DIGITIZATION OF
BALL NOSE END MILLS
BY OPTICAL 3D SCANNERS

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ABSTRACT

The paper deals with 3D scanning of two (used and unused) ball nose end mills (970L100-TRIBON Φ10x15x125 R0.5 D10) from the manufacturer SECO Jabro Tools. Digitizing was performed at the Centre of Excellence of 5-Axis Machining at Slovak University of Technology in Trnava by an optical 3D scanner ATOS II SO TripleScan, which currently is the newest product line 3D scanner of company GOM. The measuring volume MV38 (38x29x15 mm) was used for digitizing.

The article gives a procedure for digitizing and comparing the results of the scanned digital models of the two ball nose end mills (with emphasis on identifying the cutting edge wear).

Keywords: *3D digitization, GOM ATOS TripleScan, ball nose end mill, cutting edge, CAD Comparison*

1. INTRODUCTION

3D scanning of cutting tools is not as widespread as such scanning of art artifacts with free form surfaces or various machine parts. One of the reasons may be the lack of 3D digitizing devices - 3D digitizing devices capable for digitizing cutting tools,. their parts (e.g. cutting edge) with required accuracy (in the case of cutting tools hundredths of a millimeter). In this article mentioned the case for the digitization of ball nose end mills an optical 3D scanner GOM ATOS II SO TripleScan with a measuring volume MV 38 (38 mm x 29 mm x15 mm) was used, which is the smallest measuring volume in the company GOM offer. The measuring point distance is 14.70 m [1]. The PhD thesis [2] deals with the scanning of ball nose end mill deals as well as with scanning other parts of small dimensions.

2. THE 3D SCANNER

GOM ATOS II TripleScan (Fig. 1) is an optical 3D scanner (for the classification of data acquisition methods see [3]). As compared to the previous product line of ATOS 3D scanners, TripleScan uses "Blue light technology", which allows precise measurement independently of the environmental lighting conditions. Moreover, the "TripleScan" technology allows for a fast measurement process, reducing the number of single scans even on shiny or complex surfaces. The ATOS TripleScan has two cameras, all angles using the stereo camera system and functioning as three sensors in one. 3D scanner TripleScan offers two types of 3D scanners with different camera resolution (ATOS II: 5 megapixels, ATOS III: 8 megapixels) [4].

Fig. 1. The sensor (head) of optical 3D scanner GOM ATOS II SO TripleScan

3. DIGITIZATION OF BALL NOSE END MILLS

There were digitized two ball nose end mills (970L100-TRIBON Φ10x15x125 R0.5 D10) from the manufacturer SECO Jabro Tools, one of which was unused and the other has already been used (Fig. 2). The ball nose end mills are mainly used for mold cavities milling with free form surfaces in the finishing strategies [5, 6]. An essential part of the digitization in terms of wear investigation was the tool´s cutting edge. Scanning the cutting edge falls within the field of small parts digitization.

Uncoded reference points with a diameter of 0.4 mm was used for digitizing. On the shank of the mills were sticked points for better alignment of the two digital models (models of unused and used mills in the evaluation) because it was necessary to scan the mill together with the part of the holder. Due to the shiny surfaces and the sharp angles at the cutting edges of ball nose end mills, the cutting edges and the surrounding fields on the tool was sprayed with a mixture of titanium powder diluted with alcohol. This mixture is applied to the scanning objects using the airbrush.

The digitization of both mills ran equally. The mill was established on the desk under 3D scanner sensor and after each individual measurement (scan), the mill was rotated about 20° around the mill rotation axis, so the reference points on the previous scanning position was visible (requirement for stitching the two consecutive measurements (scans)).

After capturing the entire perimeter of the mills the 3D scanner is shifted by half of the measuring volume toward the mill holder. This shift was approximately 10 mm to 15 mm. Again, it was necessary to stay at least three previous points visible for the cameras. When moving the scanning area to the level of shank, it was no longer needed after each individual scan rotate mill at 20°, but enough about 45° (the rotation always depended on the number of visible points). The projection of blue light on the scanned object is given in Figure 3 is and the software GOM ATOS Professional v7 SR2 environment during the measurement (scanning) is presented in on Figure 4. Figure 5 gives a detail of the digitized cutting edge (the polygonized digital model).

