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HANSER

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Smart machining of turbine wheels

Ceramic cutting tool material - Ni-based alloys - reliable manufacturing process

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Ceramic cutting tool material ■ Ni-based alloys ■ reliable manufacturing process

Smart machining of turbine wheels

Nickel based alloys are high-strength and high-heat resistant but also very difficult to machine. SiAlON cutting tool material is ideal for machining; the robust ceramics machine up to six times faster than carbide. What you need, however, is an optimised machining process and tooling system.

by Johannes Schneider

Nickel-based alloys are HRSA (Heat Resistant Super Alloys) materials featuring extremely high warm hardness and stability at high temperatures. They are also highly resistant to material fatigue and are extremely reliable and resistant to corrosion under the special operational conditions of high pressures, jet velocities and temperatures up to 1000°C found in gas turbines. This is why nickel based HRSA materials are preferred for the construction of machine elements in the ›hot parts‹ of stationary and airborne turbines, also in exhaust gas turbochargers. This includes turbine blades and also shafts, turbine wheels and turbine discs.

1 Cutting inserts made of SiAlON ceramic cutting tool materials CSL125 and CSL725 for turning and grooving of HRSA materials. They are ideal for roughing and medium machining steps demanding high productivity. (© CeramTec)

The extreme stress demands optimised tooling concepts

The specific properties of HRSA materials lead to high mechanical and thermal stress of the cutting tool material during machining. The materials tend to cold work harden which may manifest itself by pronounced notching of the cutting edge. The cutting tool materials are extremely hard and stable at high temperatures and work under extraordinary mechanical stress. As a result high cutting forces occur.

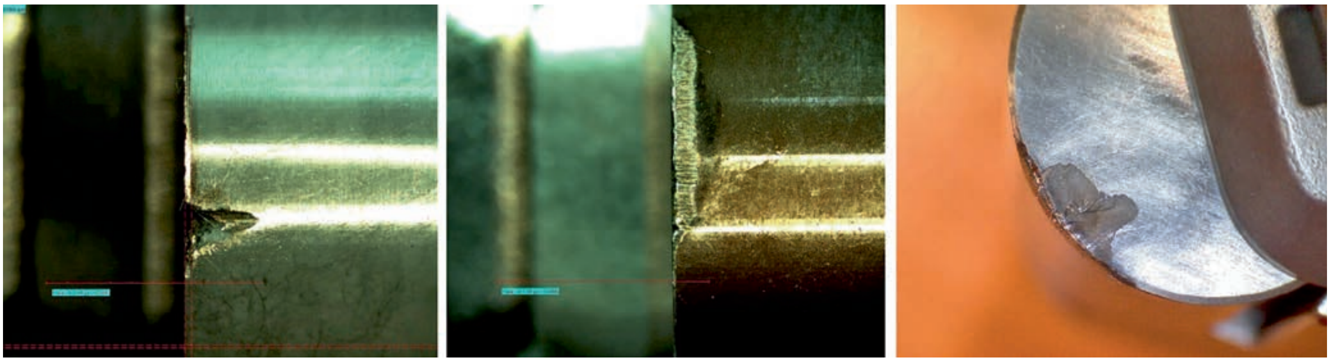
The low thermal conductivity of the HRSA materials will in addition increase the thermal stress on the cutting edge. Hard carbides embedded in the structure will also cause abrasion of cutting tool material. The tendency to form built-up edges may further impair workpiece quality and tool life.

All in all, since machining of HRSA materials is associated with extremely demanding conditions, tool wear will be correspondingly high and demand the use of suitable cutting tool materials, tool systems and technical methods of processing.Because many of the machine elements mentioned have rotational symmetry, a large proportion of machining will involve turning and grooving. SiAlON ceramics are ideal cutting tool materials for roughing and semi-finishing steps that demand high productivity. Picture 1 shows a selection of cutting inserts made of SiAlON cutting tool materials CSL125 and CSL725, suitable for turning or grooving of Ni-based alloys materials.

The type and relative numbers of grains enable modification to the material properties

A distinguishing feature of SiAlON cutting tool materials, apart from the needle-like β-SiAlON-particles (responsible for the toughness) is the option of creating the globular α-modification to clearly improve the hardness. The α/β ratio is therefore a parameter via which the cutting tool material properties may be adjusted.

Another option for increasing the hardness and thus the resistance to wear of α/β SiAlONs is finely dispersed inclusion of hard carbide type material particles. The high temperature properties of this material group may be improved by including some of the sinter additives in the crystal lattice structure of the silicon nitride particles.



2 Forms of wear when turning HRSA materials: On the left, notch wear, in the centre, flank wear and on the right, flaking on the cutting face (© CeramTec)

Another option for influencing the performance of α/β SiALONs lies in the manufacturing process per se. Because new manufacturing methods allow the creation of a particularly hard and extremely wear-resistant surface on a tough insert core. This will allow the hardness, so decisive to the outstanding application properties of the α/β SiAlONs, to be retained in the peripheral zone and combined via a gradient to the excellent tenacity of the substrate core.

Continuous cutting during turning will cause considerable heat which may be useful for softening of the chip but must also be controlled via an adequate cooling lubricant supply, to prevent excessive thermal load on the cutting edge.

