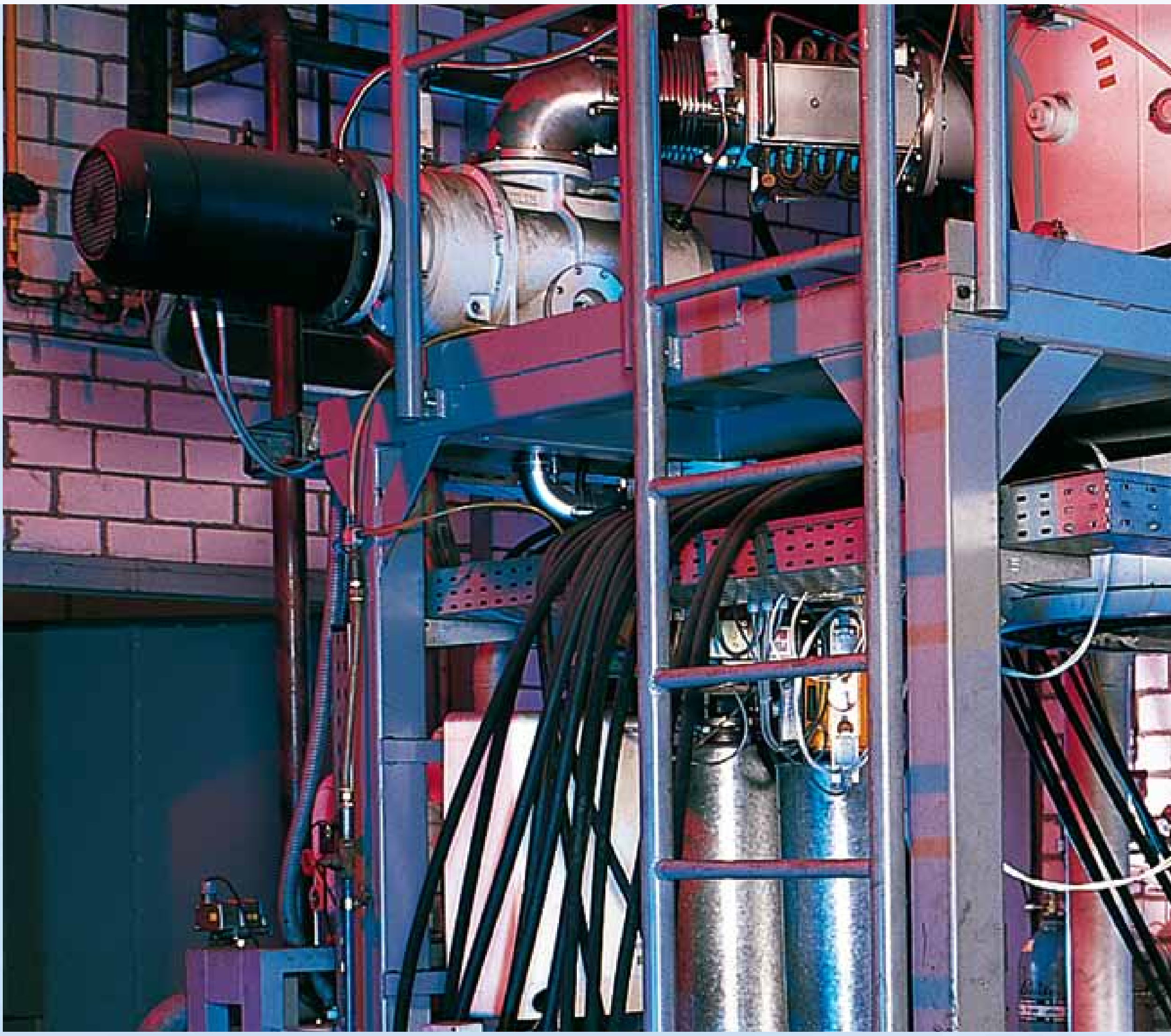
Ferro-Titanit®
Guidelines on Machining

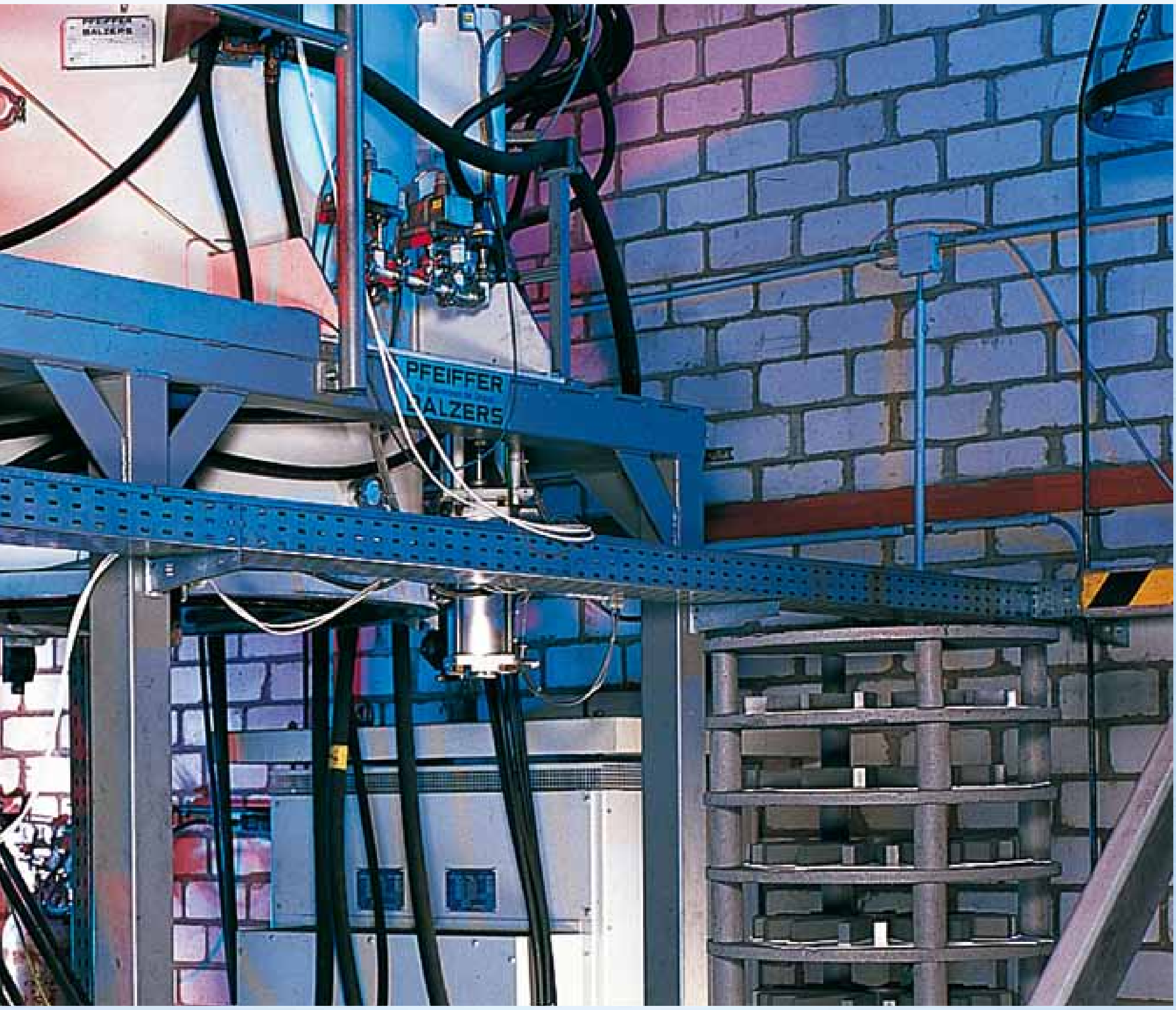
DEUTSCHE EDELSTAHLWERKE

Providing special steel solutions

Contents

Sintering furnace

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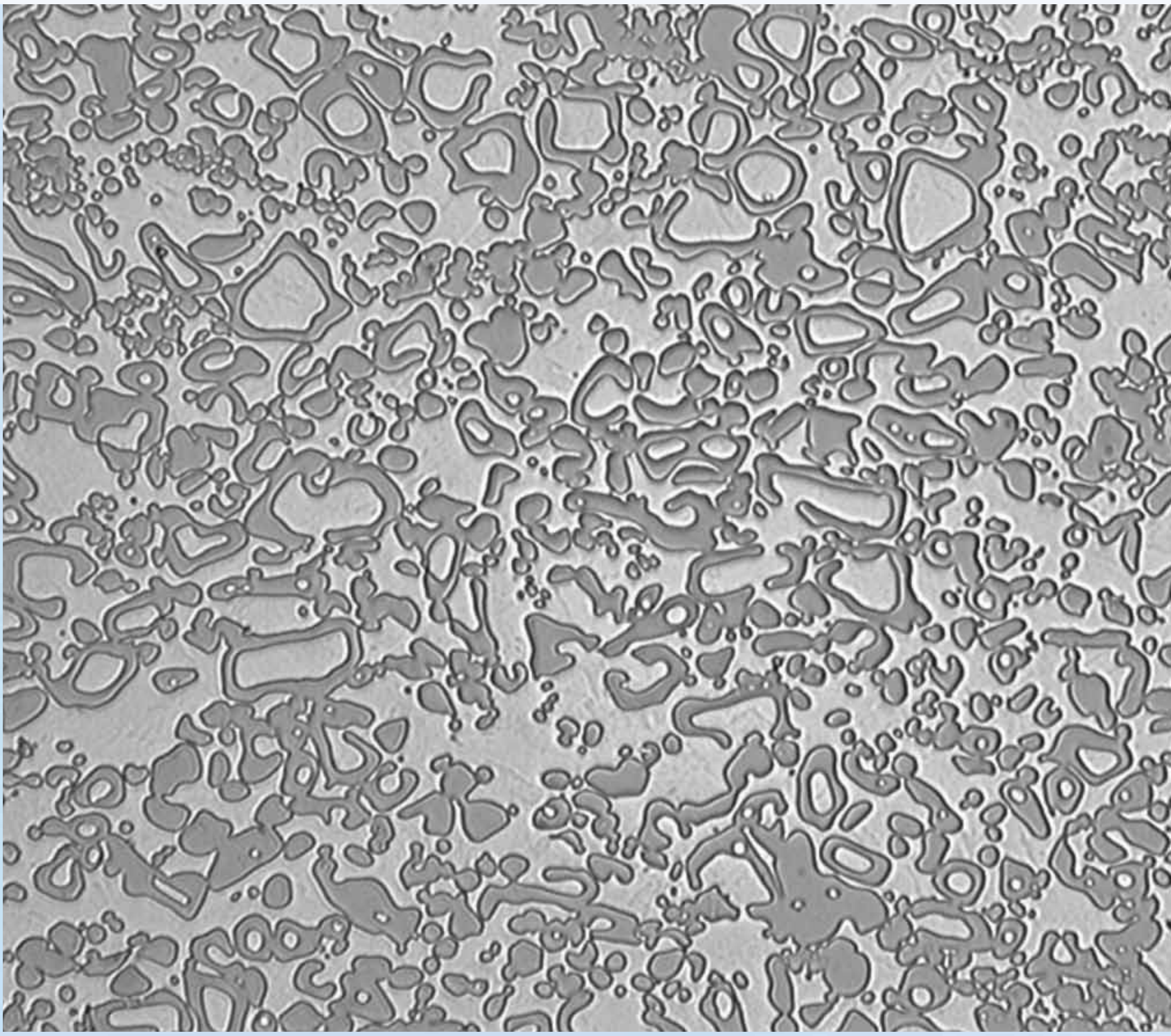
The material

Ferro-Titanit® is the trademark used by Deutsche Edelstahlwerke GmbH for machinable and hardenable alloys produced by powder metallurgy techniques. Materials that have so far been available for tools and wearing parts have included tool steel and tungsten carbide alloys. Ferro-Titanit® material combines the properties of steel and tungsten carbide alloys. It is possible to machine this material by conventional methods in the asdelivered condition. When hardened (up to 69 HRC), Ferro-Titanit® can be used to economically solve many wear problems. The advantages of powder metallurgy compared with usual melting methods - no fibering, no segregation, homogeneous fine-grained carbide distribution, no impurities, etc. - allow Ferro-Titanit® to be alloyed with one of the hardest carbides (titanium carbide) by as much as 45% by vol. without losing the machinability.

Titanium carbides in steel matrix, scale approx. 1:2000



Advantages of Ferro-Titanit®

- low specific weight of 6.5 g/cm^3
- machinable by sawing, milling, turning, drilling, etc.
- hardenable up to 69 HRC with very little distortion
- change in dimensions < 0.1%
- frequent possibility of recycling by annealing, machining and rehardening