Fig. 2. The scanned ball nose end mills
(lef – unused, right- used)

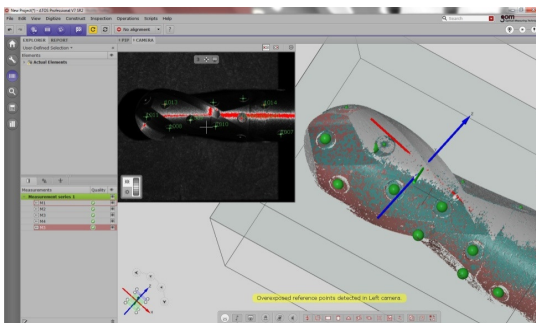Fig. 3: The projection of blue light

Fig. 4. The software GOM ATOS Professional v7 SR2 environment during the digitization
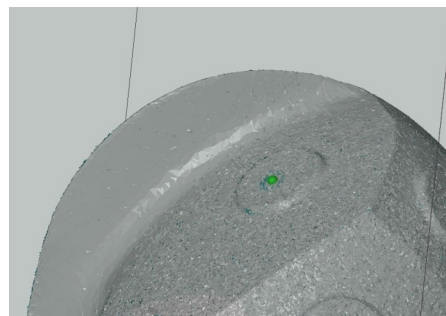

Fig. 5. The detail of the digitized cutting edge (the polygonized digital model)

At each area where reference point was stuck, a hole occurs after the polygonization. These holes must be closed. Two different „types" of polygonization „process" was used. In the first case, the software GOM ATOS Professional function called „Fill reference points" was used and in the second case, this feature was turned off (Fig. 6). „Fill reference points" means that GOM ATOS Professional software automatically fills

the holes which leaves the reference points. When using the software feature for an automatic hole filling, the filled areas are not giving the best result in some cases (Fig. 7). The polygonization was done also without the automatic filling of the holes and they were the holes subsequently filled „manually".
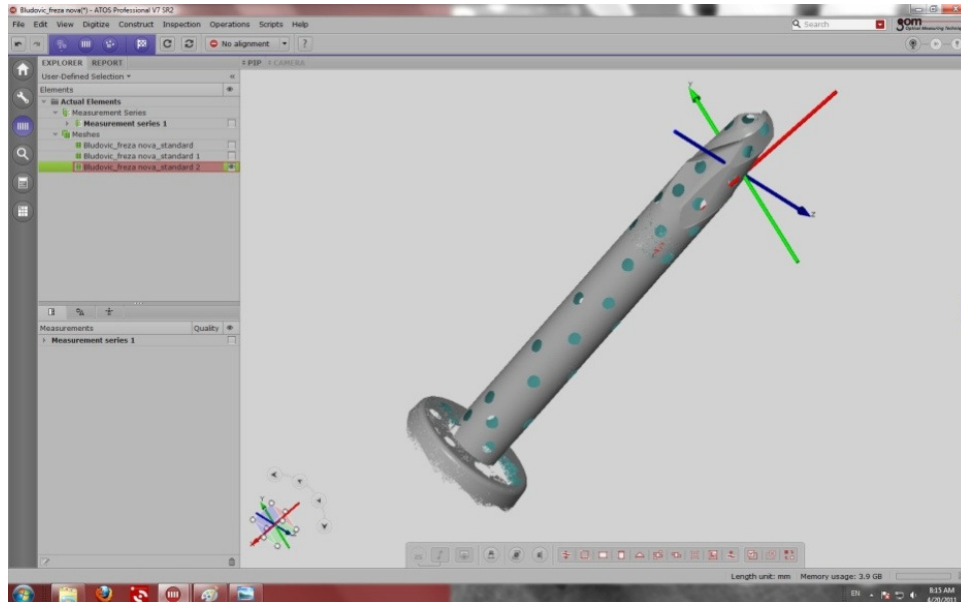
Fig. 6. The result of the polygonization
(the software feature „Fill reference points" was turned off)
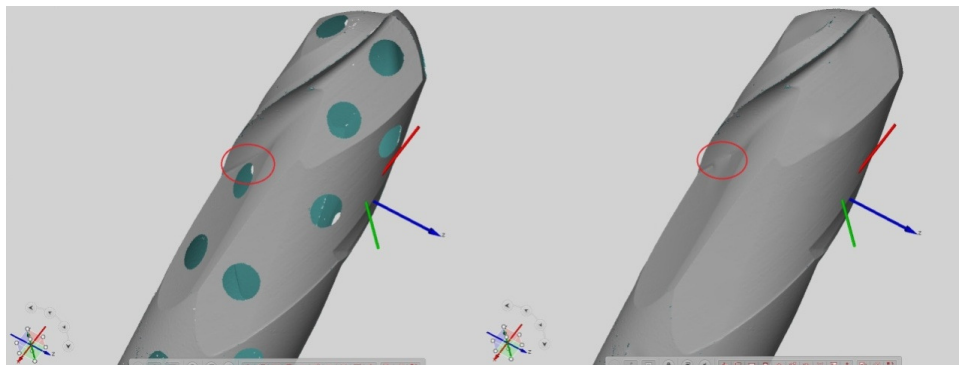
Fig. 7. The result of a „manually" mode of closing the holes (the deformed polygonal mesh near the hole)

