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PCD carbide composite: A wear-resistant engineered material

WEAR PROTECTION: NOT JUST A QUESTION OF HARDNESS

Wear refers to continuous material loss from the surface of a solid body, caused by the mechanical, thermal or chemical impact of a solid, liquid or gaseous contacting body. It therefore makes sense to use the hardest material possible for components prone to wear: diamond.

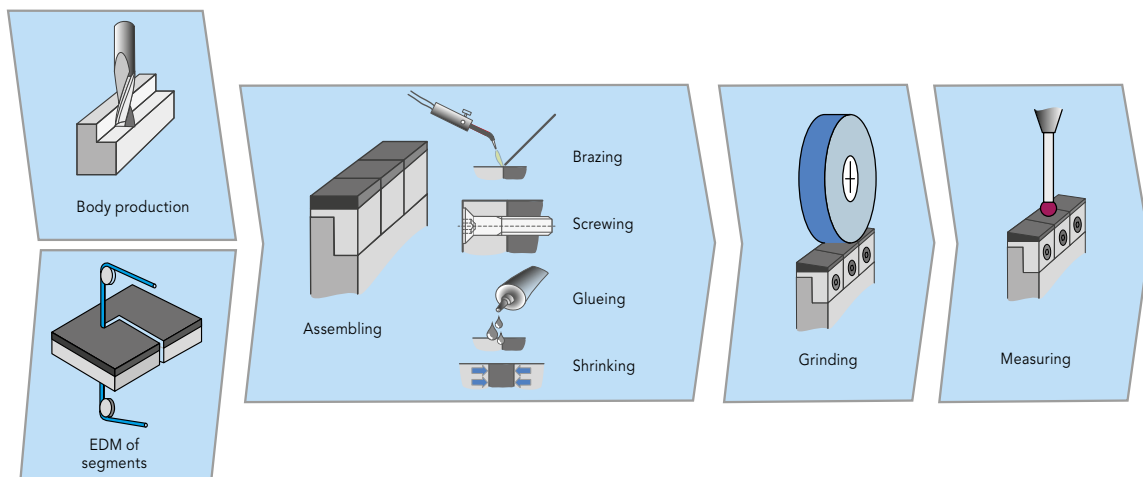
But it is not hardness alone that is the key factor: diamond also features good frictional and gliding properties and can be produced with very high surface qualities. This opens up the opportunity for new applications and process optimizations, because in a diamond version your component will feel virtually no contact.

Processing diamond as a construction material for high-precision wear protection components calls for state-of-the-art production technologies and many years of experience: DR. KAISER has both.

MANUFACTURING PROCESS

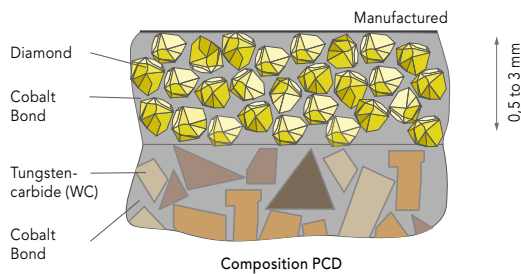
Essentially, manufacturing involves shaping diamond segments by eroding or laser ablation. These are soldered, pressed, stuck or shrunk onto precisely manufactured base bodies made of carbide or steel. It is therefore possible to perform repairs or geometrical adjustments on individual segments by simply replacing them in most cases. The greatest expertise lies in finishing the diamond segments

joined to the base body, in order to achieve the required dimensional and shape accuracy on the wear protection components. Together with suitable measurement techniques, high-precision components can therefore be manufactured from the very hardest material and wear in the application process can be reduced to a minimum.



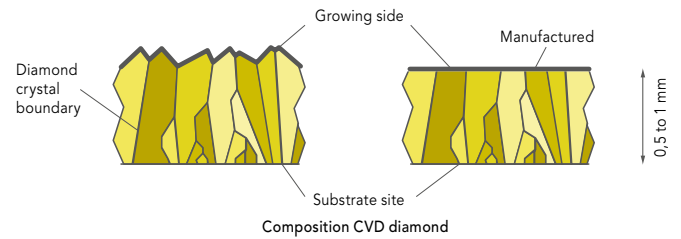
POLYCRYSTALLINE DIAMOND (PCD)

Polycrystalline diamond (PCD) is a synthetically manufactured, extremely hard conjoined mass of diamond particles in a metal matrix. During manufacturing using a high-pressure liquid-phase sintering process, a diamond layer is attached directly to a carbide base body containing cobalt. As a starting material, defined diamond grains with a diameter between 0.5µm and 50µm are used. The liquid cobalt from the carbide base body penetrates the remaining hollow spaces between the diamond grains, dissolves the graphite located there and joins the diamond together. The diamond coatings have a thickness of 0.5 to 3mm with an overall thickness with the carbide base body of up to 10mm.



CVD DIAMOND (CVDD)

CVD diamond is produced in a chemical vapor deposition process at temperatures of 2000 °C to 2800 °C from a hydrogen-methane mixture. The diamond crystals grow to the desired layer thickness of a few tenths of a millimeter at layer rates of 0.1 to 3 µm/h. The generated diamond discs with a thickness of 0.5 to 1 mm are then processed and separated into desired shape elements by means of laser cutting.