- good possibilities of combination with tool steel due to favourable technological properties
- minimum pick-up with other materials
- good damping properties

The composition of the machinable Ferro-Titanit® alloys consists of approximately 45% by vol. titanium carbide and 55% by vol. of a steel matrix that is tailored to the intended application. The matrix can be pearlitic, or nickel-martensitic for precipitation hardening grades, or also austenitic (see table). The carbides are embedded in the particular matrix (see figure on the left).

Ferro-Titanit® grades

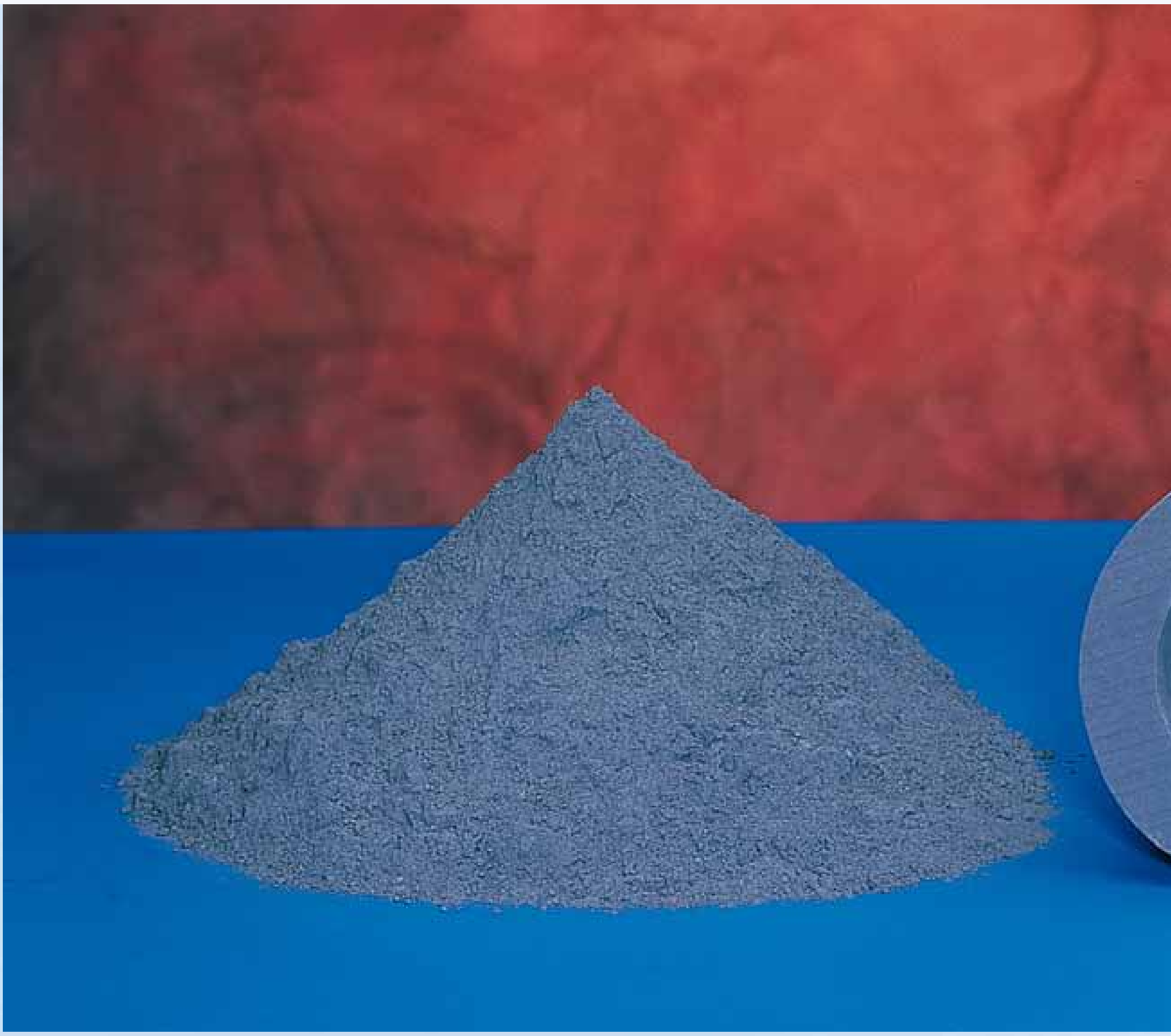
		Microstructural condition		
Carbide-alloyed materials	Hardness after annealing HRC	annealed	hardened	Service hardness HRC
C-Spezial	49	pearlite	martensite	69
WFN	51	pearlite	martensite + precipitations	69
S	51	pearlite	martensite + precipitations	67
Nikro 128	52	nickel martensite	nickel martensite + precipitations	62
Nikro 143	53	nickel martensite	nickel martensite + precipitations	63
U	51	austenite	austenite	51
Cromoni	52	austenite	austenite + precipitations	54

General information on machining

Ferro-Titanit® material contains twice as many carbides as steel (more than 45% by vol. compared with 28% by vol.). The carbides are relatively uniform in their shape and distribution over the whole cross-section. The titanium carbides which, with a hardness of 3200 HV, predominate along with chromium carbides, are considerably harder than the carbides, for example in high-speed steels (WC = 2400, VC = 2800, Mo_2C = 1500, Cr_3C_2 = 1300, Fe_3C = approx. 1100 HV).

