alicona
That's metrology!

White Paper

Quality Parameters of Cutting Tools

Alicona Imaging GmbH
Dr.-Auner-Strasse 21a
8074 - Raaba/Graz
Austria

Phone: +43 316 403010-0
Fax: +43 316 403010-711
sales@alicona.com
www.alicona.com

Version 2 - September 2015

Alicona Imaging GmbH
Dr.-Auner-Strasse 21a
8074 - Raaba/Graz
Austria

For a free copy of this publication, please contact: marketing@alicona.com.

Version 2 - September 2015

www.alicona.com

alicona
That's metrology!

Table of Content

Quality Parameters of Cutting Tools

Challenges for Manufacturers

Ever increasing customer demands on performance makes measuring in research and production indespensible.

Users of drills and milling cutters often complain about edge defects, rapid wear, long machining times or unsatisfying results on the workpiece. In most of the cases, failures can be attributed to the tool's incorrect surface finish or lack of know-how. Testing and constant measuring in research and production is the only solution for manufacturers to produce cutting tools according to the ever increasing customer demands on tolerances and performance.

Perfect surface finish

One major factor determining the cutting quality of a drill or a milling cutter is their surface finish. It requires a great adjustment to the material that is machined. A mismatch inevitably leads to the premature break of the cutting tool. In general, the rougher the cutting edge, the faster the tool will be worn or even torn. Therefore, the cutting edges preparation is of utmost importance.

Furthermore, an incorrect roughness value in the flute means poor up to no chip removal at all. In these cases, heat is not being deflected which results in unwanted built-up edges. By that, users are facing altered edge geometries, advancing cracks and uncontrolled chip removal, all leading to faster tool wear and a bad machining outcome.

Poor surface quality of the workpiece also arises from an unfitted edge preparation or ineffective clearance faces. Often, workpieces are too rough or chatter marks are even visible.

Correct machining parameters

The most important parameters for the cutting process are feed rate and cutting speed. Similar to the surface finish, they have to be attuned to the applied material, otherwise users are confronted with the following issues:

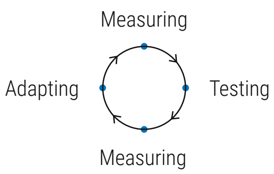
- material removal is not as effective as desired
- cutting edges break
- quality of workpiece is unsatisfying

Another issue is resources being tied up in the machining process. If tools constantly break and need changing or if wrong machining parameters lead to longer processing times, resources with regard to tools, machines and personnel are wasted unnecessarily. In short, the machining output is sub-optimal.

» **Edge defects** are a major issue in the cutting tool industry and can lead to a broken tool. They occur either due to incorrect machining parameters, wrong edge rounding or mismatch between tool and material. By constantly testing and measuring, manufacturers optimize the performance of their tools.

Importance of measuring

Only through constant testing as well as measuring in both, research and production does the manufacturer achieve the production of tools satisfying all customers' needs.



Besides the quality control during manufacturing, researchers in the lab use measurements to inspect the tool and the workpiece before and after the test at different materials. If any weak spots are quantified, the parameters concerned are adapted and the test cycle starts over again.

The procedure is repeated until the ideal tool and machining parameters are identified - a guarantee for customer satisfaction.

Measurement advantages of Focus-Variation

- Form and roughness with one system
- Small radii and (wedge) angles even across large measurement volumes
- Steep flanks
- Components with varying surface finishes or coating
- Full form measurements
- Profile and areal based roughness

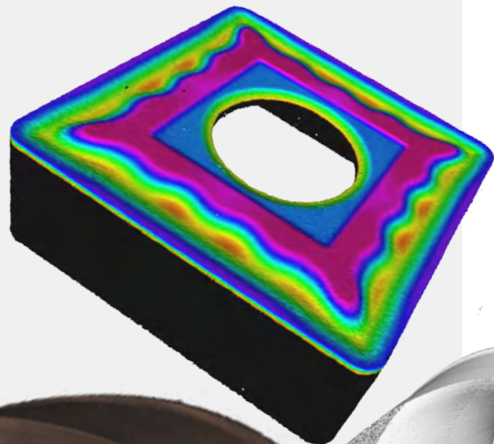
Why Measure Optically?

Advanced optical systems deliver high-resolution measurements of sharp edges

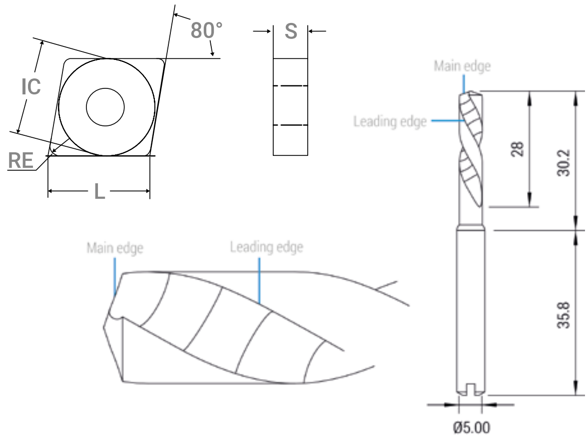
Optical measurement brings huge benefits in comparison to conventional methods. Especially the working distance represents an important feature for the tooling industry.

Optical metrology enables the non-contact, repeatable and traceable 3D measurement of cutting tools. A large working distance allows the accurate measurement of sharp edges. Edges are measured regardless of type, size, material or surface finish of the tool. A complete form measurement (360°) is possible by using an advanced grip. The speed when measuring areas is also striking.

Advanced visualization including registered color information delivers transparent and provable quality assurance. An intelligent illumination technology enables optimized illumination of surfaces with short exposure time, leading to fast measurements.



Cutting Edge Preparation



Technical drawing of a drill and an insert

After the production of drills or milling cutters by e.g. grinding, edges are not yet ready for cutting. They are determined by high jaggedness. Only a downstream cutting edge preparation enables the achievement of a tool with ideal cutting characteristics.