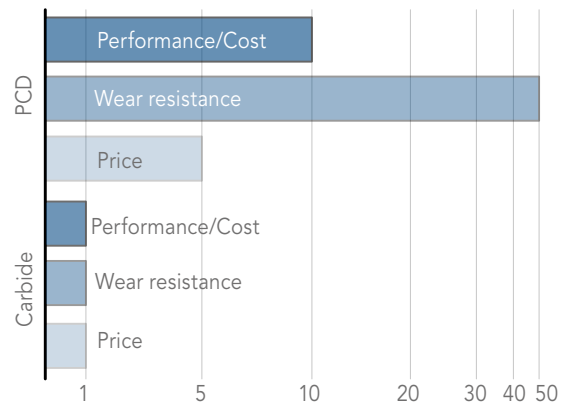
CARBIDE

Carbides of tungsten, titanium, tantalum and niobium (WC, TiC, TaC, NbC) in a binder matrix of cobalt or nickel are sintered at temperatures of approx. 1400°C. A distinction is made between coarse grain variants with grain sizes > 1 µm (HW) and fine grain variants with grain sizes < 1 µm (HF). Compared to PCD and CVDD, tungsten carbide is significantly less expensive, but does not come close to their performance.

LIFE CYCLE

Hardness and compressive strength are the key properties of a material. These influence wear behavior and therefore determine the life cycle of components.

Because of its hardness and ductility properties and its comparatively good machining possibilities, carbide is often used for wearing components. However, PCD and CVD diamond offer unbeatable advantages. Wear protection components made of these extra-hard materials are characterized by lifetimes that are often more than 100 times those of carbide. Another advantage is the strong frictional behavior compared to steel. Less friction improves component quality and the process behavior in operation.



	CVD diamond (CVDD)	PCD	Ceramic (Si ₃ N ₄)	Carbide	Steel
Friction coefficient against steel [-]	< 0,1	0,1	0,2	0,3	0,8
Therm. conductivity [W/mK]	2000	550	29	80	48
Compression strength [MPa]	65000	7700	6600	5500	1850
Fracture toughness [MPa m ^{1/2}]	3...9	3...9	6	12	48
Hardness [HK]	10000	5000	1800	1500	600

WORKPIECE SUPPORTS

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MAXIMUM ACCURACY FOR A LONG PERIOD OF TIME

Centerless grinding processes are often highly developed series processes for the economically efficient machining of rotationally symmetrical components, such as piston rods, jet needles, gas pressurized springs, needle rollers, crankshafts, camshafts and valves.

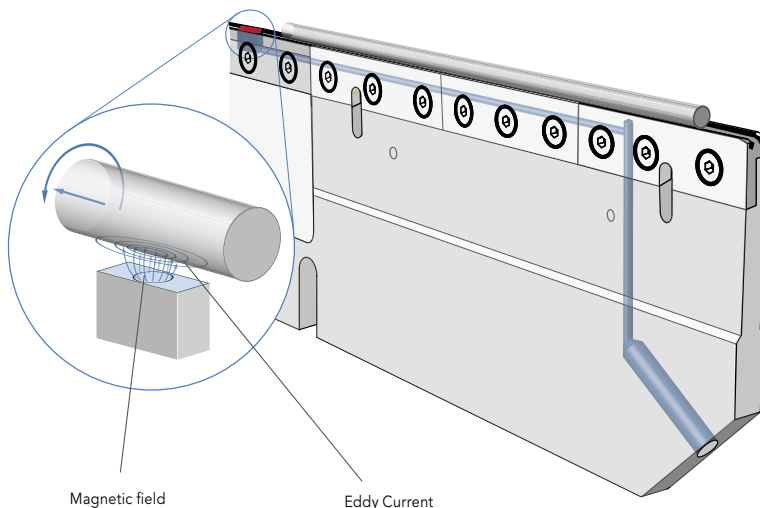
The support ruler for supporting components during the grinding process is one of the most important wearing components on the machine, and this plays a large role in determining the dimensional and shape accuracy as well as the surface quality of the component. The low friction of diamond compared to steel reduces the machining forces and therefore improves the quality of the work pieces. Often, PCD can do even more than this: the polished PCD surface smooths down the work piece surface and reduces roughness.

To achieve optimum results over a long period, there is no real alternative to PCD coatings.

IN-PROCESS TESTING THROUGH SENSORS

Efficiency and quality must form a single unit in mechanical machining processes. A clever solution for process monitoring is the 100% in-process control for the series production of centerless machined workpieces. An eddy current sensor integrated in the guide ruler determines the component hardness during machining and simultaneously checks the surface for microcracks. For this technology,

precisely defined measuring distances between the sensor and the component surface are a prerequisite that can only be achieved with PCD support rulers: a decisive advantage for series production that is made possible by DR. KAISER's many years of know-how.

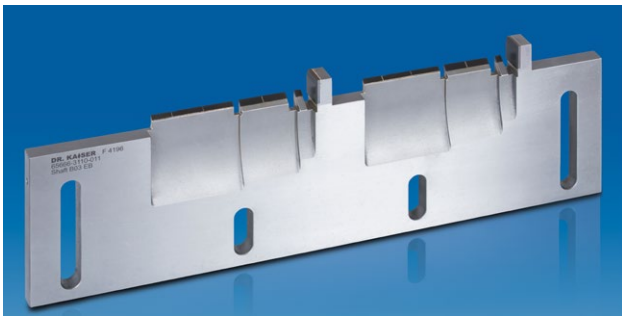
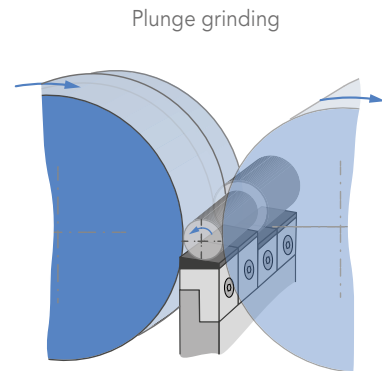
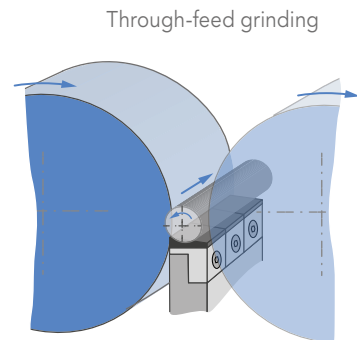


CENTERLESS GRINDING

Centerless grinding is a special form of external cylindrical grinding. Instead of being clamped between the headstock and tailstock, the work piece is fed between the grinding wheel and regulating wheel. The work pieces are supported by a work-rest blade.