Typical parameters for turning of HRSA materials using SiAlON cutting tool materials are cutting speeds vc between 150 to 300 m/min, feeds f from 0.08 to 0.20 mm and at cutting depths ap up to 2.5 mm. The cutting data may be adjusted for any specific case and will ultimately be determined by the type of HRSA material, the component geometry and the machining required.

SiAlON ceramics may be deployed for turning at up to six times the cutting speed achievable with hard metal (HM) cutting inserts, with correspondingly higher machining speeds possible. This also requires, however, that the technical prerequisites for machining are satisfied.

The interaction between workpiece material and cutting tool material composition must first of all be examined. Depending on composition, different types of SiAlON cutting tool materials may exhibit completely different wear under the same operating conditions, thereby shortening tool life. A typical wear criterion would be notching on the indexable insert at cutting depth of cut level. Other tool life criteria may be defined, such as excessive flank wear due to flaking, or a combination of the types of wear mentioned (Picture 2).

Four practical options to minimise notch wear

In addition to selecting a suitable combination of cutting tool material-workpiece material, specific technical machining methods may also be deployed to reduce ›notching‹. One option would be to vary the cutting depth for each of several sequential cuts. This may be achieved by ramping - either by conical turning of the different cutting steps or by varying the depths of cut.

Another option would be to carry out the first cut through ›rolling in‹ the cutting insert over the first edge of workpiece. This will also change the cutting edge - workpiece point of contact. Small, effective attack angles may also be used, for instance by using round indexable inserts and matching cutting depths. The specific small and precise effective attack angles may finally be configured by matching the ratio of cutting depth to diameter or to the corner radius of the indexable insert.

The following additional HRSA machining techniques will likewise benefit manufacturing reliability and tool life:

- The first cut on a workpiece will ideally be via a chamfer on the workpiece to reduce the load and distribute the cutting section over the length of the cutting edge.
- A chamfer on the workpiece will minimise burr formation on the workpiece on the exit point of the tool.
- The feed will be reduced for greater cutting depths in order to reduce the mechanical stress on the cutting insert.
- The feed rate will be selected such that material hardening is prevented by setting an adequate undeformed chip thickness h. Overstressing and thereby both, chipping or breaking of the cutting edge must be avoided.

Inconel 713LC turbine wheels are used for stationary gas turbines or for exhaust gas turbochargers (Picture 3). Economical manufacture of these components greatly depends on the tool systems and the method used.

SiAlON ceramic grade CSL125 may here be used for turning. Machining

INFORMATION & SERVICE

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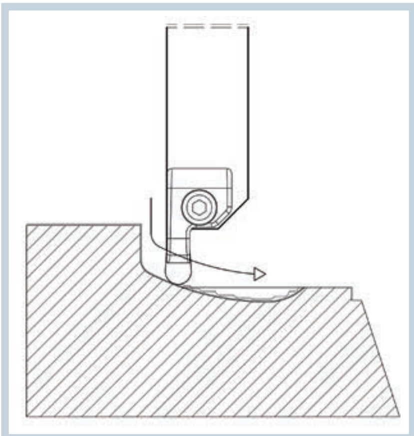
3 **Turbine wheel made of Inconel 713, used for stationary gas turbines or ex haust gas turbochargers, as blank (left) and as finished part (right)** (© CeramTec)

will be with a cooling lubricant supply and a cutting speed vc up to 270 m/min., a feed f up to 0.10 mm and a cutting depth ap up to 1.0 mm. A CNGA120412T indexable insert will normally be used for defined workpiece sections for facing and external turning of the hub.

A separate machining cycle will be run for other sections requiring the removal of material at very high rate. This effectively reduces notch wear and a greater metal removal rate is achieved, with high reliability and safe production. A RCGX-06 indexable insert, also of type SiAlON CSL125 will be used for turning the required contour shape.

Contour-turning and grooving combined

Another strategy for machining of turbine wheels is based on rhombic CNGN indexable inserts combined with grooving, including lateral travel with the grooving tools. In the first machining step, the CNGN120412 insert will turn the inner face and the cylindrical first cut of the contour. After contour shaping the opposite outlet side of the workpiece will be machined with the mirrored tool.



4 **Pre-finishing the contour by lateral travel of the grooving tool** (© CeramTec)

The next step will be the use of a 8 mm grooving insert. The SiAlON grade CSL725 is the basis for cutting in at several levels, depending on contour depth. This is performed with several adjacent cuts followed by pre-finishing the required contour with the grooving tool from both sides, travelling sideways (Picture 4). A final finishing cut is then made, with the grooving tool tracing the entire profile in one step.

Feed rate and cutting width are decisive for grooving, whilst for lateral movement the cutting depth is decisive to the stress on the tool system. A chip cross-section of approx. 0,60 mm^2 is feasible for grooving on this material. With lateral travel, it is recommended to select the lateral feed and cutting depth to create a chip cross-section around 0,10 mm^2. All machining steps require a cooling lubricant.

Combining SiAlON cutting tool materials CSL125 for turning and CSL725 for grooving, with a matching machining strategy and optimised cutting data will reduce the manufacturing time by a factor of six for this application. Compared to conventional manufacture using HM tools, manufacturing time will be reduced from 120 to 20 minutes. . ■

Translated by CeramTec GmbH