Various alloys are used as binders in the steel matrix of Ferro-Titanit®. Totally different microstructural constituents, or modifications with very dissimilar hardnesses, such as 80 to 90 HV for ferrite, 210 HV for pearlite, 180 HV for austenite, 900 HV for martensite, and 900 to 1000 HV for ledeburite, come about as a function of the alloy contents and the heat treatment. Machining is performed only in annealed condition.
Adherence to the greatly reduced cutting

Production steps: powder, pressed blank, sintered blank, machined sleeve of Ferro-Titanit®

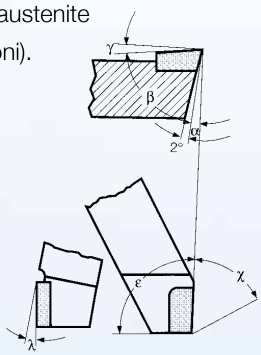


speeds, that are required in comparison with steel machining, is essential.
Finish-machining in one operation, i.e. with full depth of cut, is an advantageous method.
Except for the case of grinding machining should not be conducted with rinsing fluids or coolants. Machining with rinsing fluids or coolants is not allowed except in the case of grinding.

The individual types of machining

Turning

It is possible to machine Ferro-Titanit® using high-speed steel at low cutting speeds. However, heavy notch and edge wear occurs which leads to rapid tool failure. For this reason, it is preferable to use tungsten carbide with a supporting chamfered edge (see illustration). For guideline values on turning operations, please refer to table.
An even lower cutting speed down to as little as 4 m/min may be necessary for diameters less than 10 mm and for tough carbide-alloyed materials with a matrix of nickel martensite (Ferro-Titanit® 128, 143) or austenite (Ferro-Titanit® U and Cromoni).



Carbide-tipped tool chamfered for turning Ferro-Titanit®, conforming to DIN 4971 (ISO 1)

Drilling

Carbide-alloyed materials with a steel matrix can be drilled in annealed condition using tungsten carbide or highspeed steel (see table). Lubrication or cooling has to be omitted, since detached carbides in combination with fluids and pastes act as an abrasive. Drillings are conveniently removed from drill holes by means of compressed air.
If drilling is performed by hand, a constant contact force must be ensured. When diameters greater than 10 mm are drilled, the centre line between cutting edges is shortened by point thinning. The main cutting edge should not be shortened by more than one-third in this respect. The feed force is thereby reduced while, at the same time, the start of drilling is made easier.

Turning guideline values

Cutting edge geometry and cutting conditions		Tool Tungsten carbide K 10/K 20/M 10	Tool High-speed steel
Clearance angle	α	6°	6°
Rake angle	γ	-6 to 0° (+6°)	-6 to 0° (+6°)
Inclination angle	λ	-4°	0°
Cutting edge angle	χ	60 to 70°	60°
Corner radius	r	1.0 mm	1.0 mm
Cutting depth	a	if possible, over 1 mm	if possible, over 1 mm
Feed rate	s	0.02 to 0.1 mm/rev	0.02 to 0.1 mm/rev
Cutting speed	v	5 to 18 (20) m/min	3 to 9 m/min

Drilling guideline values

Cutting edge geometry and cutting conditions		Tool Tungsten carbide K 10 High-speed steel
Feed rate	s	0.05 mm/rev
Cutting speed	v	2 to 4 m/min
Angle of twist	λ	15 to 20° (20 to 30°)
Point angle	ε	90 to 120°

Milling

Milling is mostly more economical than planing. Although the surfaces produced by down-milling are rougher than those produced by up-milling, down-milling is recommended for Ferro-Titanit®. Up-milling quickly blunts the tool. In down-milling, the workpiece and tool have the same direction of movement. Spiral-fluted endmilling cutters (15 to 25°) have proven suitable in vertical milling machines, while face milling cutters are preferable when working on horizontal milling machines. Both high-speed steel and tungsten carbide tools can be used for either type of milling.
Tungsten carbide tools allow higher cutting speeds and result in longer cutting distances without failure.
For guideline values on milling work, please refer to table.
In slot milling and end milling, the sharp edges on the faces must be rounded off.

Planing (slotting)

As already mentioned, milling is mainly more economical than planing, which is why the latter machining method is used less. In exceptional cases, the shape of the tool being manufactured makes planing indispensable. An important aspect during planing is that the machining tool lifts off on the return stroke, as otherwise the tip of the cutting edge is easily damaged, resulting in a poor surface and a high rate of tool wear.

If this precondition is fulfilled, however, a superior-quality surface is mostly produced in comparison to milling.
For guideline values on planing, please refer to table.

Milling guideline values

Cutting edge geometry and cutting conditions		Tool Tungsten carbide K 10/K 20	Tool High-speed steel
Clearance angle	α	8 to 10°	In case of rollers and roller face cutters made of HSS, the types normally used for steel-working can be employed. Spiral-fluted milling cutters have proven wellsuitable.
Rake angle	γ	0 to +8°	
Edge radius	r	0.5 mm	
Cutting depth	a	if possible, over 1 mm	if possible, over 1 mm
Feed rate	s	0.1 to 0.2 mm/tooth	0.1 to 0.15 mm/tooth
Cutting speed	v	6 to 15 m/min	2 to 6 m/min

Planing guideline values

Cutting edge geometry and cutting conditions		Tool Tungsten carbide K 20	Tool High-speed steel
Clearance angle	α	8°	8°
Rake angle	γ	0°	0°
Inclination angle	λ	-8 to 0°	0° (-5°)
Point angle	ε	120°	120°
Cutting edge angle	χ	45°	45°
Corner radius	r	1.0 mm	1.0 mm
Cutting depth	a	if possible, over 1 mm	if possible, over 1 mm
Feed rate	s	0.2 mm/double stroke	0.2 mm/double stroke
Cutting speed	v	8 to 12 m/min	6 to 8 m/min

Countersinking

The cutting edge geometry and cutting conditions for the countersinking of Ferro-Titanit® are the same as for drilling with HSS or tungsten carbide.