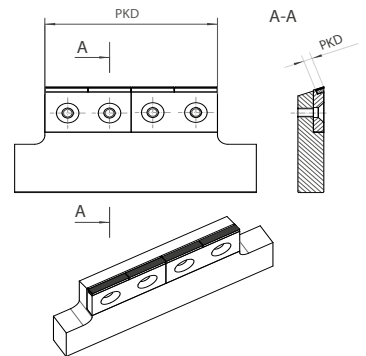
Centerless through-feed grinding is particularly efficient for machining cylindrical work pieces without recesses, such as bolts, shafts, pistons or spindles.

With centerless plunge grinding, complex recessed work pieces can be machined using straight plunging or, for machining an additional diameter, in an angular plunge process.



SEGMENTING

Easy-to-maintain machines and components make it possible to design process sequences in a simplified and cost-effective way. In many cases, support rulers from DR. KAISER are structured in segments. Individual diamond inserts are joined to the geometrically complex base body using pressing, sticking or soldering. This technique allows for repair work to be carried out easily and efficiently.

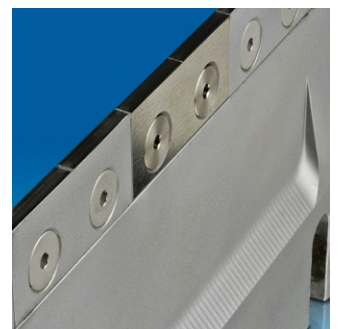


MODULAR AND SUSTAINABLE

A little carelessness or incorrect loading of the machine can have big consequences. Fortunately, segmented PCD rulers' can be repaired in most cases. Defective or damaged segments are simply replaced and the work-rest blade is then almost new again.



Damaged



Repaired

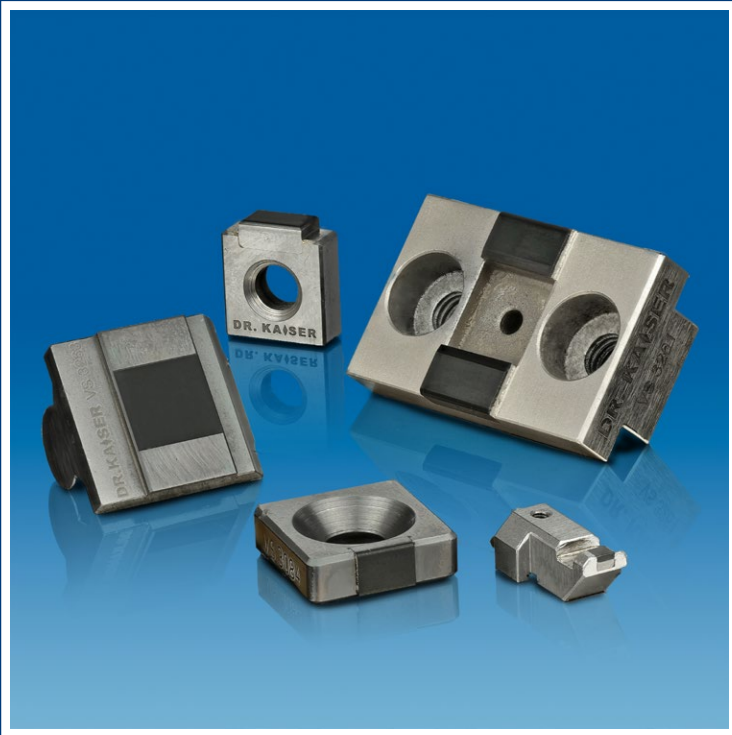
ALSO IN HARD METAL AND CERAMIC (Si_3N_4 , SiC)

Support rulers and rails for highest demands and accuracies are of course also available from DR. KAISER also supplies rulers and rails in carbide or ceramic for your applications.

This extends the range of applications, e.g. also for applications in the field of food production.

