Possible solutions:

- Reduce peripheral speed, increase work piece speed
- Replace the dressing tool
- Change the dressing parameters
- Optimise the supply of cooling lubricant (e.g. nozzle)
- Use a grinding wheel with a somewhat coarser grade

## Surface irregular, uneven

### Description of the error:

Fluctuations in dimensions/evenness; surface irregular

### Possible causes:

- Machine is inaccurate
- Dirt in the coolant and in the area of the work piece clamping

### Possible solutions:

- Check the machine and correct if necessary
- Decrease the grinding depth
- Dress more often
- Adjust the wheel somewhat softer and more open

## Wheel wear too great / loss of profile

### Description of the error:

The grinding wheel loses too much contour/profile and causes dimensional/profile problems in the work piece

### Possible causes:

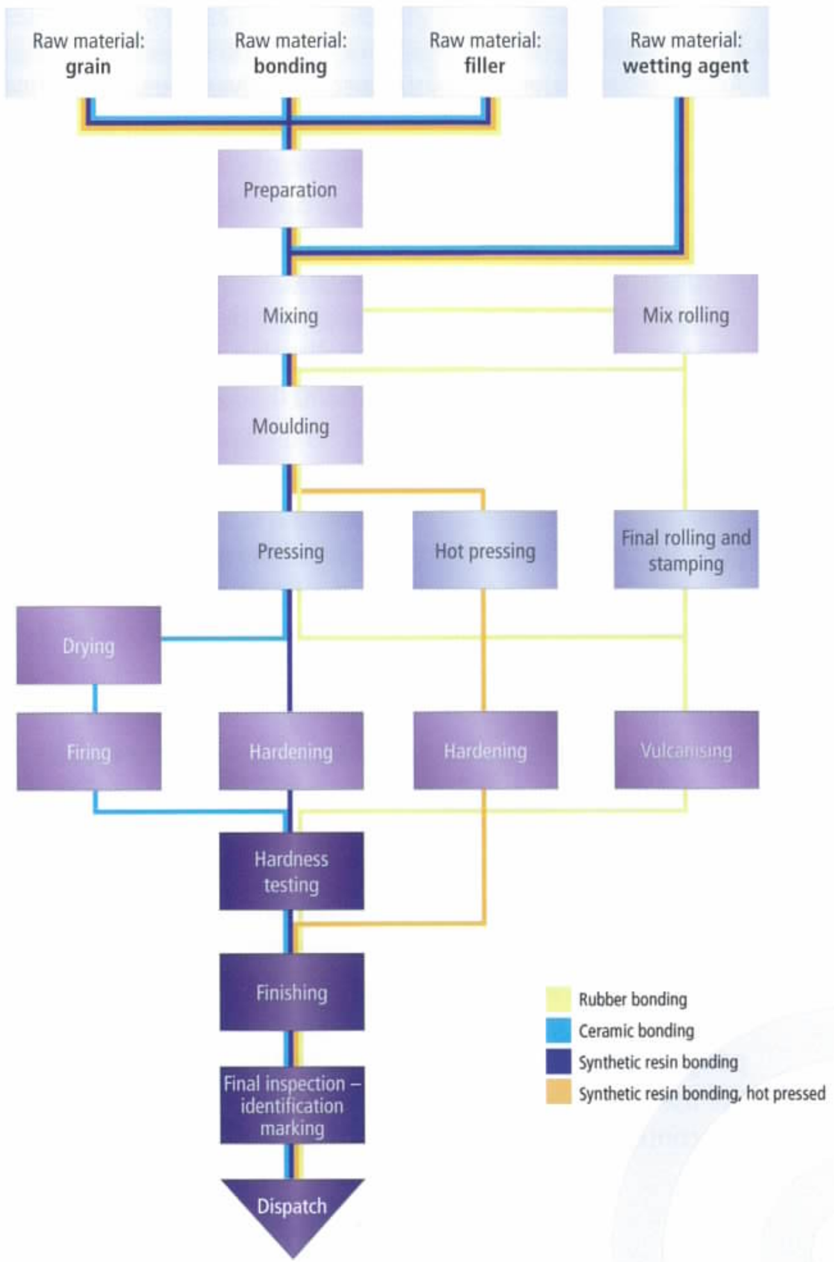
- grinding wheel too soft

### Lösungsmöglichkeit:

- Increase $v_s$ (observe maximum permissible working speed)
- Reduce feeding speed and grinding depth
- Select a harder wheel with a denser structure (pores) and a finer grade