Reaming

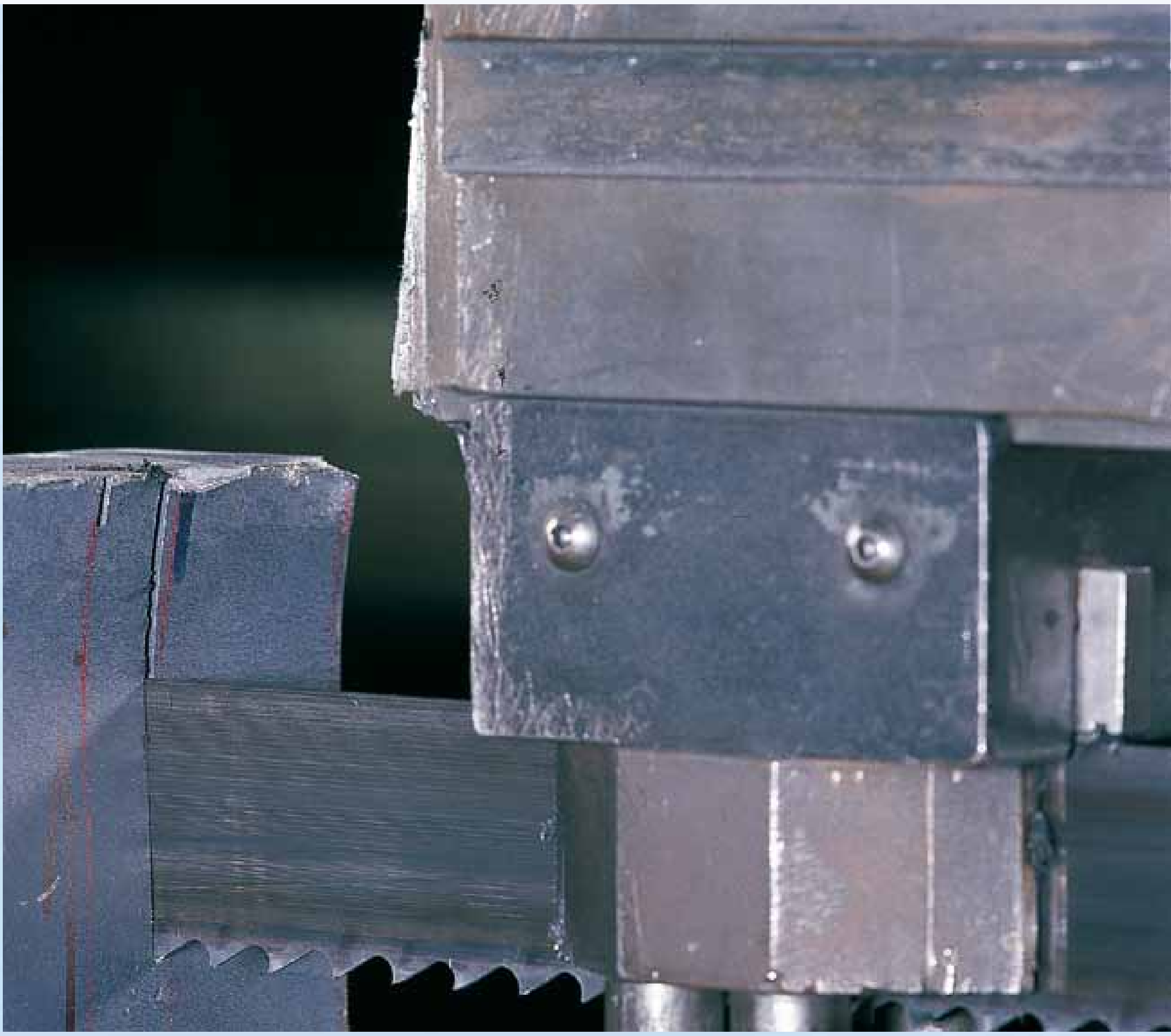
Reaming with small machining allowances is difficult and leads to imperfect surfaces.

To peel out the fine carbides, an allowance of around 0.25 mm on the diameter is advisable. The abraded material must be removed with compressed air. Cutting speed: HSS 3 - 5 m/min, tungsten carbide 6 - 8 m/min.

Band sawing

The sawing of Ferro-Titanit® requires blades with a coarser pitch and a lower cutting speed than are normally used for steel. The saw blades must be set, as otherwise the tooth flanks blunt quickly and the blades become stuck. The contact pressure applied during sawing should be greater than for steel and should not be allowed to decrease during cutting. The number of teeth is 3 per inch. Thin-walled parts require 8 - 10 teeth per inch. The cutting speed is 5 to 10 m/min. Band saw blades with a 2% tungsten alloy content are equally as economical as those made from high-speed steel.

Sawing of Ferro-Titanit®



Tapping

Tapped holes should be forgone if the carbide-alloyed material workpieces are to be subjected to high levels of stress. The acute threads can be starting points for stress cracking and fatigue fractures. A thread depth of 1.5 x D is sufficient for fastening purposes. Overlong threads only increase the tool costs. Female threads smaller than M 6 can be produced only by carefully keeping to all the appropriate guidelines. Such small threads should be avoided, especially in blind holes. Whatever the circumstances, the guidelines given below should be followed:

- Where possible, through-going threads should be provided; for blind-hole threads, an adequately deep drillhole must be selected.
- The core hole diameter should be 3 to 5% larger than for steel workpieces. Examples:
  - up to M 5 thread core diameter 1/10 mm larger
  - greater than M5 thread, up to M 10 core diameter 2/10 mm larger
  - for larger threads
    M 12 x 1 drillhole diameter 11.1 mm
    M 14 x 1 drillhole diameter 13.0 mm
- The tap is turned slowly forwards.
- Before and while the tap is turned back, the drillings must be removed by blowing out with compressed air. Given their grainy form, they very easily become stuck between the tool and thread, with the result that the cutting edges run the risk of chipping.
- If the tap becomes hot to the touch, the operation must be discontinued immediately, as the steel tap will jam in place as a result of its greater expansion compared with the carbide-alloyed material and may become damaged.
- So-called “thread-cutting strands” have proven particularly advantageous for tapping in blind holes. The stearin-like strands, which are available for any diameter, act as lubricants and convey the abraded material to the surface.
- Liquid lubricants are not recommendable since they cause the drillings to stick together and the thread to consequently become chipped when the tap is turned backwards.

Recognised thread tap manufacturers supply special tools for Ferro-Titanit® which are characterised by an extensive “undercut”, a wide chip channel and a rake angle of 0°. In many cases, it is sufficient to work with only one bottoming tap whose cutting-face rake angle has been reduced by grinding.

On drilling machines, threads are cut directly after drilling, without changing the chucking device. The tap with centre pin is inserted into the drill spindle in place of the twist drill. The taper tap is used for the in-line starting cut or roughing out of the thread, and for this reason, has a centre pin. When threads are cut in through-holes, the operation is performed without a plug tap. A plug tap is required only for threads in blind holes, to fully rough out the depth of thread reduced by the taper tap centre pin. The bottoming tap renders the thread true to gauge. If hand taps are used whose cutting geometry and type are tailored to Ferro-Titanit®, it is necessary to also heed the following working conditions:
core hole diameter to DIN 336, series II (corresponding to the diameter of the centre pin on the taper tap). At the time of ordering, it must be indicated that the taps are intended for Ferro-Titanit®. If threads are to be cut on lathes, pitches less than 0.5 mm are not recommendable.

Turning of a round bar of Ferro-Titanit®

Grinding

The high carbide content and the titanium carbide's high hardness make it self-evident that special attention must be paid when grinding. In which respect, it is of decisive importance whether the carbides are present in a soft-annealed or in a hardened steel binder phase. Grinding in hardened state leads to significantly higher grinding wheel wear. For guideline values on grinding, please refer to table.

If possible, Ferro-Titanit® should be extensively preground in unhardened condition, in which respect an allowance of 0.02 - 0.08 mm per side is sufficient.

This permits economical grinding after hardening, as the dimensional changes during heat treatment are extremely small. Corundum wheels with a ceramic bond and porous structure have proven a suitable medium. Diamond wheels made from plastic-bonded, nickel-coated synthetic diamonds with a concentration of 75 c - 100 c in a diamond grit size of D 107 - D 151 are recommended particularly for the finish-grinding of Ferro-Titanit® in hardened state.

Attention must be paid to the following basic rules when grinding:

- Grind with a powerful, rinsing stream of coolant directed as close as possible to the wheel/workpiece contact point.
- Select the smallest possible in-feed rate.

Grinding guideline values

Surface grinding		
Cutting speed of the wheel	v_c	20 to 30 m/sec
Feed rate	v_{ft}	10 to 25 m/min
Transverse in-feed	a_p	1/4 mm/stroke of wheel width
In-feed	a_e	0.01 mm/stroke
Cylindrical grinding		
Cutting speed of the wheel	v_c	20 to 30 m/sec
Table velocity	v_{fa}	1 to 2 m/min
Workpiece circumferential velocity	v_w	10 to 20 m/min
In-feed	a_e	0.01 mm/stroke
Internal cylindrical grinding		
Cutting speed	v_c	20 to 25 m/sec
Table velocity	v_{fa}	1 to 2 m/min
Workpiece circumferential velocity	v_w	15 to 20 m/min
Workpiece feed rate	a_e	0.01 mm/stroke

Grinding with diamond wheels

To gain maximum performance from carbide-alloyed materials, grinding with diamond wheels - chiefly made from synthetic, reinforced diamonds in a plastic binder - is recommended. The following advantages are derived compared with natural diamonds:

- Better adherence of the reinforced diamonds to the binder.
- Higher thermal conduction through the metal reinforcement.
- Greater material removal rate due to the irregular crystalline structure of the synthetic diamonds.