STEADY REST BLOCKS

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LONG LIFETIME AND COMPONENT QUALITY THANKS TO DIAMOND

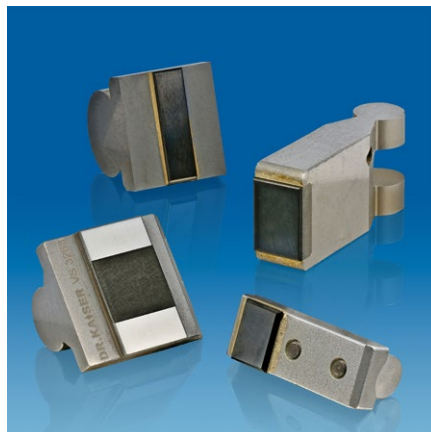
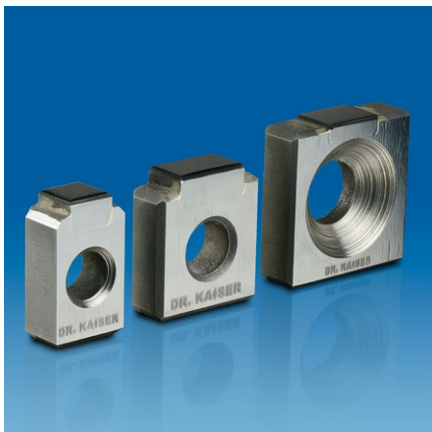
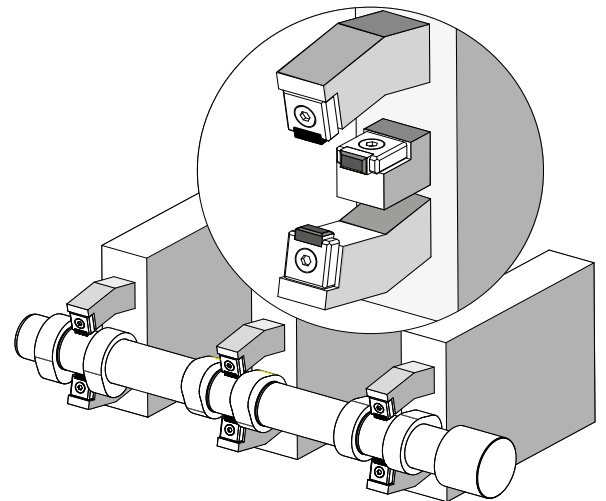
During precision machining, such as grinding, honing or polishing, rotationally symmetrical components must be supported, held or guided, to absorb process forces and prevent a deflection due to the component's own weight. In maximum precision machining, this can only take place by means of fixed guiding elements, such as prisms, sliding blocks, tips, hollow tips or steady rest blocks, as an antifriction bearing on the guiding elements has a negative effect on the process. During machining, the guiding elements rub and slide on the work piece surface and thus influence the quality of the components. Low friction values and a high wear resistance are called for: an ideal task for diamond!

STEADY REST BLOCKS

A fixed steady rest is used to support long, thin workpieces so that they do not bend during machining. Compared with white metal, bronze, Pertinax or special plastic, PCD is clearly superior as a steady rest material both economically and technologically. Whether in crankshaft and camshaft production or in the manufacture of valves or piston rods: Steady rests are used in many areas.

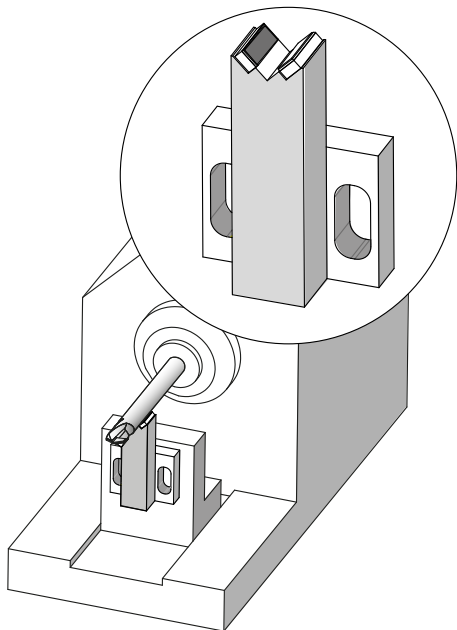
SELF CENTERING PENDULUM STEADY REST BLOCKS

If the installation of a steady rest is very time-consuming due to an exact alignment, self-aligning single-axis PCD steady rests (pendulum steady rests) can be an alternative. By means of a gimbal suspension, the self-aligning biaxial PCD steady rests from DR. KAISER self-align their supporting surface in two axes to the workpiece. This results in an optimum support pattern of the steady rests without time-consuming alignment to the workpiece.



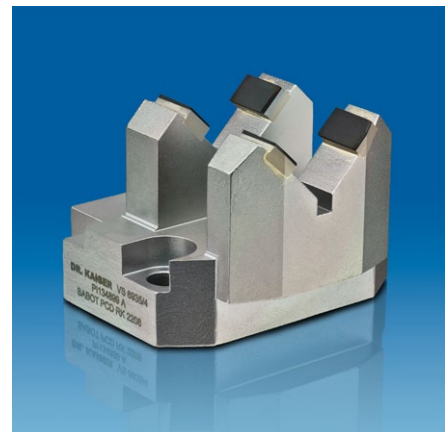
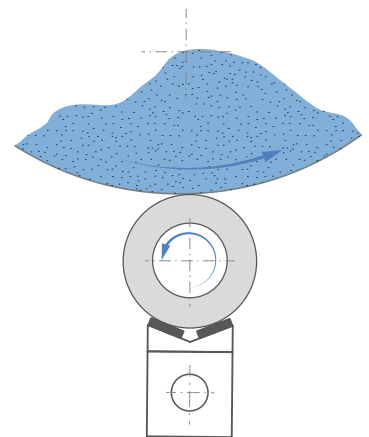
POLYCRYSTALLINE DIAMOND ALMOST WEAR-FREE

Who wouldn't want it: a tool that lasts forever. PCD is a material that has proven its worth in many areas. High-precision workpiece guides made of PCD in particular are significantly more durable than carbide and have a number of advantages. In addition to the long service life, it is primarily the low coefficient of friction between diamond and steel that often leads to enormous accuracy advantages when grinding supported, guided components. This quickly offsets the higher material costs and more complex manufacturing. However, there are also disadvantages: PCD adapts less well to the process because of its high hardness. And thus the workpieces guided by steady rests or prisms can get gloss streaks because of the small support surfaces. But even for this, DR. KAISER offers a solution: PCBN guideways. Polycrystalline CBN is significantly more wear-resistant than carbide, but more compliant than PCD.



