Methodology Measuring Geometry of the Shank Cutting Tools

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This paper focuses on geometry measuring of the shank cutting tools by the use of optical measuring devices. The scanning is realized in the system Atos Triplescan II and also in the system Zoller Genius 3. This paper provides a proposed methodology of shank cutting tools geometry measuring based on our scanning and measuring for the system Atos. The proposed methodology consists of the calibration, setting and tool clamping, preparation reference point and measuring in software. Part of the work also includes a comparison of measured results between the devices Atos and Zoller. This paper provides a contribution to the study of measurement geometry of the shank cutting tools.

Key words: Tool, Atos, Zoller, Measurement, Measuring volume, Geometry

1 Introduction

Scanning parts for several years is not a new technology, but one of the standard methods for obtaining data. Research of the three-dimensional shape and size measurement is currently in the process of rapid development. In certain sectors of the engineering industry (especially automotive) have been hardly able to imagine the process of designing new components without reverse engineering, thus 3D scanning. Accurate, fast and non-contact optical measurement methods are important in various industrial applications involving the inspection quality, control of surface, or visual systems for assembly lines [1]. GOM develops and distributes optical measuring systems with its main focus on applications like 3D digitizing, 3D coordinate measurements, deformation measurements and quality control [2].

Geometry of cutting tools we control in their production, at unconventional tools in their renovation - sharpening operations and also in experiments. The most frequently we check geometric parameters of the cutting edge, which are face angle and back-off angle, fillet radius, respectively chamfer of the tool tip, fillet of the cutting edge, the angle of inclination of the cutting edge and angle of adjustment. The importance of controlling the geometry of cutting tools consist in ensuring the stability and repeatability of the cutting process and increase durability of the cutting edges and tool life.[3]

2 Scanning selected of the shank cutting tool

Scanning will be done on the scanning system Atos triplescan II and for this device will be proposed methodology for measuring the geometry of shank cutting tools. The second applied scanning system for measuring geometry will be Zoller Genius 3. This device will be used to compare the measured results with the system Atos, because Zoller is a specialized device for measuring geometry of tools.

2.1 Scanning tool in Atos Triplescan II

For measuring on both scanning devices was chosen end mill from Seco JABRO^{MT} TORNADO Ø20 mm. Cutter was given before scanning degreased and sprayed with titanium powder for better visibility in scanning system Atos Fig. 1 a). We are used to measure and compare the quality of three selected volumes. In Tab. 1 are differences between measuring volumes.

Tab.1 Measuring volumes

system configurations	*MV38*	*MV100*	*MV170*
measuring Area [mm]	*38x29x15*	*100x75x70*	*170x130x130*
measuring points distance [μm]	*14,70*	*45,09*	*70,59*
measuring distance [mm]	*490*	*490*	*490*
camera angle [°]	*28*	*28*	*28*

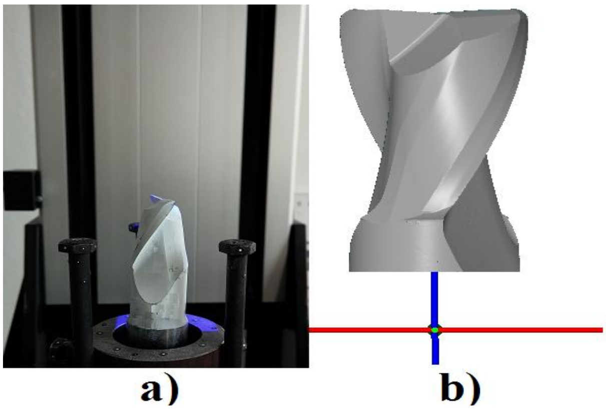

Fig. 1 Scanning in Atos; a) scanning process, b) scan of tool by MV38

Best quality scan of tool was obtained using MV38. Comparison of quality between MV38 and MV100 can be seen in Figure 2 by using the color map of deviation. The largest deviation was approx. 0.04 mm. When we compared the MV38 with MV170 was created the largest deviation approx. 0.08 mm. Second comparison we have carried out in section of measured tool.