# Grinding tool manufacture – the process



# Manufacture of grinding tools

## Preparation

An essential prerequisite for constant delivery quality of grinding tools is precise compliance with specified raw material quantities during preparation. The use of electronic scales guarantees the correct filling weights within the closest possible tolerances. The amount of bonding agent specified in the recipe is monitored by the system and weighing errors during manual drawing off of raw materials are detected immediately. In order to fulfil our high quality demands, all steps are carefully recorded both manually and digitally.

## Mixing

Only by careful mixing of the individual raw material components can optimum homogeneity of the grinding tool be ensured. Experienced personnel, the latest mixing systems and constant checks guarantee the evenness of the products.

## Moulding

Just as the qualitative homogeneity of the grinding tool is dependent on the mixing, so is the careful moulding of the finished mixture decisive for the even structure of the grinding tool. Special feeding devices for the bulk material and digitally-controller distributors as well as modern scales and measuring instruments on the presses guarantee precise, even moulding and hence high accuracy of the grinding tools. Particularly for today's high speed grinding with peripheral speeds of up to 150 m/s (equivalent to 540 km/h), the use of balanced grinding wheels is indispensable within the context of internationally valid delivery tolerances.



## Pressing

The raw moulding of grinding tools in ceramic and synthetic resin bonding takes place preferably by means of volumetric, displacement-controlled pressing Even compaction over the entire height and surface of the grinding wheel plays a significant part here. The prerequisites for this are accurately working presses and high precision moulding tools. Even distribution of the mass in the pressing mould is naturally indispensable, because irregularities here would lead to varying compaction of the premoulding. For large and wide grinding wheels, Naxos-Diskus use heavy presses with pressures of up to 25,000 kN, which are supplied alternately by 2 to 3 moulding workbenches. Small to medium grinding wheels are moulded and pressed on modern round-table presses with several work stations. Our digital network supports the production of flawless and reliably working products here too by means of testing measures directly on the presses.

## Hot pressing

Naxos-Diskus use multiple hot presses for the production of highly-compacted grinding wheels. The wheels are compacted under high pressure at temperatures between 140 and 180 °C so that virtually pore-free grinding tools are created that can also withstand the very high mechanical stresses of use in the finishing lines of steelworks. The constantly increasing demands of the steel industry necessitate very high expenditure on research and development as well as considerable investment in production and testing equipment.

## Rolling, stamping and pressing (rubber bonding)

For rubber-bonded grinding wheels, the final mixing is carried out by means of a rolling process. An homogeneous rolled product (skin) is formed by passing the grain and bonding several times through a mixing roller. The skin which comes out of the rolling unit is rolled out to the final thickness required for the respective grinding wheels on a calendar roller. In the subsequent operation the blank wheels are then stamped out of this skin in the required dimensions. The wider rubber-bonded tools, in particular control wheels, which take care of work piece guidance in centreless grinding, are pressed from several blank wheels depending on the width.

## Drying and firing

Following a drying process, in which the largest portion of the wetting agent evaporates, the ceramically-bonded grinding tool is fired in a continuous or periodically-working kiln. The melting characteristics of the bonds are matched to the grinding tools and their firing temperatures. These temperatures generally lie between 900 and 1300 °C.The kilns are heated by oil, electricity or natural gas. We place particular importance here on saving as much energy as possible in order to protect raw material resources and to produce in an environmentally-friendly manner. The continuously-working tunnel kiln comprises a heating-up zone, a firing zone and a cooling zone. These zones have different lengths and the temperature transitions are fluent. The temperature in the individual zones is always constant. In order to avoid cost-intensive heating-up phases, our tunnel kiln is in continuous operation. This enables us to meet increased demands for grinding tools at any time. The fired goods, i.e. the grinding tools, are moved through the kiln at a constant speed. Very complex firing curves can be applied in the periodically-working kilns (hood kilns, trolley kilns or chamber kilns). The widest variety of firing conditions for the corresponding wheel types can be applied here, depending on the size of the wheels and their composition. The ceramic bond melts or sinters during the firing process, producing the previously mentioned glass or porcelain-type bonding bridges.