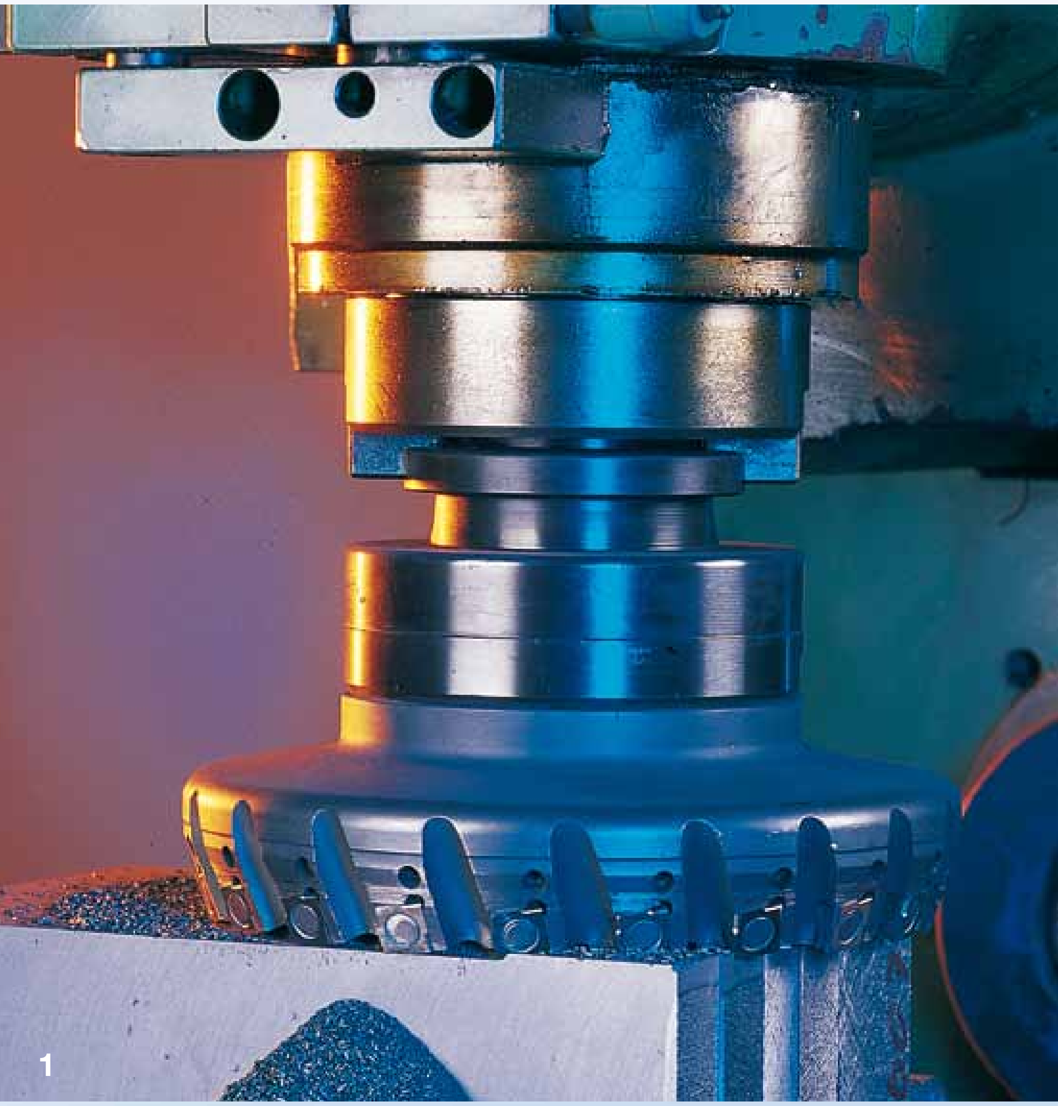
In the course of diamond grinding, the titanium carbides are both peeled off and ground by the diamond tips. To quickly and completely remove the material abraded from the diamonds, as well as the particles ground from the binder and workpiece, it is necessary to operate with a powerful, possibly double, jet of rinsing fluid and/or coolant. This applies chiefly when grinding larger surface areas involving a high volume of machining. Coolants containing a high amount of oil must be avoided.

Pure water dissipates heat five times better than oil. When grinding with diamond wheels, an adequate in-feed must be ensured so that the wheel can constantly work out and does not slide over the workpiece. Many additional factors besides absolute roundness and correct dressing of the wheel are essential for economical grinding. For this reason, there should be no hesitation to make use of the technical advisory services provided by experienced diamond wheel manufacturers.

All leading diamond wheel manufacturers supply wheels for the machining of hardened Ferro-Titanit®. Wheels made of Borazon can also be used, in place of diamond wheels.

Surface grinding
Vibrations, when the wheel comes into contact with the workpiece, should be kept to a minimum by using stable grinding machines with very little bearing clearance. This also includes the reversing movement of the table taking place at a reasonable distance. The value a = 0.4 x D mm (diameter of the grinding wheel) has proven useful as the average interval for the start-up and overrun positions of the grinding wheel.
It is possible to work with coolants on all surface grinding machines. Wet grinding should therefore be selected, especially for carbidealloyed materials. Hardened Ferro-Titanit® should be handled with the smallest allowance possible.

Cylindrical grinding
Wheel compositions similar to those used for surface grinding are recommended for cylindrical grinding in annealed condition.
Here, too, the rule applies that only preferably small allowances should be given before hardening. Small diameters with greater lengths can easily distort during heat treatment so that, occasionally, a bigger allowance may be necessary. The surface quality required for a long tool life therefore has to be achieved by subsequent lapping of the outside diameter with a diamond paste and by diamond grinding on the top (e.g. for a piercing mandrel).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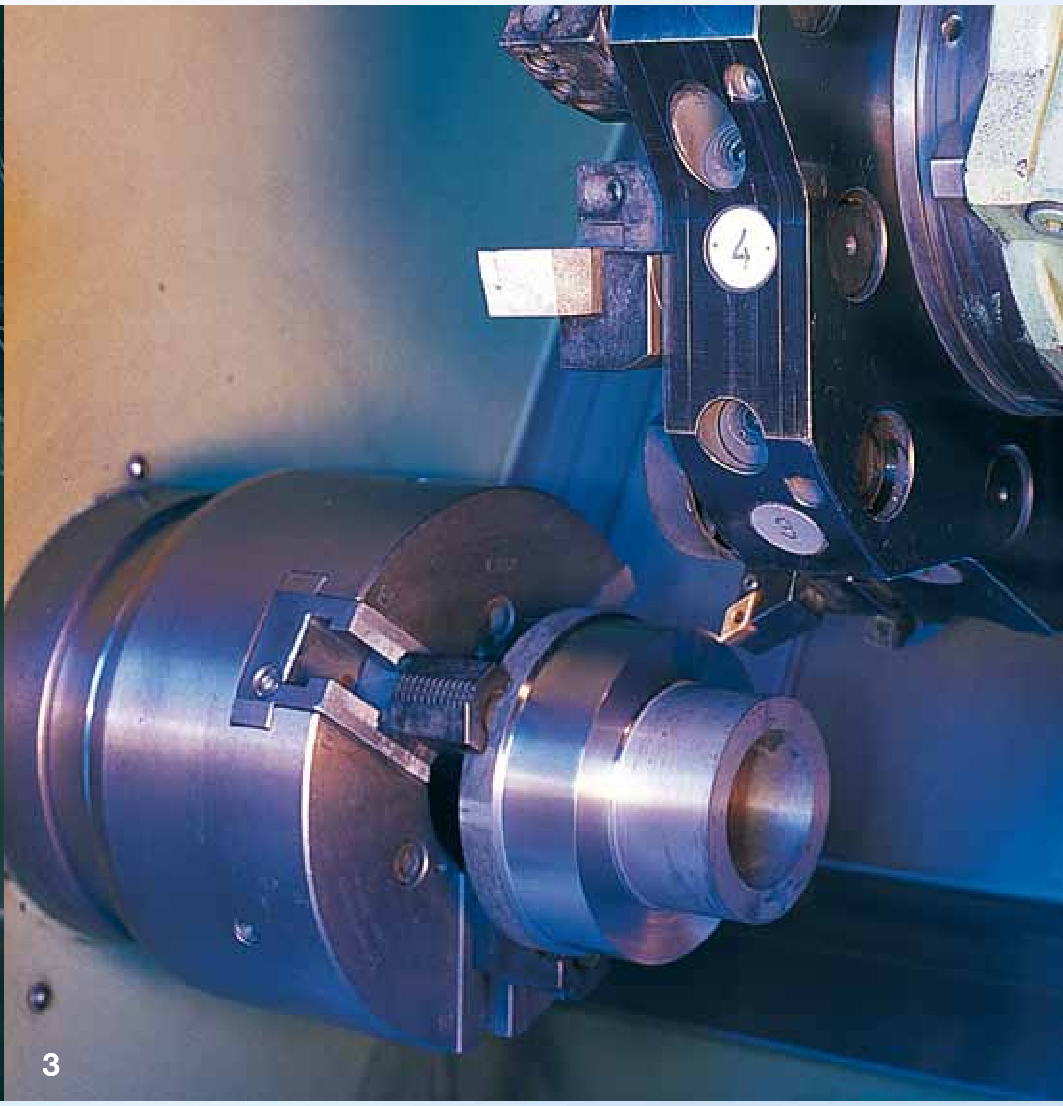
Internal cylindrical grinding
Borazon grindstones have proven suitable for the internal grinding of drill holes. Normal grindstones can be used for rough-grinding if diamonds are used for finish-grinding after the hardening treatment.