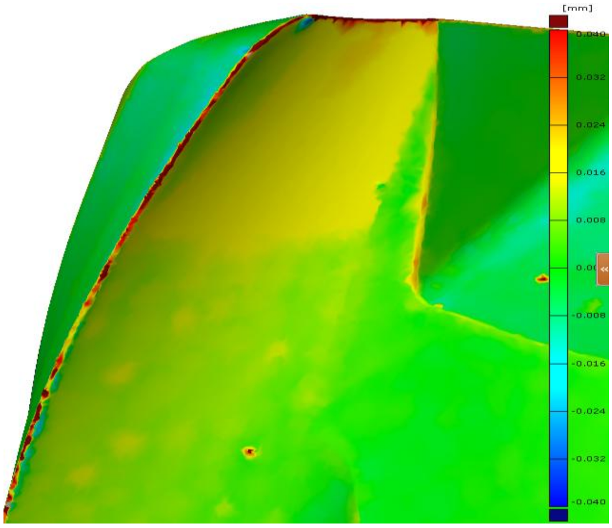

Fig. 2 Color map of deviation MV38 vs MV100

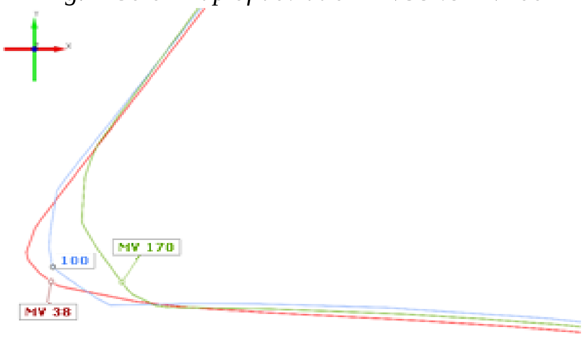

Fig. 3 Comparison in section

2.2 Measuring of tool in Zoller Genius 3

The chosen tool in this case was not necessary to prepare for scanning as in the previous point. Clamping of cutter was realized by means of hydro - clamp with collet. Before scanning, we calibrate the device which runs than most operations in Zoller Genius 3 in fully automatic mode. Various geometric parameters in the measurement, we divided according to their location on the body of cutting tool. Specifically for measuring geometric parameters of the circumference and the end face of the cutting tool.

For measuring geometric parameters on the circumference shank of the cutting tool were selected:

- angle of rake γ,
- back-off angle α_1,
- back-off angle α_2,
- diameter of tool.

For more detailed illustration of obtained values on the circumference of tool, we have chosen measuring the angle of rake see Fig. 4. The principle of measurement methodology of geometry in this device is found (manual principle) measuring point with camera (angle of rake on first tooth) and selecting the measuring field. After this operation, control system Pilot will ensure fully automatic measuring process (the focus of the measuring field, rotate 180° for subsequent measurement of the second tooth). In Tab. 2 we can see measured geometrical parameters on the circumference of tool.

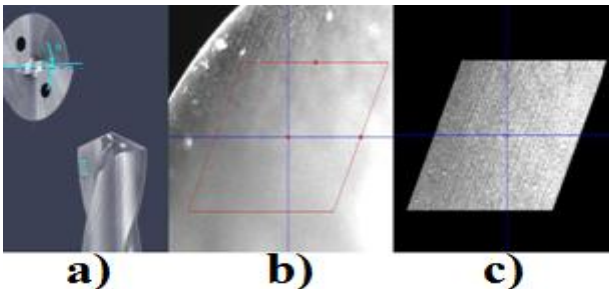

Fig. 4 Measuring of angle of rake on the circumference
a) define of parameter measurements; b) manual selection of the measuring field; c) auto focus

Tab.2 Geometrical parameters on the circumference of tool

Parameters	*tooth 1*	*tooth 2*
angle of rake γ	*18°34′*	*18°39′*
back-off angle $\alpha1$	*15°05′*	*14°57′*
back-off angle $\alpha2$	*20°22′*	*20°16′*
diameter of tool (mm)	*19,96*	

The selected geometric parameters measured on the face of cutter are:

- angle of rake γ,
- cutting-clearance angle α_1,
- cutting-clearance angle α_2,
- width of flank surface for α_1,
- width of flank surface for α_2.

On the face of cutter we show for change the measurement cutting-clearance angle α_1 Fig. 5. The difference between the measurement of the circumference of tool and on the face of cutter is an alignment of cutting edge in the coordinate system of device. Focused cutting edge we select and mark and the software automatically aligns of tool according to the coordinate system.