PRISMS AND SLIDING BLOCKS

To fix the position when machining long rotationally symmetrical components, such as jet needles, valves and rods, a wide variety of prisms are used. In the anti-friction bearing industry, these guiding elements are called sliding blocks. Short work pieces (bearing shells) are driven by magnetic chucks or driving pins.



CENTER POINTS

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MAXIMUM PRECISION: THANKS TO DIAMOND

High-precision machining of complex, rotationally symmetrical components is often carried out by clamping between tips. Revolving conical tips are not suitable for maximum precision of less than $1\mu\text{m}$ due to the bearing dynamics. In high-precision machining applications, therefore, only fixed tips are used. Here, the process forces are transferred directly to the tips – generally made of carbide – via the work piece. In many applications, the contact chamfers are only a few tenths of a millimeter, meaning that large surface pressures lead to high friction and a fast wear rate.

Maximum accuracies, especially in continuous operation, can only be achieved economically with PCD tips: the low friction compared to steel benefits the process behavior and improves the shape, position and roundness of the work pieces.

COMPACT OR SEGMENTED

Small hollow points up to 36 mm in diameter are manufactured from solid PCD. Beyond that, hollow points are manufactured segmented.

CENTRING TIPS

For work pieces with large diameters – flexible and precise:

The center hole in the component enables accurate re-chucking and machining beyond the end areas. The low friction value between diamond and steel means that very high levels of accuracy can be achieved on the component.

HOLLOW TIPS

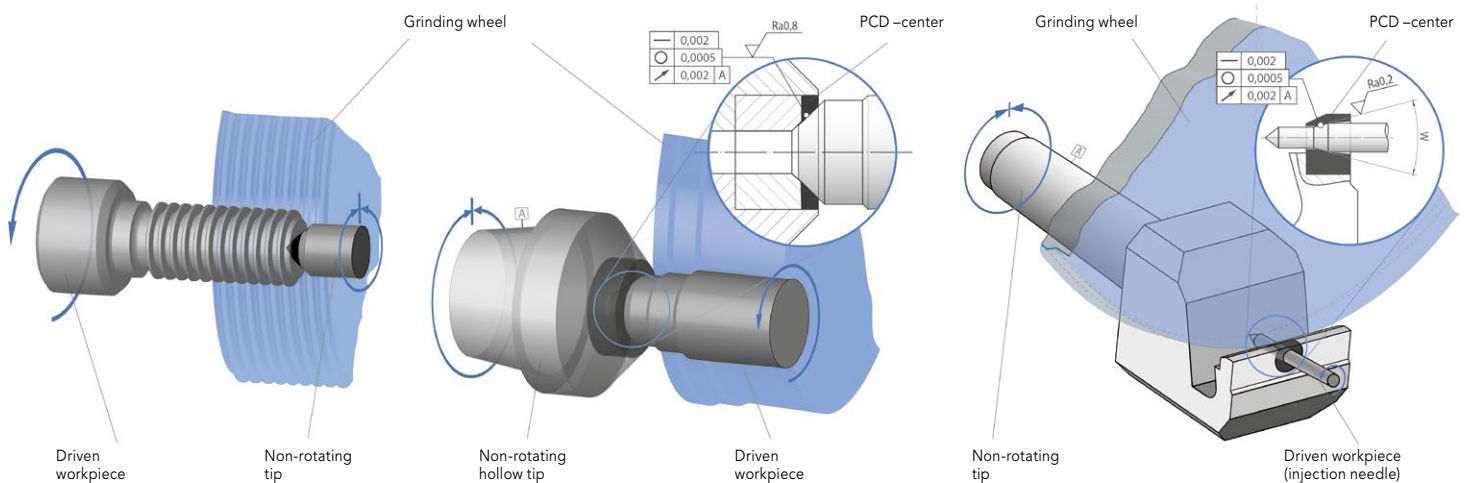
Indispensable for long components, such as jet needles:

The high-precision hollow conical tip with roundnesses of $< 0.5\mu\text{m}$ on the PCD internal tapered surface. Components with bevelled ends can therefore be machined around the perimeter with high precision.

SPECIAL TIPS

Long, slim, multi-recessed components or the machining of end contours (e.g. jet needle):

Special solutions for the highest demands are DR. KAISER's specialty, in a PCD or carbide version.





MEASURING AND TESTING: A SPECIALTY OF DIAMOND

Whether in an industrial production environment or in clean rooms: measuring systems have to work accurately and reliably over a long period of time and therefore require robust and wear-resistant sensing devices. Diamond is the ideal material here as well.

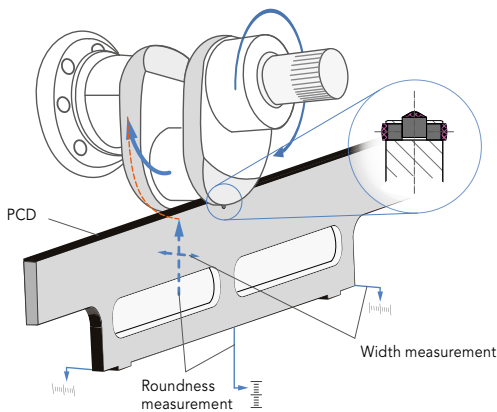
Whether it's a PCD or CVD diamond version: the manufacturing expertise of DR. KAISER enables a wide variety of applications in the field of measurement and testing technology.