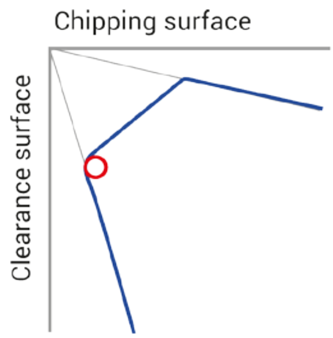
Effects of unsuited cutting edge preparation

» Uneven wear
» Non-optimal cutting ability
» Mismatch between tool and material of workpiece
» Machining result not as expected by user (surface finish and geometry workpiece)
» Excessive wear as far as edge break
» Too small radii diminish coating friction

To verify the cutting edge preparation measurement is necessary

Ideal cutting edge radius leads to

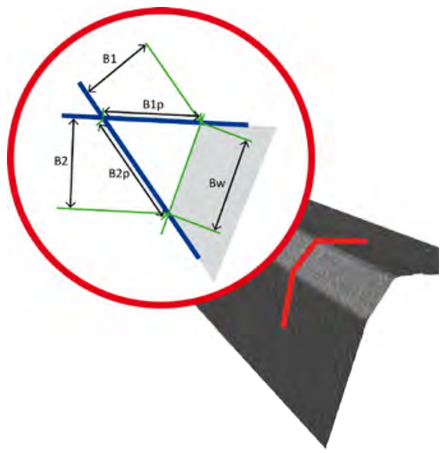
» Increase in tool-lifetime
» Increase in maximum feed rate
» Best possible surface finish on workpiece
» Trouble-free deployment of tool (no chatter marks, noise reduction)
» Prevention of tapered drill holes



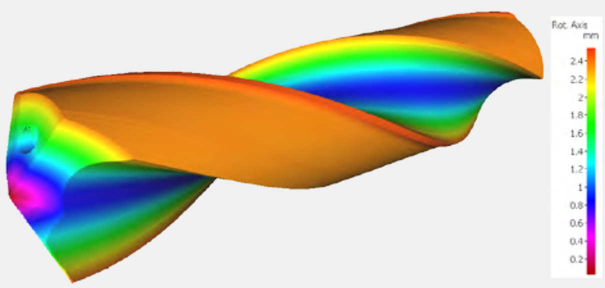
The cutting radius influences the tool stability

Exception: Edges with bevels

» Bevels support the cutting tool when machining particularly hard materials by deflecting the force with the bevel
» Optimum deflection makes tools machine even harder material
» Correct bevel geometry prevents tools from premature break



Bevels support the cutting tool by deflecting the force whilst cutting; especially necessary for roughing

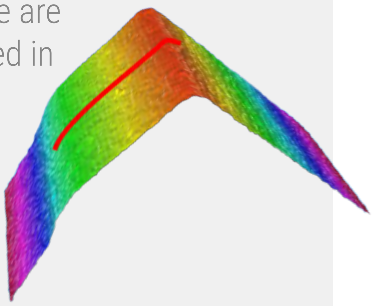


» **Cutting edge preparation** determines the roundness of the edges. The radius has a major impact on coatability, chipping, cutting performance, wear and lifespan.

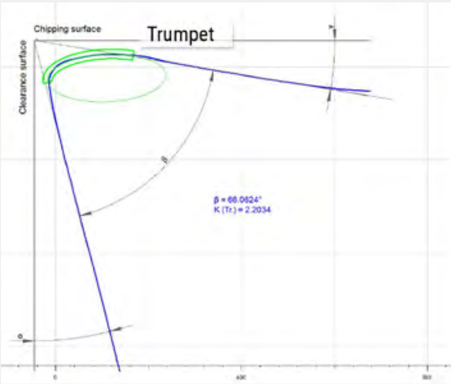
Measuring the real edge

» Measurement of actual edges' shapes through ellipse fitting method in addition to limited radius-fit approach for asymmetrical edges.

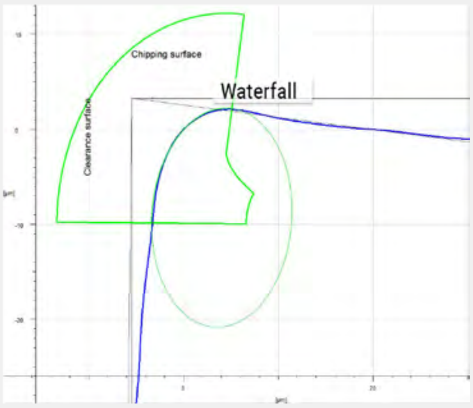
» Basket arches with both, waterfall and trumpet shape are traceably measured in high repeatability.



» An elliptic shape measurement in the edge region describes the shape by more than one circle parameter.



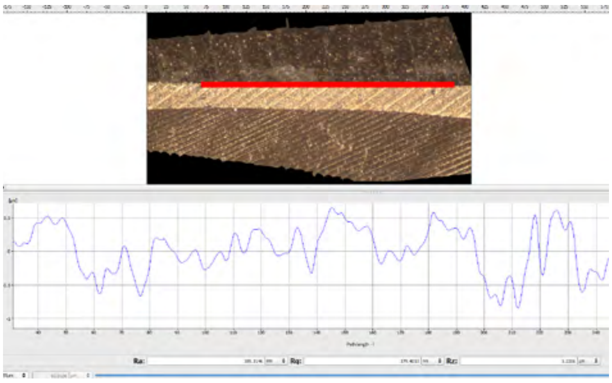
» The edge can also be compared to user-defined basket arch files of arbitrary shape.