## Hardening

Electrically-heated chamber kilns with hot air circulation serve for the hardening of synthetic resin-bonded grinding tools. The temperature programme is controlled by regulators and temperature recorders. Two independent systems work here in order to prevent fluctuations in quality in the event of faults. The hardening temperature lies between 160 and 200 °C, depending on the type of wheel and bonding, and the duration of the hardening process is between 10 and 60 hours.

## Vulcanising

Rubber-bonded grinding tools are vulcanised in electric or steam-heated pressure vessels (autoclaves) at temperatures up to around 160 °C and low pressure. During vulcanisation, the soft plastic grinding tool mass is converted to hard rubber with the aid of sulphur and vulcanisation agents. The duration of vulcanisation and the temperature are jointly decisive for the properties of these special grinding tools.

## Finishing

Some types of grinding tools (e.g. segments) are already given their final geometric form during moulding. Most, however, are moulded oversize, since the required precision of the grinding tool can often only be achieved by machining away the oversize in a specific finishing process. Today, many modern, powerful machines are available for this. Very tight tolerances and evenness of the grinding tool diameters are maintained easily on our CNC machines.

We invest regularly in training and new machines here also, in order to improve our market position with new products and services. Integrated lathe tool wear compensation guarantees the highest degree of geometric accuracy and reproduction reliability. If necessary, we adapt our machine pool to suit the demands of our customers or their orders.

## Final inspection

In order to guarantee that the grinding tools are of the quality and working reliability which the customer expects, great importance is placed on a reliable final inspection. The following tests are carried out in particular: Dimensional check, imbalance check, hardness test, crack test by means of an acoustic test, strength test by means of a test run, and material and structure tests. These checks ensure that we satisfy the requirements of DIN EN 12413, for grinding tools, and DIN EN 13236, for grinding tools with diamond or boron nitride, in respect of production lines and regulations for the prevention of accidents. Our own in-house test specifications go beyond the officially applicable regulations in many cases. Compliance with the specifications is ensured by the use of the latest checking equipment.

## Identification marking 1

Before the grinding tools can be dispatched, they must be provided with identification markings in accordance with regulations. A label with all relevant grinding tool details is attached for identification.



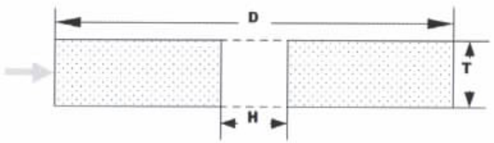
## Dispatch

The task of dispatching to the customer is often underestimated. In order to ensure trouble-free dispatch to almost every country in the world, we cooperate with many freight forwarders, who we select according to requirements. International regulations and requirements for packing and dealing with formalities are no problem for our well-trained personnel.

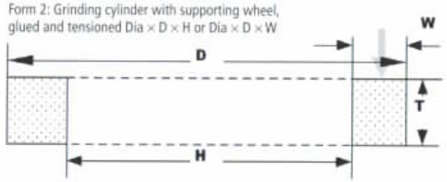
**Regardless of how high your requirements are, we always try to meet them and to exceed your expectations.**

# Basic grinding wheel forms

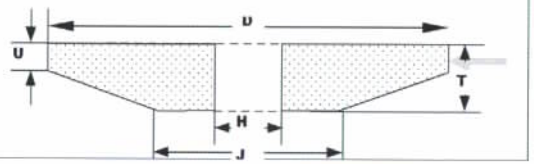
Form 1: Straight grinding wheel Dia × D × H



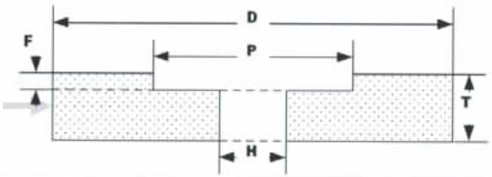

Form 2: Grinding cylinder with supporting wheel, glued and tensioned Dia × D × H or Dia × D × W