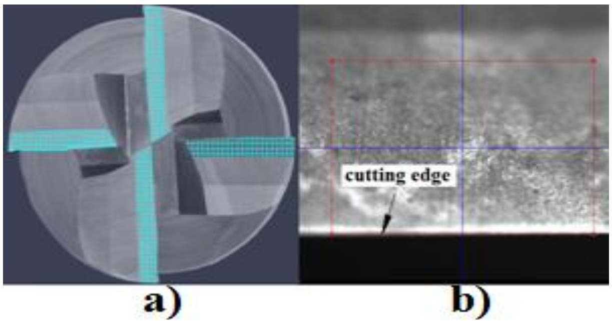

Fig. 5 Measurement cutting-clearance angle α_1
a) measuring area, b) measuring field with aligned cutting edge

Tab.3 Geometrical parameters on the face of cutter

Parameters	*tooth 1*	*tooth 2*
back-off angle α_1	*14°58′*	*14°57′*
back-off angle α_2	*21°07′*	*21°09′*
width of back-off surface for α_1 (mm)	*0,86*	*0,85*
width of back-off surface for α_2 (mm)	*1,59*	*1,63*
angle of rake γ	*8°03′*	*8°*

These geometrical parameters we will measure in Atos Triplescan too.

3 Methodology measuring geometry of the shank cutting tools in Atos

Suitably proposed methodology should assist in particular provide repeatability of the measurement process. Scanned tool with MV38 is compared with a specialized measuring system for tools Zoller Genius 3, based on which we will be able to define more precisely the accuracy of devices respectively differences between them.

3.1 Calibration

We do calibration when changing the measuring volume because it is necessary to change the camera and lens of device. For scanning process it is not necessary, but if we won't make a calibration, we reduced accuracy. For calibration we are used of calibration boards, which are different sizes depending on the MV. In Fig. 6 is a calibration board for MV38. The board is fixed on the rotary head which contains a magnet. Other movements so provides with "the cradle". One example could be that system Atos requires to change the position of the scanner head for calibration e.g. 20 mm in the positive direction of the Z axis. By the movement device changing position of head until the system automatically does not signal the correct location. Once all similar acts are complete calibration is done. Motion Replay is a function for automatic calibration. The principle consists in the classic calibration which for selected MV we store this and re-use calibration is running automatically. In our case, we used both principles of calibrations.

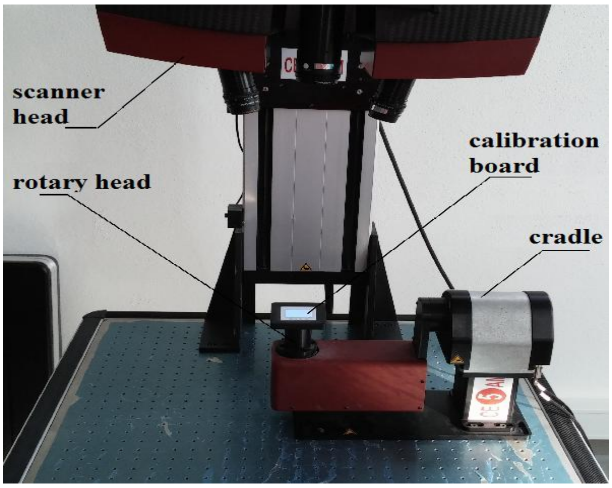

Fig. 6 Calibration process for MV 38

3.2 Preparation of the tool and reference points

For appropriate course of scan process it necessary to suggest the fixture Fig. 7 which should ensure the following properties: clamp and adjust of shank tool, in rotation tilting to keep the initial setup, usable for all selected MV, highly visible in the scanning system, suitable for multiple diameters of tools and include places for sticking reference points. The fixture has been clamped to the rotation head with a magnet (part of Atos equipment). Of all the optical scanning, positioning is the most basic and most important point [4].

The next of the most important things directly affecting the scanning process is correct choice of location uncoded reference points.

Fig. 7 Reference points on fixture

Some specific rules about reference points are:

- They are used for joining individual images and must be placed on the scanned object or surroundings. Location of object to the reference point must not be changed during the whole process of scanning,

- Always should be three common reference points for one snap-shot and should not lie on one straight line,
- Seek of reference points performs software that based on measuring the volume distinguishes the size of individual points. For example 0.4 mm reference point for the MV38 and the volumes of 100, 170 were used reference points of 0.8 mm,
- Reference points increases the accuracy of the scan.