Chipping measurement

By edge preparation manufacturers remove chips on the cutting edge. This leads to:

» Improved wear behaviour
» Avoidance of breakage by reducing the notch effect

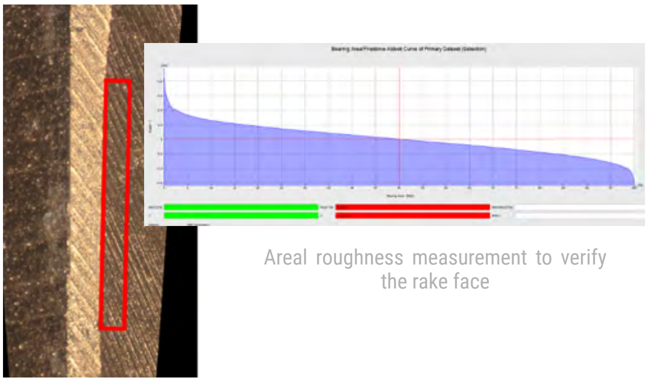


Chipping measurement by analyzing the profile-roughness along the edge to quantify existing chips

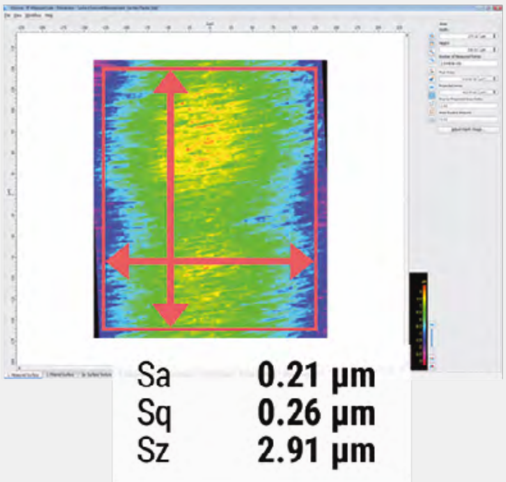
Roughness on rake face

Besides the profile based measurement, knowing the areal based roughness on the edge is vital. Ideal roughness leads to:

» Faster chip removal
» Increase in the maximum feed rate and cutting speeds
» Less breakage at the cutting edge by little jaggedness (more material has contact with the workpiece's surface, thus the force is more evenly distributed)
» Improvement of coatability by suited core void volume (= quantifies the amount of material which can be applied to receive optimum coating on the cutting edge)



Areal roughness measurement to verify the rake face



Why areal based roughness?

Texture measurement according to ISO 25178 allows the user to measure roughness not just on a profile but also on a large area. The multitude of measurement points enables a more robust result. Also, more significant values about the state of the surface are achieved.

Statistics include bearing area curve, fractal dimension, autocorrelation, gradient or spectral distribution, local homogeneity, etc.

Roughness in the Flute

Roughness in the flute informs about the amount of resistance the chip has during its evacuation.

Effects of unsuited roughness in the flute

- Bad chip evacuation leads to heat buildup
- Removed material melts in the flute which results in a bad machining quality
- Drills can get stuck in bore hole
- Bad coatability

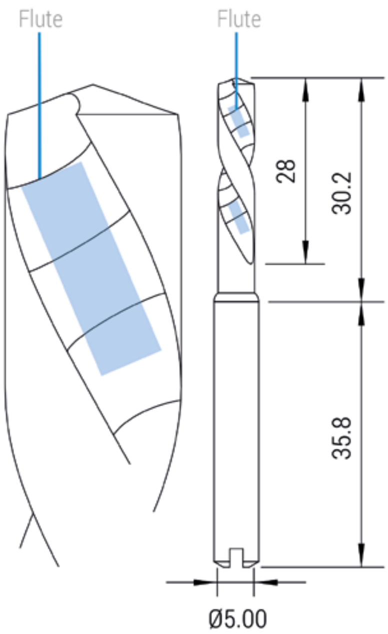
Ideal roughness in the flute leads to

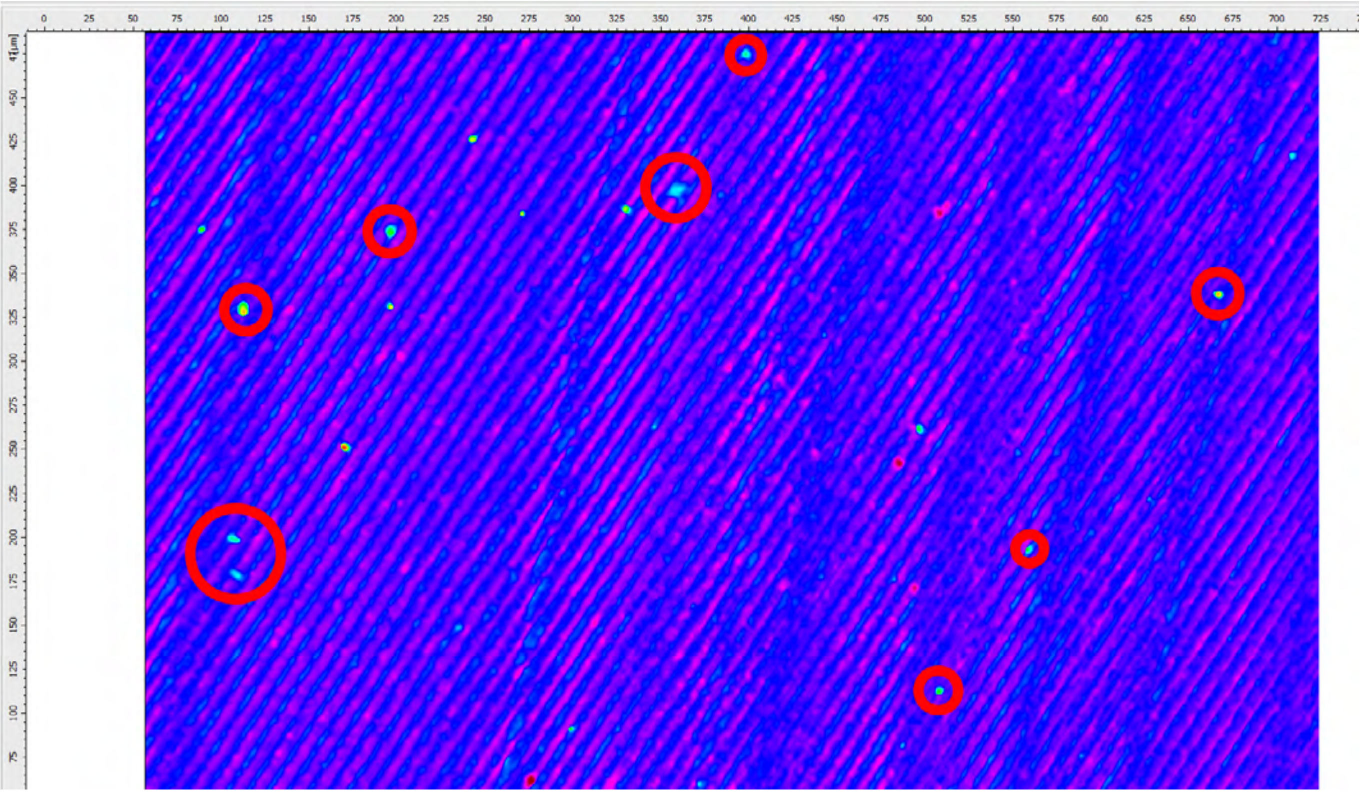
- Improvement of coatability by suited core void volume (= quantifies the amount of material which can be applied to receive optimum coating on the cutting edge)
- Faster chip removal
- Reduced generation of heat
- Higher maximum feed rate and cutting speed
- Prevention of built-up edges