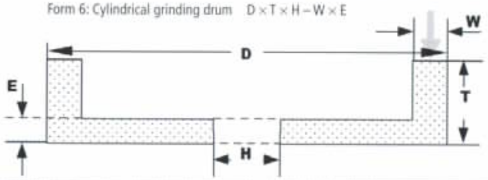

Form 3: Single-sided conical grinding wheel D/J × T/U × H



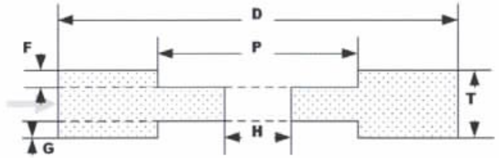

Form 5: Single-sided recessed grinding wheel D × T × H – P × F



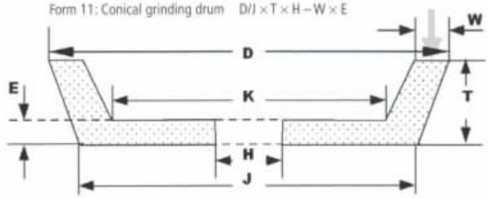

Form 6: Cylindrical grinding drum D × T × H – W × E



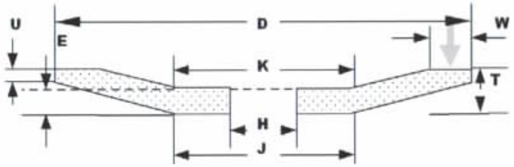

Form 7: Double-sided recessed grinding wheel D × T × H – P × F/G



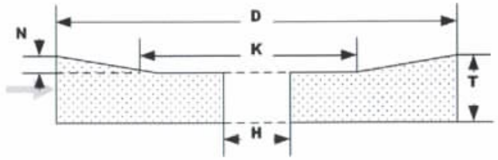

Form 11: Conical grinding drum D/J × T × H – W × E



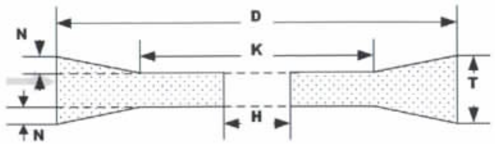

Form 12: Grinding plate D/J × T × H



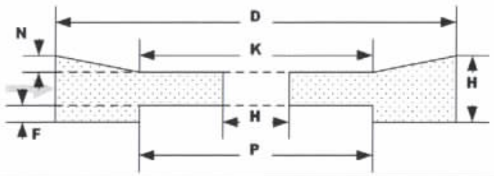

Form 20: Single-sided tapered grinding wheel D/K × T/N × H



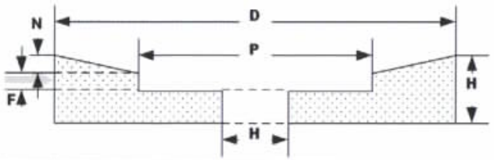

Form 21: Double-sided tapered grinding wheel D/K × T/N × H



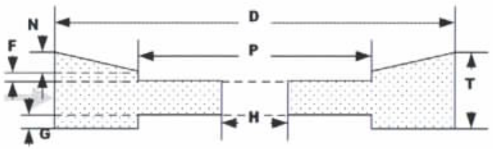
Form 22: Single-sided tapered, on opposite side recessed grinding wheel
D/K × T/N × H – P × F



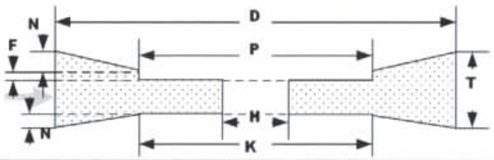

Form 23: Single-sided tapered and recessed grinding wheel
D × T/N × H – P × F




Form 24: Double-sided recessed, single-sided tapered grinding wheel
D × T/N × H – P × F/G




Form 25: Double-sided tapered, single-sided recessed grinding wheel
D/K × T/N × H – P × F




Form 26: Double-sided tapered, double-sided recessed grinding wheel
D × T/N × H – P × F/G