According to operating experience, it is possible to achieve a 30 - 50% saving in machining time when using Borazon grindstones, compared with carbon compounds.

1) Milling of Ferro-Titanit®
2) Turning of a composite-sintered part made of steel and Ferro-Titanit®
3) CNC machining of a composite part



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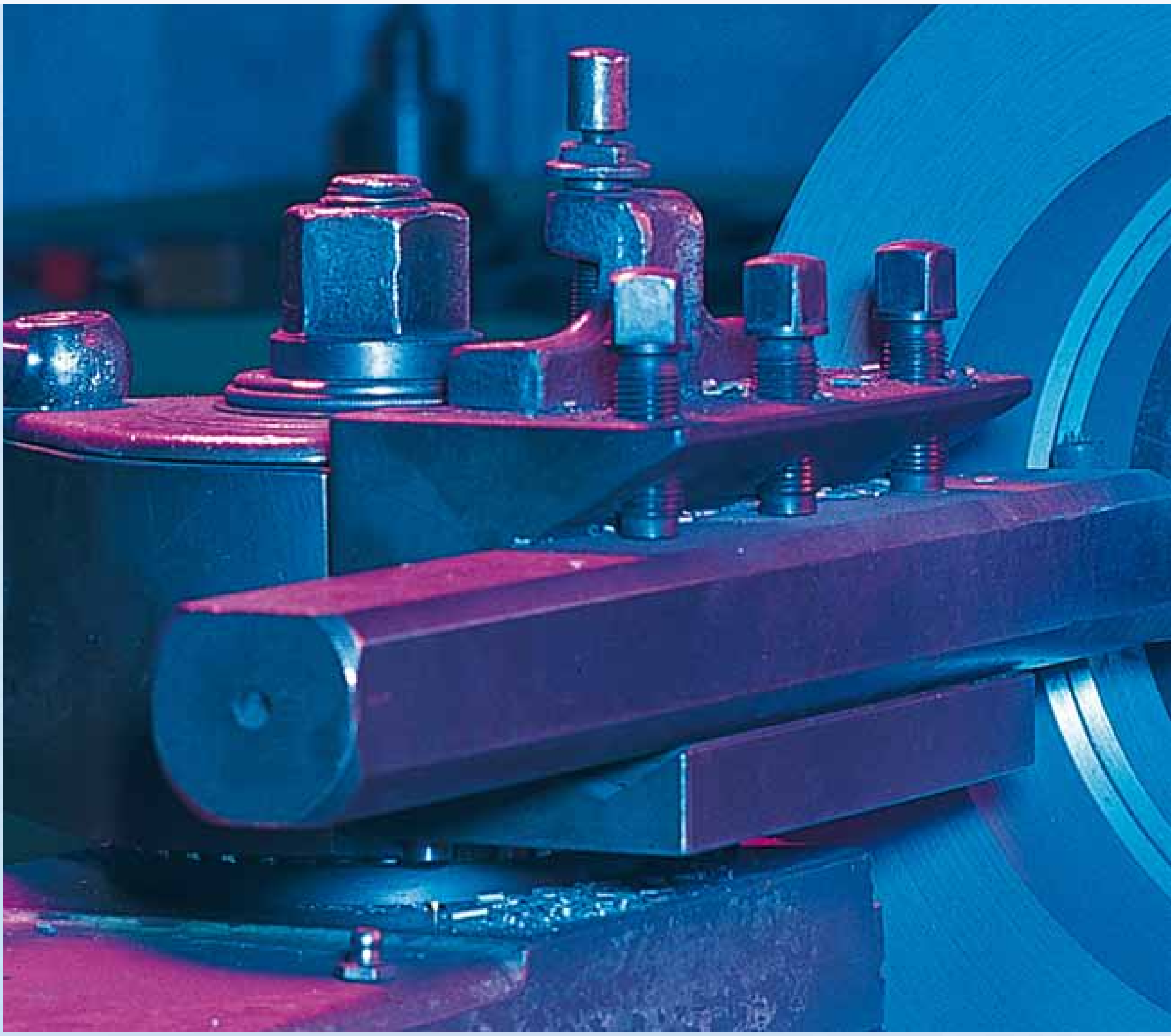
Lapping (polishing)

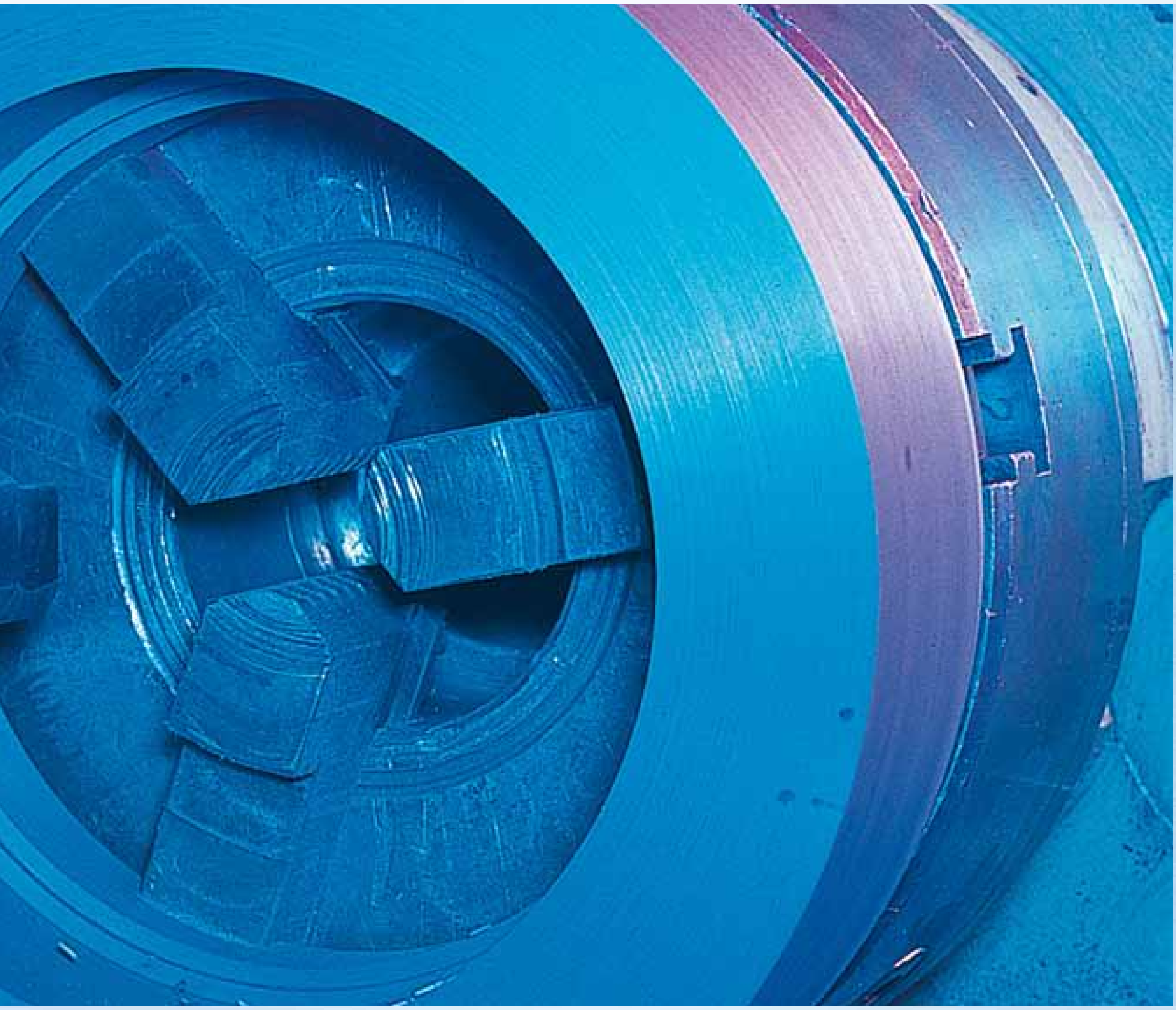
Lapping is a method by which surfaces of a high quality and great geometrical accuracy, as well as precise compliance with the closest tolerances, are possible. It is also partly suitable for eliminating structural deficiencies left by previous operations. Where carbide-alloyed materials in particular are concerned, the quality of the surface is instrumentally important, just as much for the life of the tools and machine components as for the precision of the parts that are to be manufactured. To reduce lapping to a minimum, it is necessary to pre-grind with a diamond wheel. The wheels used comprise synthetic, reinforced diamonds in a plastic binder with a diamond grit size of D 120 to D 70, depending on the surface roughness and surface zone. If diamond wheels with differing grit sizes are employed, grinding must be performed in alternating directions.