TIP: Since the degree of roughness increases during coating, it is advisable to smooth the surface before it is coated.

Droplets on coating

During most coating processes droplets are generated on tools. These defects increase the surface's roughness and therefore seriously influence the flow of the chips. By measuring, it is verified that droplet heights are within tolerance or that a polishing process is needed.

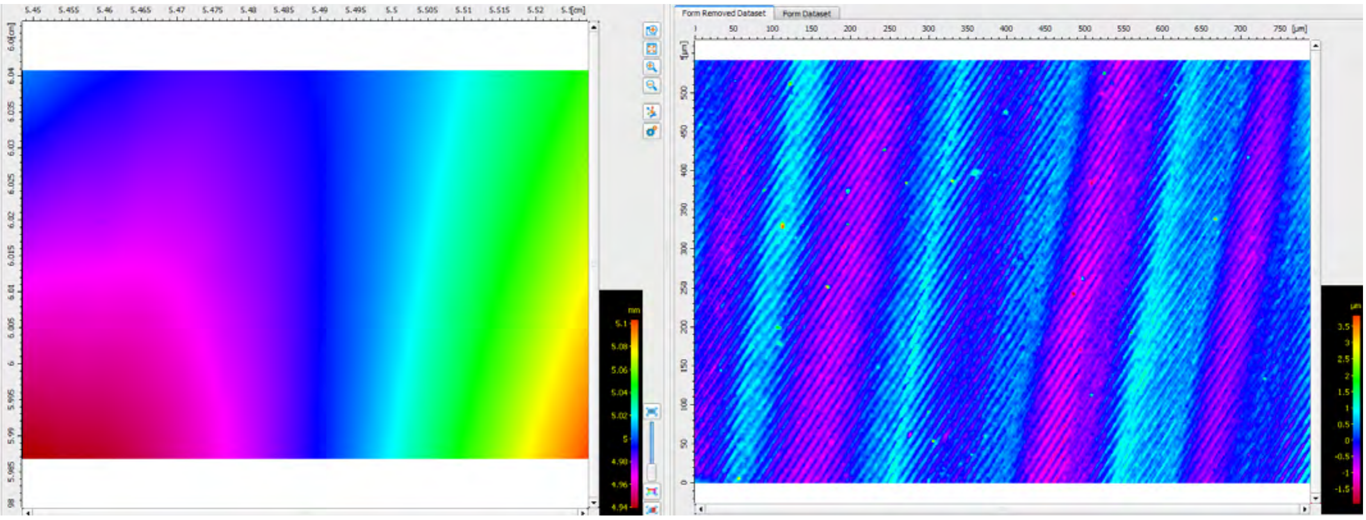




Droplet measurement: Areal roughness measurement in the flute informs about the amount of resistance the chip has during its evacuation. In this example droplets are clearly visible (red circles).

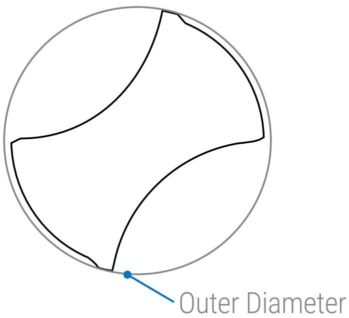
Form removal (flute measurement)

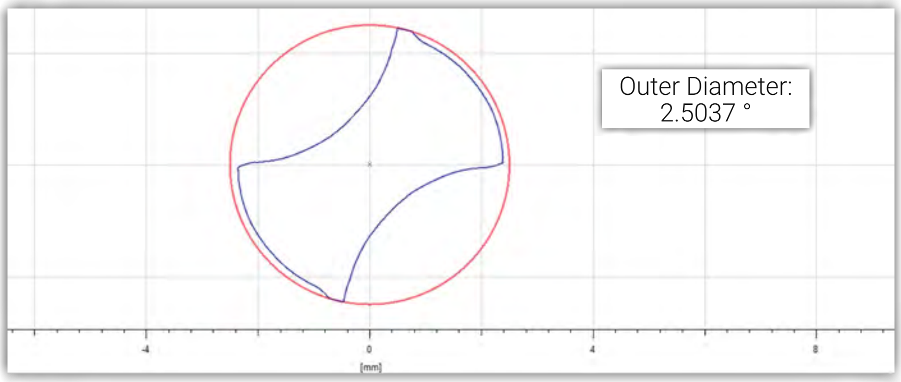
If a 3D dataset includes a significant form like the flute is featuring, it must be removed in order to obtain correct roughness values.