3.3 Setting the scanning parameters

We used to measure the rotation table. The principle consists in separating individual images to a number of steps in rotation of the table. In Fig. 8 you can see 25 steps, which correspond to the number of snap-shot per rotation table e.g. in our case of rotation of the rotary head with the fixture. The number of steps is an individual, the more steps thus is better assumption digitized object. Of course, images must be correctly assembled into one unit.

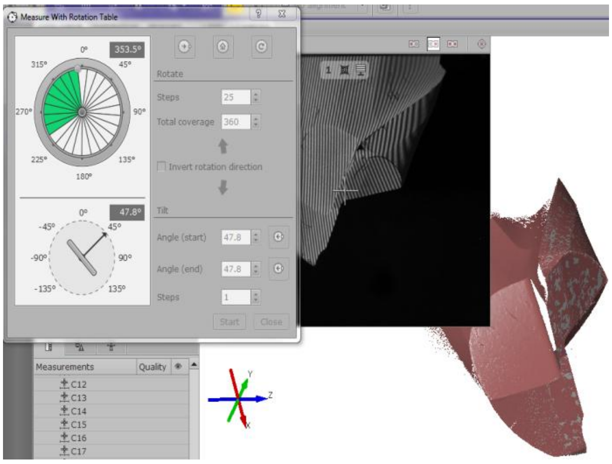

Fig. 8 Scanning process

3.4 Measurement of geometry in ATOS Professional

Alpha and omega in measuring with imported, measured object is necessary to this model alignment with the new coordinate system. The easiest way to alignment is with CAD model. This function is a “prealignment”.

In our case, we did not have CAD model, therefore it was necessary to import STL model as a CAD model. It was our tool but measured by MV 320 because bulkier MV captured a whole tool. For the alignment in this case we used the function 3-2-1 three points that determine the X axis of the two points that determine Y and one point for Z. The final step was necessary to import STL model of tool measured MV 38 and with function “prealignment” alignment him.

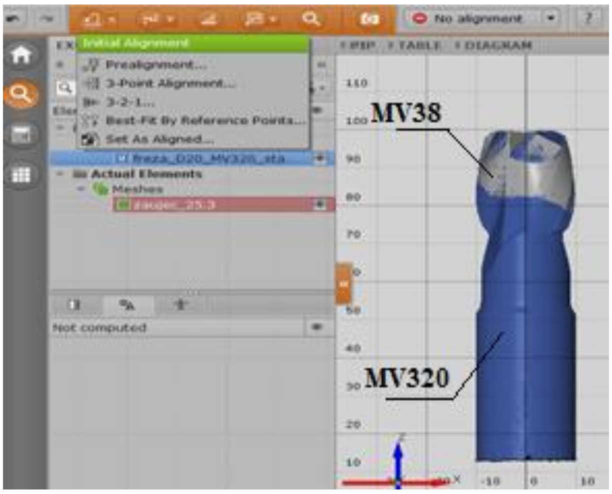

Fig. 9 Alignment of tool

3.4.1 Measuring geometric parameters on the circumference

To measure previously mentioned parameters is necessary to make a number of important steps, the first is cut of tool at an appropriate high and plane. For sectional view of part was used function “single section” in the plane Z = 89.5 mm, see Fig. 10. We must select a given area for cut of the tool.

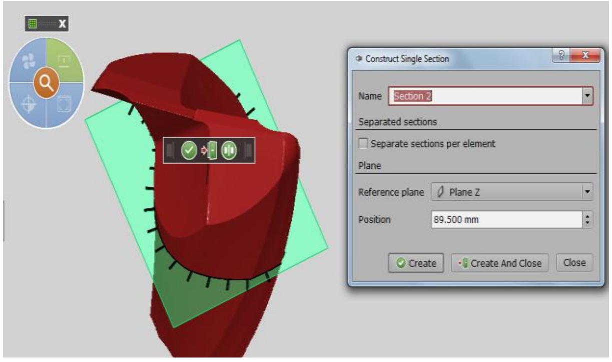

Fig. 10 Section of tool

After of section of tool is necessary to create a line on the edges of tool. In Fig. 11 a) is an example of selecting edges using a function "through select surface". On selected place we created a line "Auto line" and thus formed the line was necessary join with selected place "fitting element". This function (must be used for each line, point, etc.). In Fig. 11 b) are created line and point function "intersection point", which we created as the intersection of two lines, that we are able from this point measure the geometric parameters. This method must be applied also for tooth # 2.