This is then followed by lapping. One lapping tool may be used only for a certain grain size. In case of machine-lapping, a lapping paste is applied to the workpiece, while for manual lapping it is applied to the lapping tool. This should be commenced with a minimum of diamond paste and light pressure on the lapping tool. The paste will darken in colour and thicken due to the abrasion. A solvent suited to the diamond paste, as well as fresh paste itself, must now possibly be added in order to re-increase the polishing efficiency. Rough-polishing is performed with diamond grit D 15, and finish-polishing with D 3. If necessary, a follow-up polish with grit size D 1 is possible. Polishing is carried out using hardwood or hard felt wheels



Turning of a Ferro-Titanit® ring

that are obtainable from the diamond product manufacturers. Given below are a few tips that deserve particular attention:
Before lapping is commenced, and between each operation with different grit sizes, it is necessary to thoroughly clean the surfaces by rinsing with benzene, or similar grease-free cleaner's solvents, and with cotton wadding.
If each piece of advice is followed, and the pre-grinding and subsequent lapping of the workpiece are performed well, a scratch-free polish will come about after approximately 10 minutes over an area of 2 cm^2 of hardened Ferro-Titanit® in which the carbides lie freely exposed at the surface.
This should be the aim of any polishing!
When the titanium carbides lie freely exposed, they can exert their resistance to wear and pick-up. If a surface is poorly lapped, the carbides only remain in the background because they have been smeared over by the steel matrix.
The reason for this is that polishing has not been carried out for long enough, or that too fine a lapping abrasive has been used. Silicon carbide and boron carbide are similarly less suitable for the lapping and polishing of hardened Ferro-Titanit®.
Undesirable pores develop during pregrinding, e.g. when using corundum wheels. For this reason, attention is drawn again to the fact that especially diamond grinding is very important before polishing. Because, only a diamond can cleanly cut the hard titanium carbides and thus create the precondition for a closed surface structure.

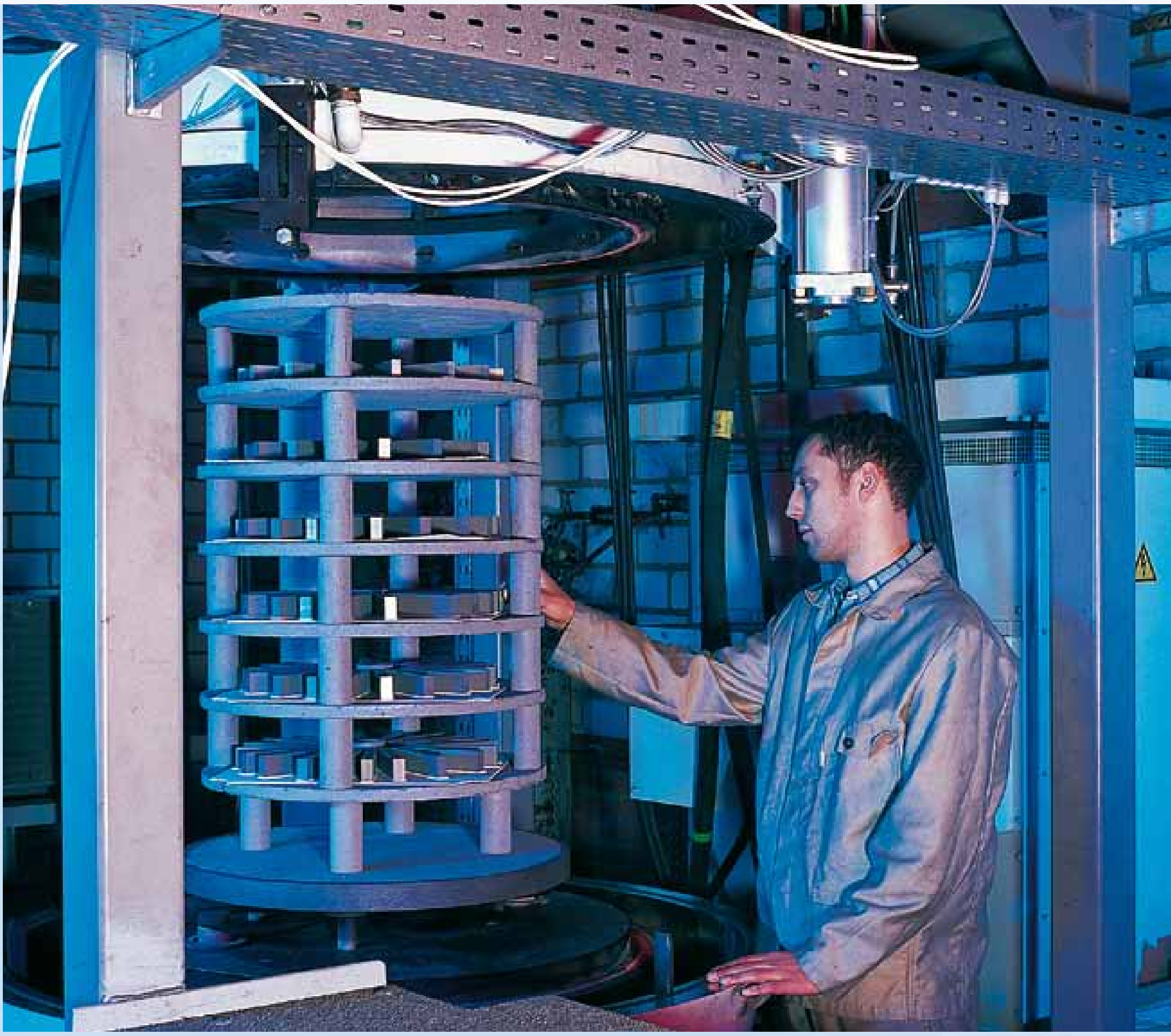


The polishing of a wrongly ground surface can take hours, as a high amount of material has to be removed. When the grain size is changed, the diamond grain becomes stuck in the pores and repeatedly causes grooving ("curves", "shooting stars"). A good polish is recognisable by extremely little roughness (less than 1 µm) and also by the so-called "dull" lustre, i.e. the surfaces appear a milkymatt-bluish colour. This appearance is due to the minor differences in height between carbide and alloy matrix. If carbide-alloyed materials are poorly polished, the surface always has a bright, clear lustre, comparable to a metal or crystal mirror.
These characteristics are of special importance for practicians. Particular attention must be paid when lapping on buffers or lathes. The circumferential velocity of the part undergoing polishing should be 10 to 12 m/min. At high speeds and pressures, it is possible for carbides to also be torn out by diamond abrasives and for the surface to become smeared over with alloy matrix material.