Cutting Tool Geometry

Outer Diameter

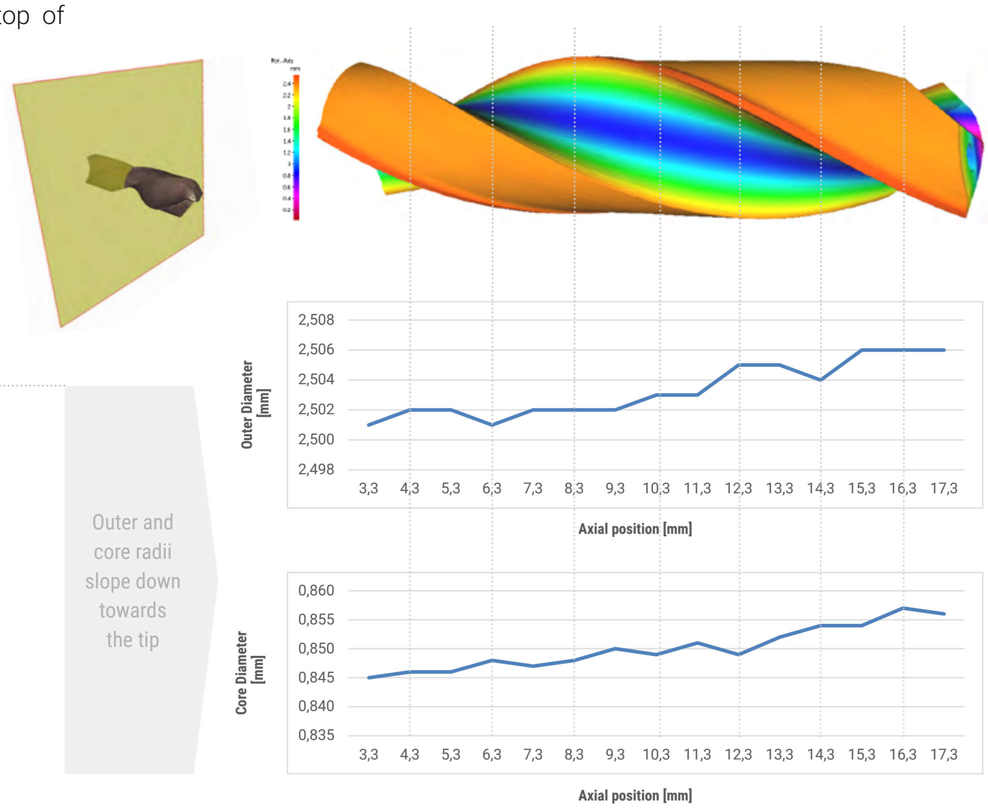




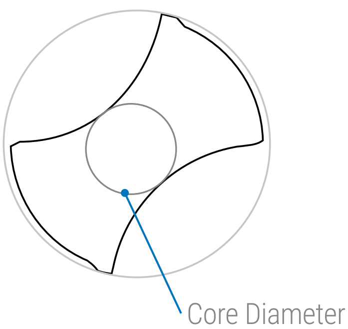
Optical 3D measurement of the outer diameter

The outer diameter is the largest diameter measured across the top of the lands behind the point.

The diameter of the drill reduces slightly towards the shank end of the drill, this is known as "**back taper**". Back taper provides clearance between the drill and workpiece preventing friction and heat.

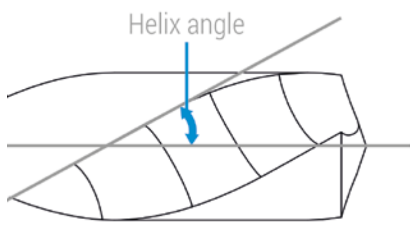


Core Diameter



The core diameter is measured in the center of the drill. The diameter increases slightly towards the chank end of the drill. This leads to a better chip evacuation as chips are evacuated in a channel of the flute shaped by increasing diameter towards the shank end.

Helix angle



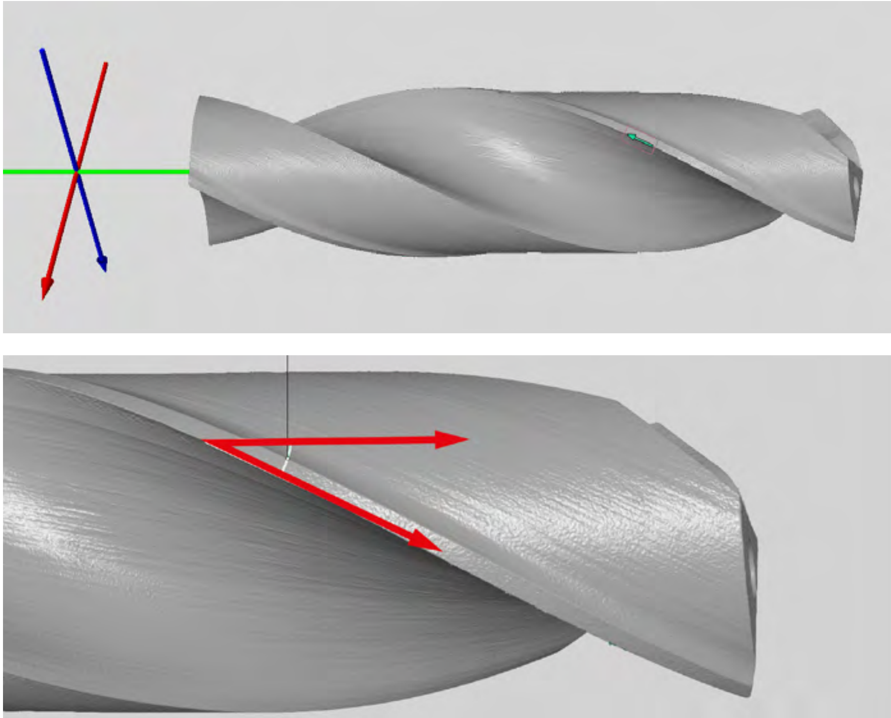
The helix angle is the angle formed between a line drawn parallel to the axis of the drill and the leading edge.