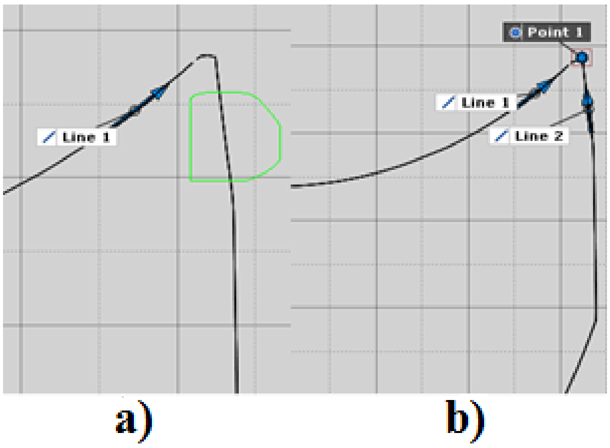

Fig. 11 Creating lines and points

Thus formed points on both teeth are needs to join with line "2-point line". Between this created point and line we have created the perpendicular with use point and corresponding plane in our case the X-axis function "perpendicular line". Measure the required last perpendicular between straight lines 5-6 and point 1 e.g. the second tooth 8-5 and point 2 see Fig. 12.

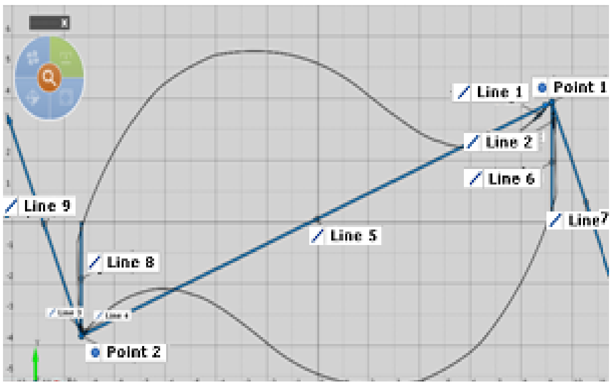

Fig. 12 Creating perpendicular line

At this stage, the tool is in 2D geometry and is ready for measuring geometric parameters of the circumference. The angle was measured always between two straight lines using 2- directions angle Fig. 13. Tool diameter was measured by creating a circle from the center of the tool to touch on the tool tip (function point normal circle).

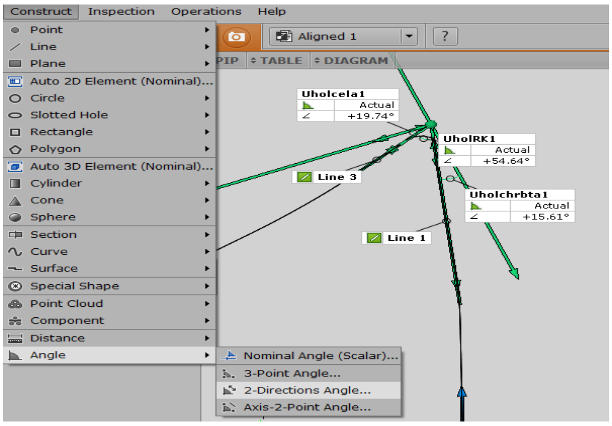

Fig. 13 An example measure of angles

Tab.4 Geometrical parameters on the circumference of tool (Atos)

Parameters	*tooth 1*	*tooth 2*
angle of rake γ	*19°44′*	*19°37′*
back-off angle α_1	*15°37′*	*15°31′*
back-off angle α_2	*21°20′*	*21°18′*
diameter of tool (mm)	*19,97*	

3.4.2 Measuring geometric parameters on the face of cutter

In Fig. 14 we can see the alignment of tool. Edge of tool had to satisfy the condition parallelism with one of the coordinate axes because the section tool had to be made on the face of cutter. Two planes (plane 1, plane 2) were made with “auto nominal plane”.