RECOGNITION OF COORDINATES

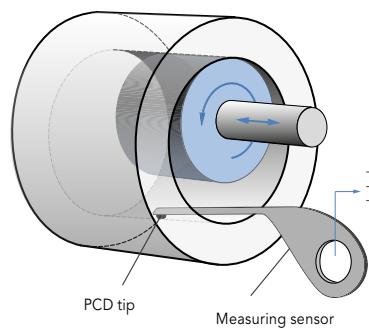
To determine the exact diameter of a grinding wheel or the position of a dressing tool in the machine, some machine manufacturers use special probes. In many cases, carbide is not wear resistant enough. PCD or CVDD gauges are particularly suitable for measuring rotating grinding wheels or dressing rolls: Ask the experts at DR. KAISER.

EXAMPLES OF INDIVIDUAL MEASURING TASKS

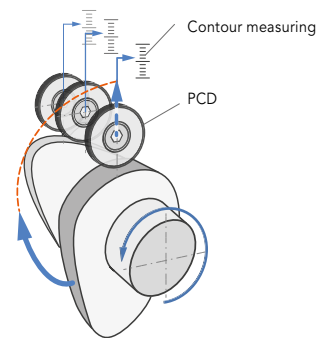
Crankshaft stroke measurement



In-process bore measurement



Camshaft contour measurement



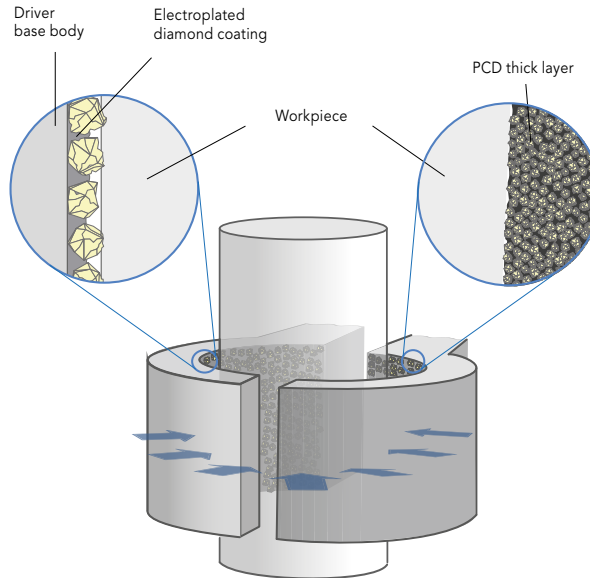
DRIVERS AND GRIPPING ELEMENTS

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FLEXIBLE DUE TO ELECTROPLATED DIAMOND COATINGS

The use of electroplated diamond coatings can be used even for complex geometries and is characterized by a non-slip and wear-resistant coating.

A wide range of grit sizes allows the roughness to be adapted to the specific application. Due to the possibility of resurfacing the undamaged base body, electroplating is a very cost-efficient option compared to new procurement. The costly, usually hardened base bodies can thus be used several times. An electroplated diamond coating is chemically resistant and has a long service life.



PCD-BACKED GRIPPING ELEMENTS

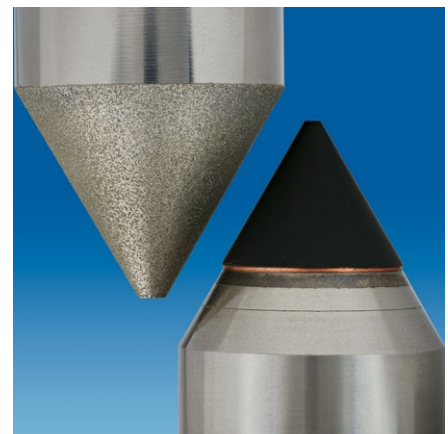
With its high wear resistance and extremely fine microstructure, PCD is the ideal material for very precise gripping elements. The geometric accuracy of PCD is thus maintained over a very long period of time, which means that the gripping process can be carried out with a high degree of process reliability. The repeatability is unsurpassed, even more than 50 times higher than that of carbide.

PCD-tipped assembly and handling elements can be realized with an accuracy in the μm range. Due to the very fine-grained diamonds in PCD and the corresponding fine machining, roughnesses of $R_z = 2 \dots 8 \mu\text{m}$ are possible. The surfaces produced in this way have a good grip, but do not damage the component surface. Ground PCD surfaces can also be produced. Another advantage of PCD is its chemical stability.

Type	Galvanic coating		PCD coating (roughened)
Diamond coating	D35	D426	Thick layer
Accuracy	0,015-0,02 mm	0,015-0,02 mm	0,002 mm
Roughness	~Rz 40 μm	~Rz 120 μm	Rz 2-8 μm
Advantages	<ul style="list-style-type: none"> • Durable • Repairable • Cost effective 		<ul style="list-style-type: none"> • Durable • High accuracy • Chemically resistant

ACCURATE - SAFE - DURABLE

The handling of components with smooth or very abrasive surfaces presents special challenges for gripping elements. High-quality diamond coatings matched to the process increase the holding force of grippers, hold-downs, guide elements, etc.. They prevent wear and securely fix the component without damaging it.