Effects of unsuited helix angle:

» Bad lifting power for chips
» Chips are not being directed outwards

Ideal helix angle leads to:

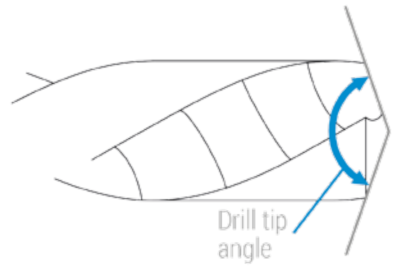
» Optimum chip removal



Optical 3D measurement of a helix angle

TIP: Angle must be adjusted to the desired deepness of the hole.

Drill tip angle



Drill tip angle is the angle formed at the tip of the bit.

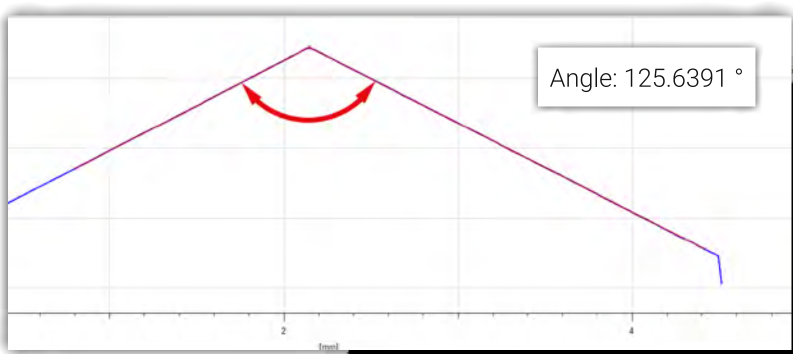
Effects of unsuited drill tip angle:

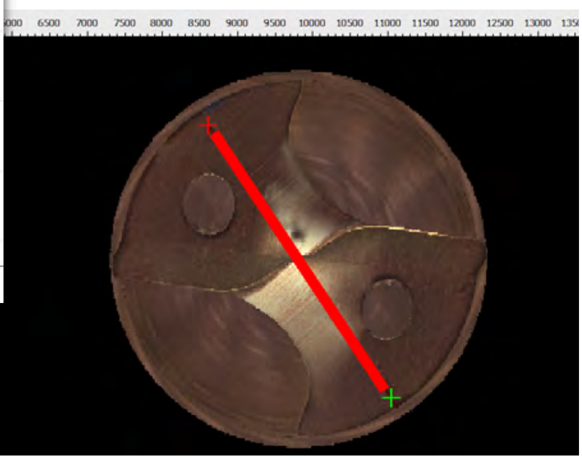
» Wandering
» Chatter
» Non-optimal hole geometry
» Fast wear

Ideal drill tip angle leads to:

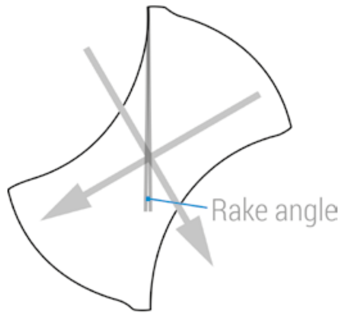
» Precise adherence to target geometry
» Long lifespan

TIP: Harder materials require a larger point angle, while softer materials require a sharper angle.