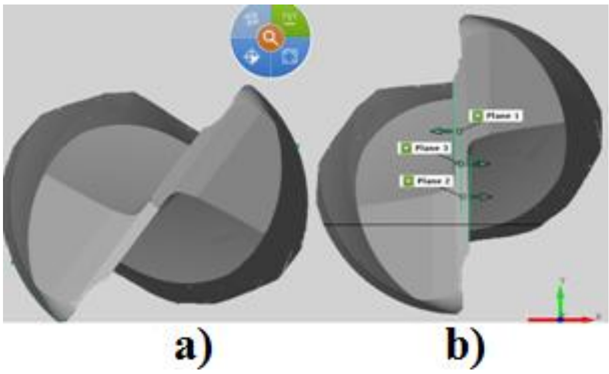

Fig. 14 Aligning the tool on the centre of coordinate system
a) Not alignment tool, b) alignment tool

Between two planes that are "ancillary" we created plane 3 “plane symmetric”, which illustrates their center thus also the tool center. Next procedure is the same as in the first case aligning of tool using functions 3-2-1. For defining the coordinates to us except for planes also serve points 1, 2 and 3 to define the coordinates X.

To perform the cut of tool was again used “single section” in the plane Y at a distance of 4 mm from circumference and -4 mm for tooth # 2. The individual sections can be made only separately.

Measurement geometry of the face of the tool requires the creation auxiliary points and lines as in the previous case. In Fig. 15 can be seen in the measurement procedure of widths of back-off surface. The measurement procedure is as follows:

- using a “2 point distance” we measure the distance between two points, that were created at the ends of (intersections) back-off surfaces,
- select the measuring principle (referenced construction), see Fig. 15 a). With this step between points 7 and 8 software stop using a warning signal. Then we can measure by “check” Fig. 15 b),
- for correct measurement of the width of the back-off surface was necessary (in this case) to choose the first option XYZ distance Fig. 15 b).

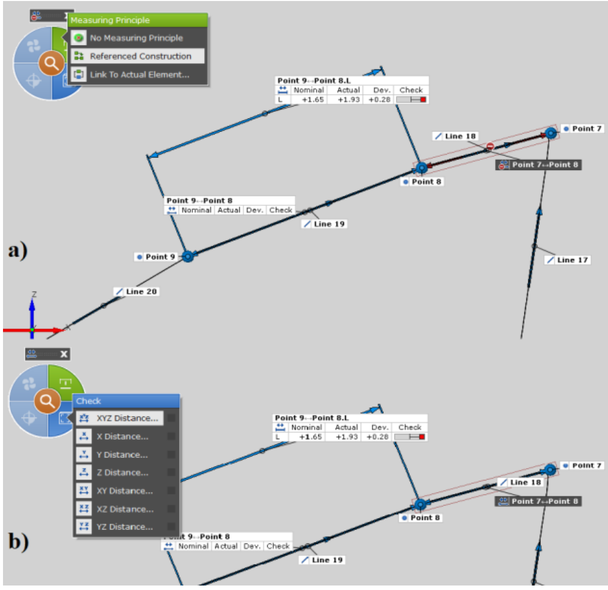

Fig. 15 Widths of back-off surface
a) Measuring principle, b) Measured second width of back-off surface

Once again we need to construct the perpendicular, namely from point 7, see Fig. 16, which was parallel to the axis X. The angle measurement procedure was the same as in measuring the widths of back-off surfaces.

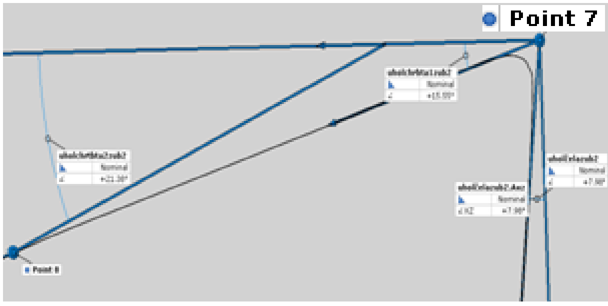

Fig. 16 Measuring geometric parameters on the face of cutter

Tab.5 Geometrical parameters on the face of cutter

Parameters	*tooth 1*	*tooth 2*
back-off angle α_1	*15°24′*	*15°33′*
back-off angle α_2	*21°21′*	*21°23′*
width of back-off surface for α_1 *(mm)*	*0,87*	*0,88*
width of back-off surface for α_2 *(mm)*	*1,66*	*1,65*
angle of rake γ	*8°*	*7°59′*

4 Comparison Atos vs. Zoller

If you look on values on the face of cutter, which are in Tab. 7, can be seen in some cases insignificant deviation especially at an angle of rake. Paradoxically, for measuring the angle of rake on circumference was almost the biggest deviation. For measuring widths of back-off surface, we recorded the largest deviation, which has a value of 0.07 mm.