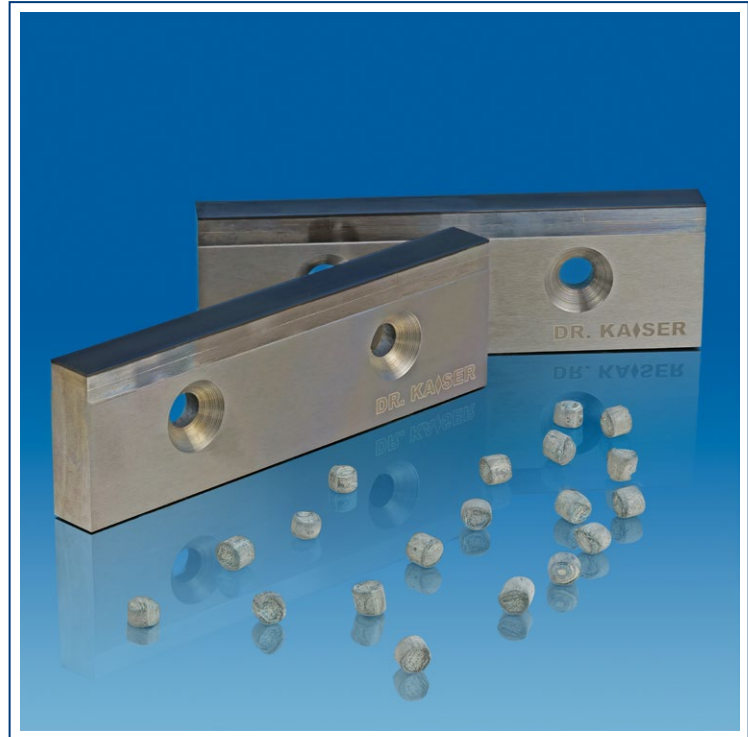


PCD-PELLETIZER KNIVES

DR. KAISER has been processing diamond in its many variations for decades and has great experience and know-how in processing PCD in segmented construction. Compared to carbide, PCD pelletizer knives achieve a service life many times longer, which means that they quickly pay for themselves.

PCD pelletizer knives from DR. KAISER for strand and underwater pelletizing of plastics with or without fillers and fiber content are used on various machines.

Innovative high-tech knives made of polycrystalline diamond (PCD) are the future for many pelletizer manufacturers, technologically and economically.

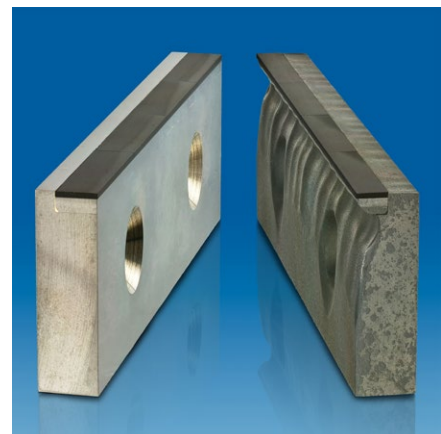
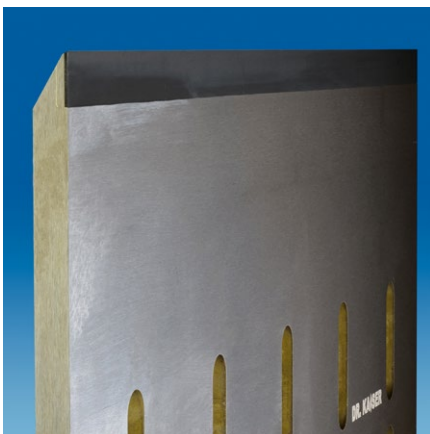
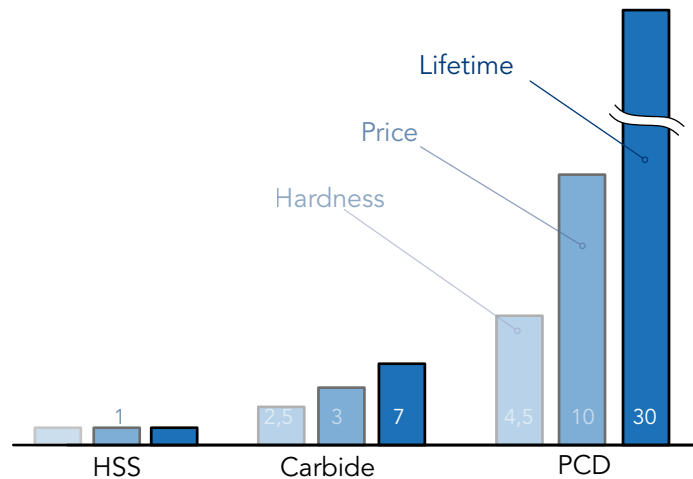


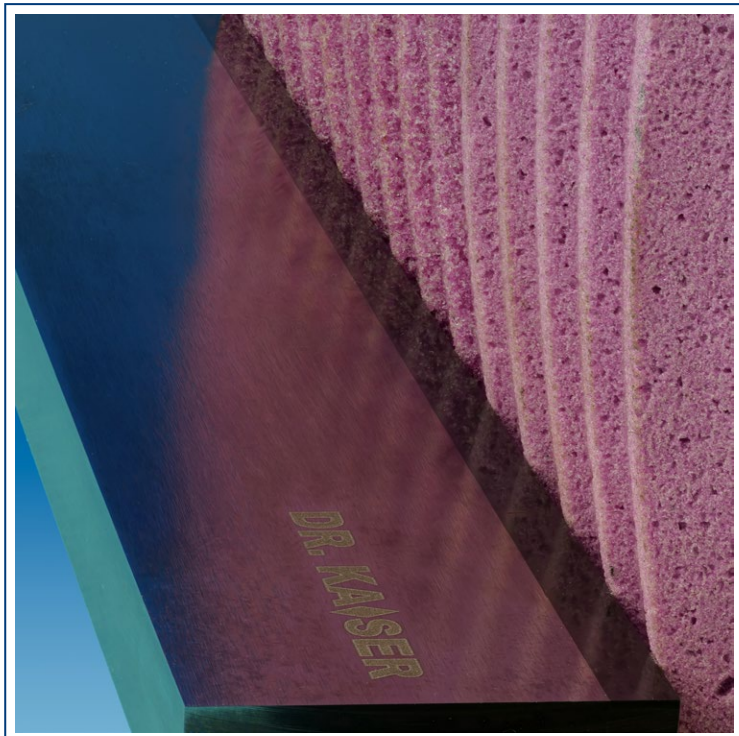
TECHNOLOGY AND ECONOMIC EFFICIENCY

The proportion of plastics that are difficult to pelletize is increasing in all areas of production. The embedded aggregates and fibers severely stress the pelletizing knives and shorten their service life. Compared to carbide, PCD is about twice as hard and leads to tool lives that significantly exceed a factor of 30 in many areas of application.