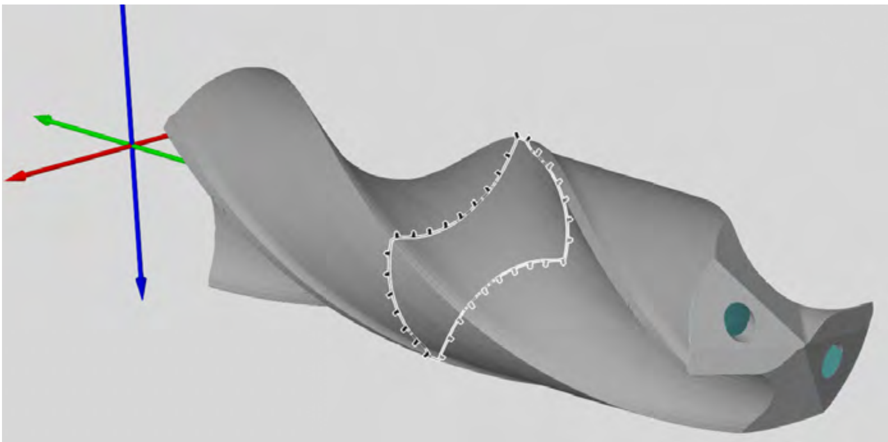




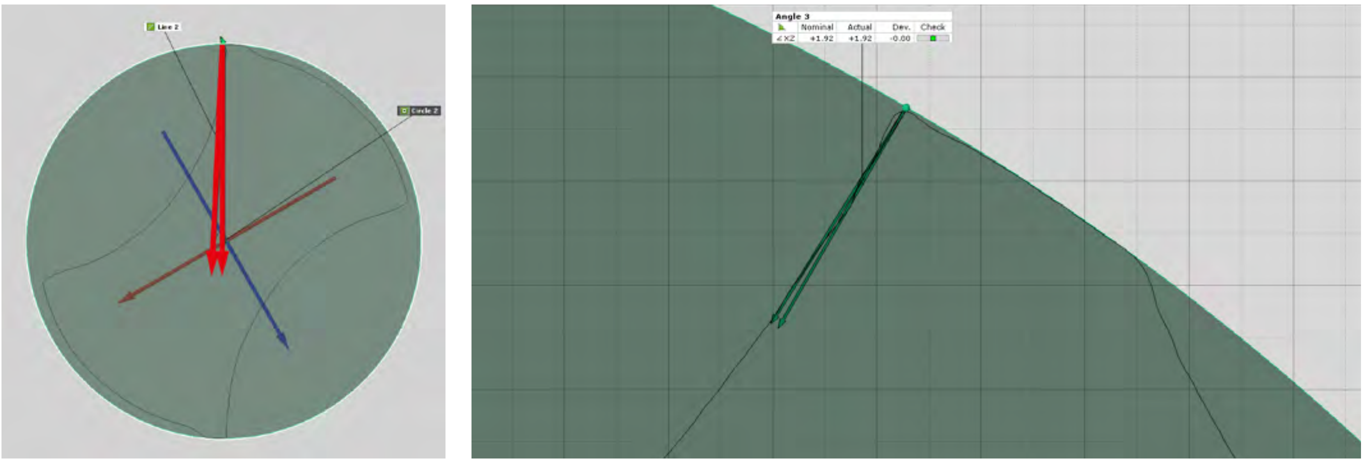
Rake angle



The rake angle is the angle of the cutting face relative to the workpiece.



Cross section of a drill carried out with Alicona Inspect Professional



Optical 3D measurements of a rake angle

Effects of unsuited rake angle:

» Excessive compression stress makes material crack uncontrolled (too steep)

» Emergence of "ploughing" (no chip formation due to a too flat angle)

» Bad guidance of chip flow

Ideal rake angle leads to:

» Optimum sharpness of the tool

» Optimized cutting forces and power requirements which suit the feed rate and the cutting speed

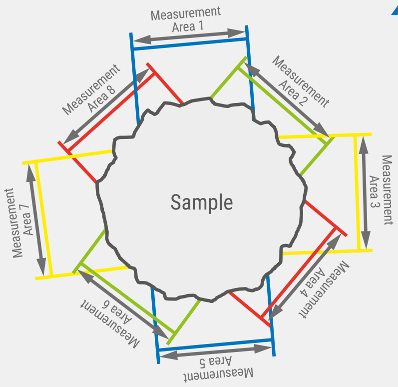
» Better formation of continuous chips in ductile materials (e.g. when cutting steel, synthetic material or gold)

» Avoidance of the formation of a built-up edge

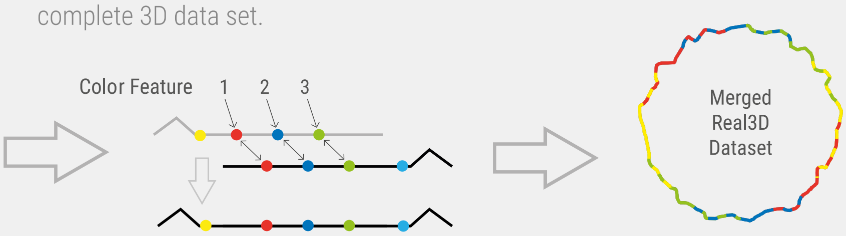
» Improved surface finish

» Optimized edge preparation

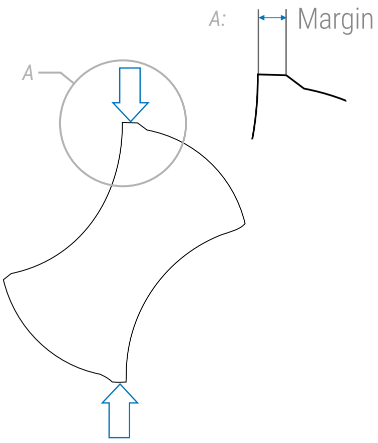
How does Real3D work?

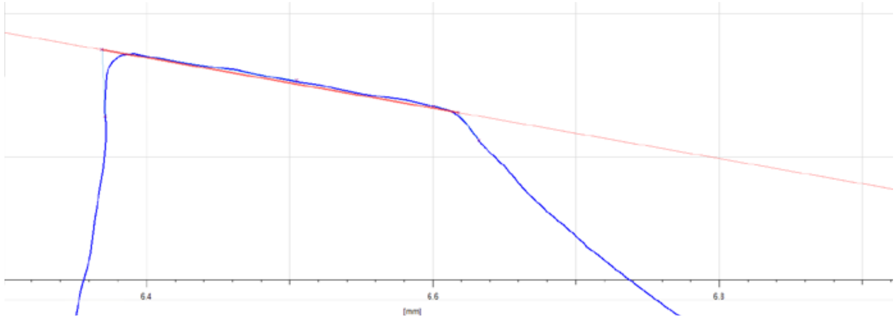


The component is measured at various rotation and tilt angles. Based on the registered true color information of each measurement point, the single measurements are transformed into a joint coordinate measurement system. The single, overlapping measurements are then precisely merged into a complete 3D data set.

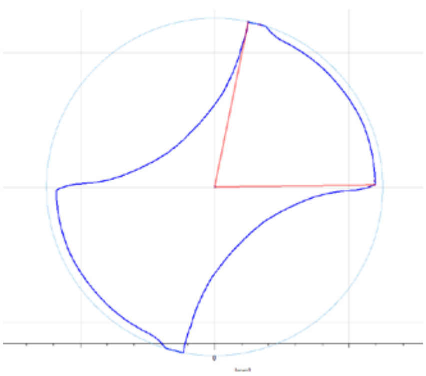


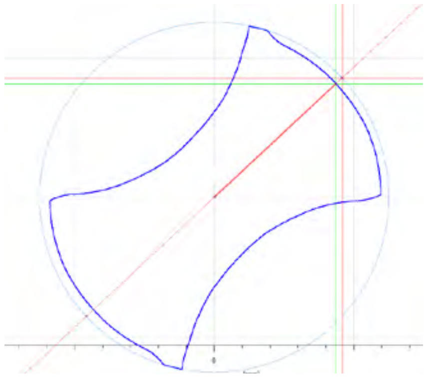
Margin




Measurement of the margin width

The margin is defined as the cylindrical portion of the land that is not cut away to provide clearance.