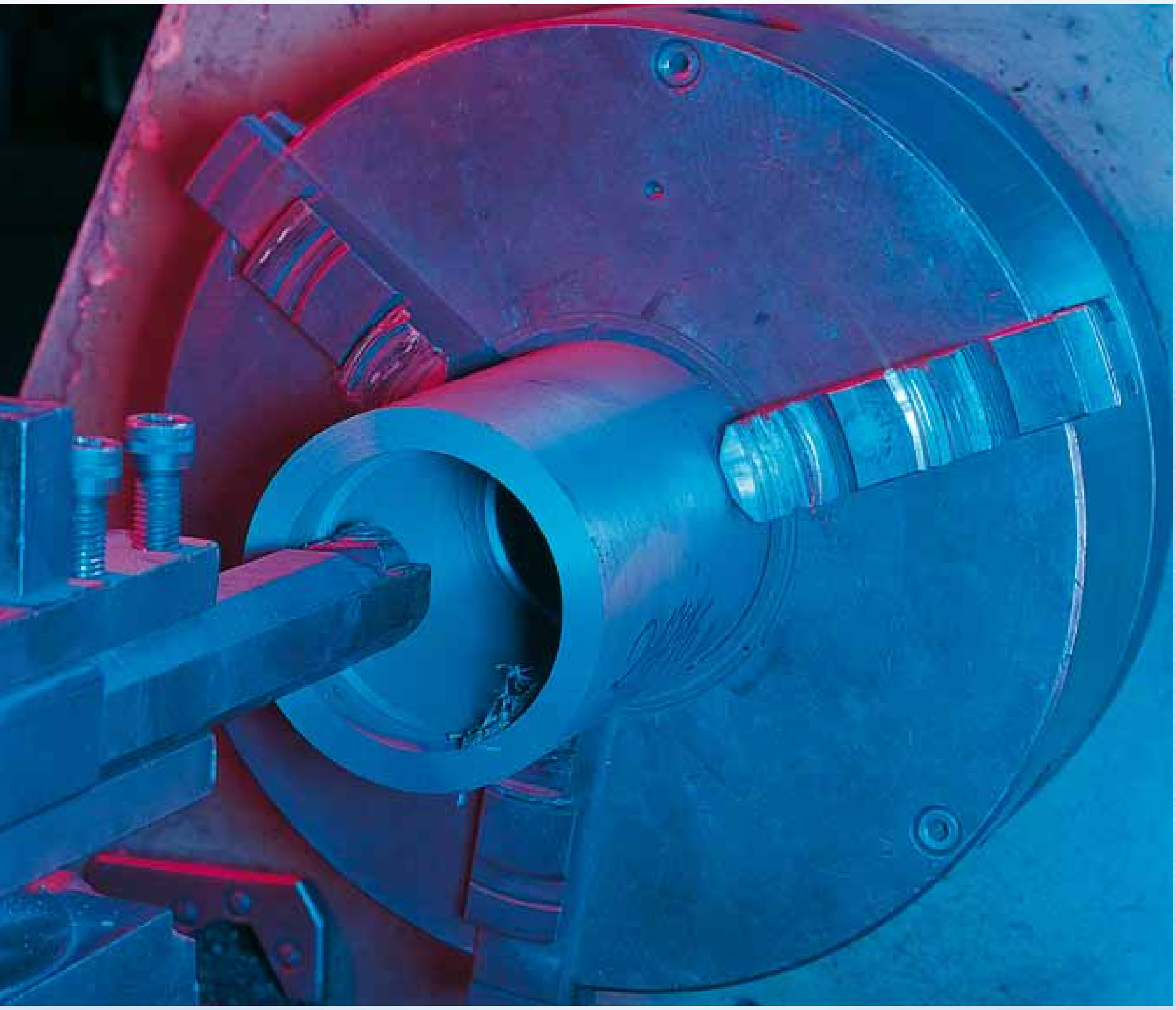
Finishing after hardening

Any of the spark erosion and electrochemical abrading processes can be used for the finishing of Ferro-Titanit® (primarily in hardened condition). It is, however, essential to bear in mind that Ferro-Titanit®, in the same way as high-speed steel, for example, consists of different

Charging of knife bars



components (matrix - carbides) and that these also react differently. The steel matrix, for instance, reacts much more strongly than carbides, in spite of differentiable composition. The structure is strongly fragmented, from which the carbides are able to break out. It thus follows, and has been proven many times in practice, that finishing is always necessary after machining by means of the mentioned processes if maximum performance is to be obtained from Ferro-Titanit® or other materials.



Internal turning of a sleeve

Product forms

The machinable and hardenable Ferro-Titanit® grades are supplied mainly as semi-finished material in soft-annealed condition, with a machining allowance of approximately 0.5 to 1.0 mm on the ordered dimensions. Typical product forms include

- disks and cylinders
- ground round bars
- rings and sleeves
- square dimensions

in turned or milled execution (finished parts upon request).

Any tool shop therefore has the possibility to machine tools and other wear-exposed parts, as opposed to tungsten carbide materials, on equipment normally used for machining steels.

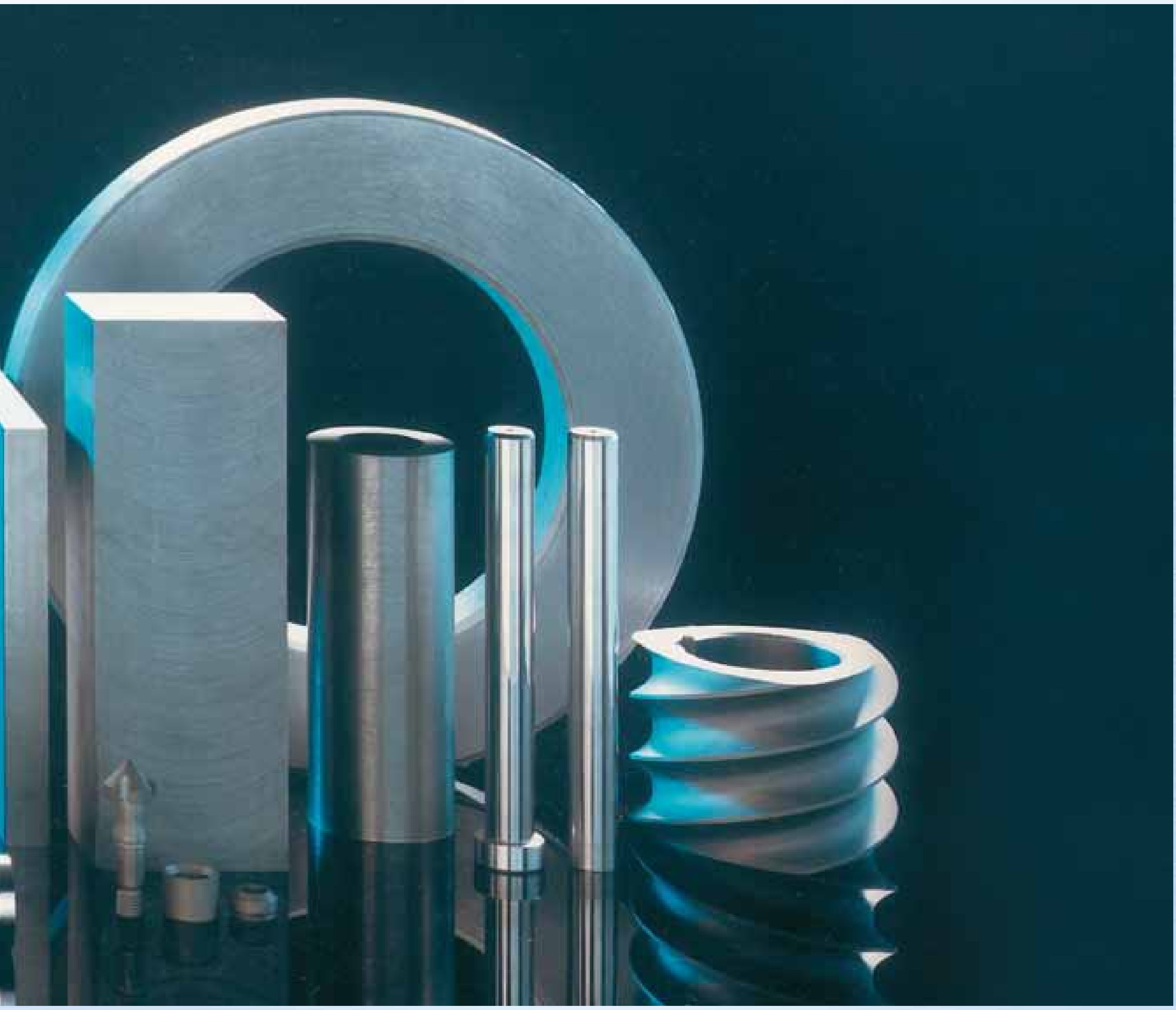
Basically, parts made of hardenable carbide-alloyed material are rough-machined as far as possible in the annealed, assupplied condition and are then hardened, preferably in a vacuum furnace, as well as tempered. Ferro-Titanit® can be hardened with little distortion, the change in dimensions being less than 0.1% of the as-supplied dimensions.

Ferro-Titanit® can be joined permanently to

steel by special methods. This possibility can be used to apply the material only toparticularly exposed areas.

General note (liability)

Statements as to the constitution or utilisation of materials or products are for the purpose of description only. Any guarantees in respect of the existence of certain properties or a particular application require special written agreement at all times.



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