Machining PCD is time-consuming and cost-intensive. Nevertheless, there are clear economic advantages compared to the use of HSS and carbide:

- Long tool life compared to conventional knives
- Reduction of set-up costs due to longer operating time
- Reduction of waste production
- Reduction of production downtimes
- Reduction in the workload of the repair shop.





PCD DRESSING BARS FOR GEAR MANUFACTURING

Dressing tools from DR. KAISER have set standards in gear production. The PCD dressing bar offers a way to quickly and reliably dress the outer diameter of grinding worms up to 450 mm wide.



INSERTS FOR DRESSING

A dressing technique that has proven itself for decades: dressing with PCD or CVD diamond triangular plates. The plates, which are available with different radii, are clamped in a holder and moved past the grinding wheel as in CNC turning.

It couldn't be simpler: And thanks to the latest CVD diamond materials, with excellent results.



DRESSING SYSTEMS IT ALL DEPENDS ON THE DRIVE

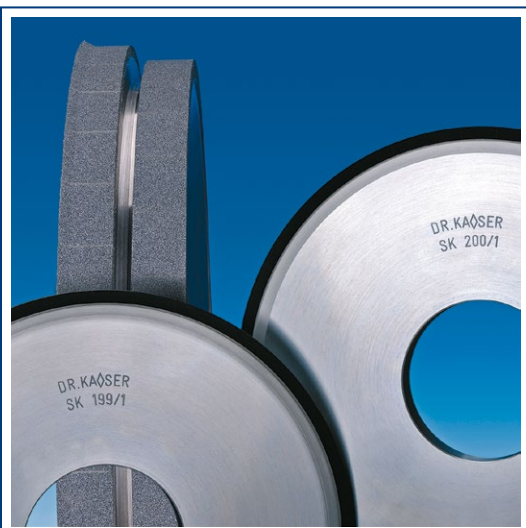
Coordinated drives are important, because not only the surface quality of the components to be produced depends on them, but also the process reliability. Depending on the application, dressing systems are designed and manufactured for dressings discs or profile rollers. These systems can be configured specifically for the process with adapted drive power and maximum dynamic rigidity with rotating sensors. Concentricity, constant speed, speed control, temperature monitoring and gate detection are essential features fulfilled by the system.

Our experts will be happy to help you select and design the systems for your application.



DRESSING TOOLS FOR ALL TASKS

Diamond dressing discs for CNC controlled dressing or profile rollers for plunge dressing: DR. KAISER supplies dressing tools for almost all applications from a single source. By using different diamond coatings (synthetic or natural diamonds, scattered or hand-set) in combination with a wear-resistant sintered bond or galvanic positive or negative coating, the tools can be specifically adapted to your machining tasks. The range of applications includes conventional alumina, SiC or vitrified bonded CBN and diamond grinding wheels. Whether in small, medium or large series: DR. KAISER DIAMOND TOOLS are used in all areas.

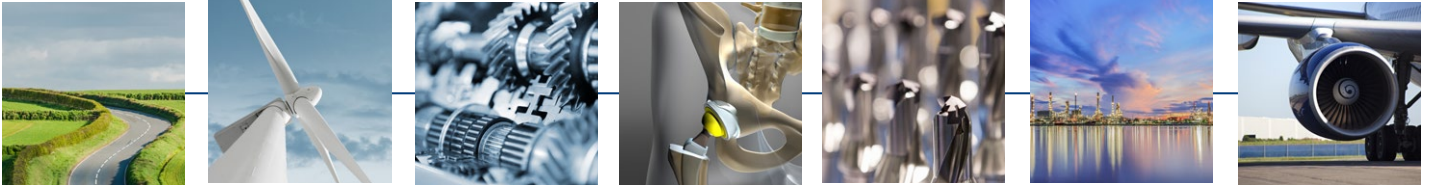


GRINDING WHEELS FOR PRECISE GRINDING

CBN in vitrified bond has made steel grinding even more efficient in recent years. When machining high-precision components made of non-ferrous materials, diamond grinding wheels in ceramic bond deliver the best results.

Whether high-performance grinding or precision machining: vitrified bonds from DR. KAISER matched to the process enable optimum use of the high-hardness abrasives.

OUR FIELDS OF ACTIVITY



EVERYTHING FROM
A SINGLE SOURCE:

DRESSING DISCS

DRESSING ROLLERS

STATIONARY DRESSING TOOLS

CVD DIAMOND DRESSING TECHNOLOGY

DRESSING SYSTEMS FOR VITRIFIED
CBN GRINDING WHEELS

DRESSING TOOLS FOR GEAR GRINDING

DRESSING SPINDLE SYSTEMS

CBN AND DIAMOND GRINDING WHEELS

PCD AND PCBN CUTTING TOOLS

PCD AND CVD DIAMOND WEAR
PROTECTION COMPONENTS

APPLICATION ENGINEERING

SEMINARS AND TRAINING

DR. KAISER
präzision durch diamant

DR. KAISER DIAMANTWERKZEUGE
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