Measurement of the margin angle


Measurement of the margin depth

Effects of unsuited Margin

» Too less clearance leads to rubbing effects as well as friction

» Not optimum stability of the drill is which leads to the possibility of chatter

» Unsuited margin depth changes the outer diameter of the drill

Ideal Margin leads to

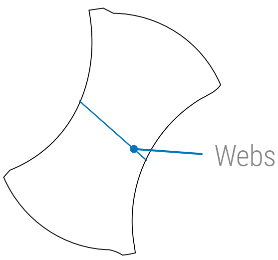
» Prevention of excessive rubbing and friction

» Improved surface finish on the workpiece

» More precise hole sizes

» Reduced possibility of chatter

Webs



Webs is the thickness measured across the base of the flutes.

Drill webs are non-cutting. They do not contribute to the cutting process. They consume power and torque to move through the work piece. Especially relevant when re-sharpening drills.

Effects of unsuited Webs

» Bad torsional strength of the drills

» Tougher material cannot be processed consistently

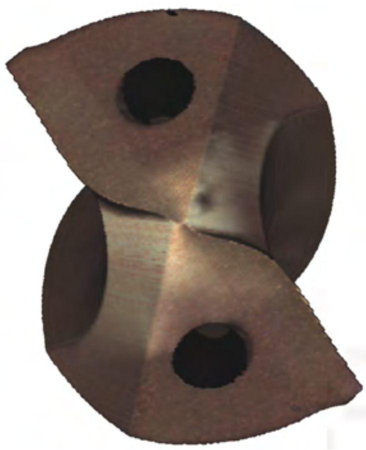
» No sufficient consumption of power and torque when moving through the work piece

Ideal Web Thinning leads to:

» Stock removal in such a way as to follow the flute contour

» Chisel edge length can be reduced to an optimum to reduce thrust

» Improves chip evacuation by improved following of flute contour


3D data set of the drill tip measurement in real color showing the webs

White Paper

Alicona delivers the all-round solution

Roughness and form in one system

For manufacturers to maximize tool performance, it is not sufficient to just know the overall geometry of the tool such as rake, wedge or other angles. Same applies to edge preparation. Instead, the total of all parameters which influence the machining results must be subject to the testing and measurement process. Only then, manufacturers are able to develop and produce cutting tools which meet the quality demands of their customers.

By choosing Alicona, manufacturers receive a measurement system with which they easily master their versatile measurement tasks. Below, an overview of selected measurable parameters is provided.

Edge parameters

r	Radius
Rmean	Mean value of the radii of all single profiles
Sα, Sγ	Distance between the apex (intersection of both chain dotted lines) and the end of the clearance or chipping roundness, respectively.
Δr	Shortest distance from the intersection of the chain dotted lines to the fitted circle.
Rcl	Ellipse-radius clearance face
Rch	Ellipse-radius chipping face

γ	Chipping angle
α	Clearance angle
β	Wedge angle
K	Edge symmetry
Ka	Edge symmetry based on areas
W	Edge width
La1, Lb2, La2, Lb2, Lb3	Length of honing width projected to chipping/clearance surface

Parameters for negative bevel

bγmean	Mean value of the bγ values of all single profiles
γb	Angle of negative bevel
bp1γ, bp2γ, bp3γ	Projected bevel lengths
bγ, bγ1	True bevel lengths

Parameters for positive bevel

bp1α, bp2α, bp3α	Projected bevel lengths
bα	True bevel length
αb	Angle of supporting bevel

Edge break parameters

Bw	Width of edge break
β1, β2	Edge break angles
B1, B2	Lengths between fitted lines and edge break points (ISO 13715)
B1p, B2p	Projected lengths
x1 neg, x2 neg	Normal distances between corridors and exit points
Bd, Bda	(Absolute) mean deviations of edge break
Bf	Form parameter
Fc	Indicates whether the shape of the edge is more like a circle or a line

Chipping measurement

Ra, Rq, Rz, Rp, Rv	ISO 4287 conform roughness parameters

A selection of over 300 measurable parameters

Form deviation parameters

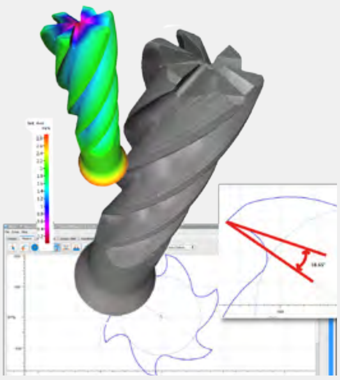
Ecq	Form deviation of circle
Ebq	Form deviation of basket arch
Fc	Indicates whether the shape of the edge is more like a circle or a line

Difference measurement

Dmin, Dmax, Dmean	Min. / max. and mean deviation to reference surface
Vp, Vv, Vdp, Vdv	Volume of peaks / valleys / peak defects / valley defects below / above the reference surface
Aproj	Projected area
Adp	Projected area of peaks above tolerance
AdcPc	Projected area of peaks below tolerance
Pc	Coverage percentage (area within tolerance)
SIMcd, SIMch, SIMt	ISO 8785 conform defect parameters

Areal surface texture measurement

Sa	Average height of selected area
Sq	Root-Mean-Square height
Sz	Maximum valley depth
Smr	Peak material component
Vmp	Peak material volume of the topographic surface
Vvc	Core material volume of the topographic surface
VVv	Valley void volume of the surface (ISO 25178)



» Completely automatic full form and roughness measurement

With an advanced rotation unit user measure surfaces of components from numerous perspectives to achieve a complete dataset in 3D. Motorized and high precision tilt and rotation axes ensure fully automated, repeatable and traceable measurement of form and roughness on the entire object.

Alicona Imaging GmbH
Dr.-Auner-Strasse 21a
8074 - Raaba/Graz
Austria

Phone: +43 316 403010-0
Fax: +43 316 403010-711
sales@alicona.com
www.alicona.com