Tab. 6 Deviation on circumference

	Zoller Genius 3		*Atos Triplescan 2*		*Deviation*	
Parameters on circumference	*tooth#1*	*tooth#2*	*tooth#1*	*tooth#2*	*tooth#1*	*tooth#2*
Back-off angle α_1	*15°05′*	*14°57′*	*15°37′*	*15°31′*	*0°32′*	*0°34′*
Back-off angle α_2	*20°22′*	*20°16′*	*21°20′*	*21°18′*	*1°2′*	*1°2′*
angle of rake γ	*18°34′*	*18°39′*	*19°44′*	*19°37′*	*1°10′*	*0°58′*
Diameter of tool (mm)	*19,96*		*19,97*		*0,01*	

Tab. 7 Deviation on the face of cutter

	Zoller Genius 3		*Atos Triplescan 2*		*Deviation*	
Parameters on the face	*tooth#1*	*tooth#2*	*tooth#1*	*tooth#2*	*tooth#1*	*tooth#2*
Back-off angle α_1	*14°58′*	*14°57′*	*15°24′*	*15°33′*	*0°26′*	*0°36′*
Back-off angle α_2	*21°07′*	*21°09′*	*21°21′*	*21°23′*	*0°14′*	*0°14′*
width of back-off surface (mm)	*0,86*	*0,85*	*0,87*	*0,88*	*0,01*	*0,03*
width of back-off surface (mm)	*1,59*	*1,63*	*1,66*	*1,65*	*0,07*	*0,02*
angle of rake γ	*8°03′*	*8°*	*8°*	*7°59′*	*0°3′*	*0°1′*

In general, we can say that the biggest difference arose when we compared these devices in measuring geometric parameters on the circumference. As a reason we might indicate tilted of tool during the scanning process. It can be assumed that the tool in a horizontal position respectively perpendicular to the scanning head could be better scanned circumference of tool. However, this method of tilted can be counterproductive to the scanning accuracy on the face of cutter. Thus, another way is to scan of tool two times, but the scan time should be doubled. The second theory of the formation of larger inaccuracies related to localization of reference points on the tool circumference. Since we reference points have not placed on the circumference, software joined individual images using the "Best Fit". The reason why we did not apply the reference points on the circumference of the tool is blot, which will remain on images [5], [6].

5 Conclusion

The aim of this work was to propose an appropriate methodology to measure the geometry of the shank cutting tools for scanning devices Atos. We can say that the aim of the work we have managed to fulfill, and that the proposed methodology provides us repeatability of the scanning process (measurements) shank cutting tools with different diameters. The methodology is applicable to all measuring volumes Atos Triplescan II. If the question was asked as follows: "It is possible to achieve similar results in the system Atos?" My answer would be yes, but the speed of the whole measurement process is difficult to achieve. What is also understandable because the Zoller specializes and developing their products for specific applications while Atos Triplescan II is designed to measure for various parts.

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References:

[1] HORÁK, K., KALOVÁ.I.,. 2005. *Optické metódy merania 3D objektov* [online] 2005 [cit.2014-10-18]. <http://www.elektrorevue.cz/clanky/05023/index.html#kap2> ISSN 1213-1539

[2] SCHNEIDER, M.; FRIEBE, H.; GALANULIS, K. *Validation and optimization of numerical simulations by optical measurements of tools and parts*. In:International Deep Drawing Research Group IDDRG 2008 International Conference. 2008. p. 16-18.

[3] JANÁČ, A., LIPA, Z., CHARBULA, J., PETERKA, J., 2002. *Technológia obrábania a metrológia*. Bratisla-va Vydavateľstvo STU, 2002. s. 194. ISBN 80-227-1711-8.

[4] ALAN, C., CHANG HUI, CH., 2011. Automatic 3D measuring for optical scanning of axial fan blades. *Springer*. ISSN 1433-3015

[5] PETERKA, J., MOROVIC, L., POKORNY, P., 2013. Optical 3D scanning of cutting tools. *Trans Tech Publications*. Applied Mechanics and Materials Vol. 421 (2013) p. 663-667

[6] MOROVIC, L., POKORNY, P., 2012. Optical 3D scanning of small parts. *Trans Tech Publications*. Advanced Materials Research Vols. 468-471, pp 2269-2273

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