For the „manual" close filling, the software user can alter the appearance of filling the holes by changing the parameters. For later comparison to the manually filled holes seemed to be a worse option than the automatic fill.

After the polygonization, the export of scanned mills ensued, i.e. the digital models in STL format. For evaluating, the software GOM ATOS Professional was used. The reference model was the scanned model of unused ball nose end mill. In this case we wanted to know how the used tool differs from the unused tool.

4. CAD COMPARISON

The first step in catching the deviation color map is the relative alignment or "joining" by the two digital models apart. On Figure 8 (left), the alignment is executed through the software function "Prealignment". It is a basic alignment, the so-called "first models alignment", which should be done always.
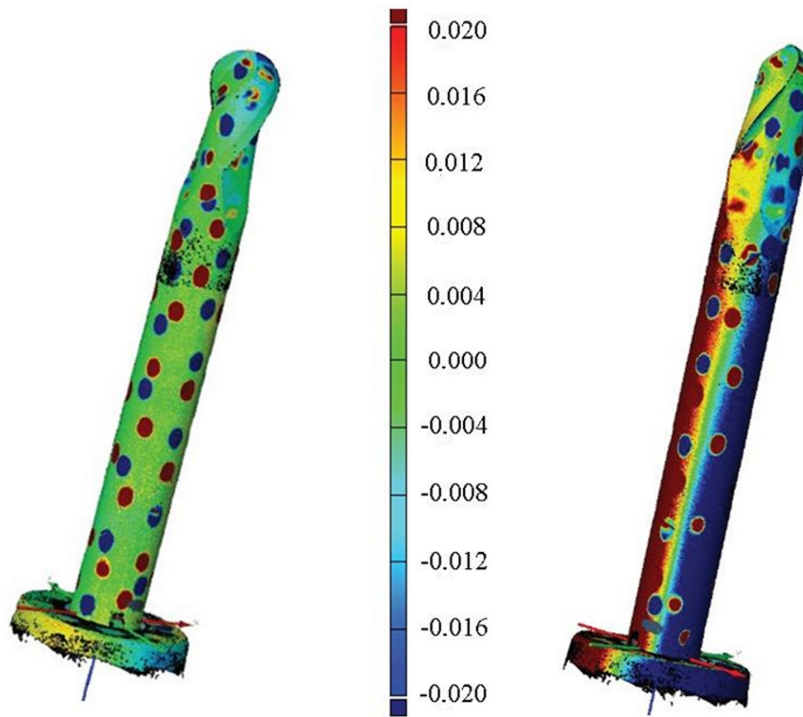

Fig. 8. The color deviation maps (left – "Prealignment", right – "Local best fit")

The software establishes the digital models through their whole surface similarity. The software finds the most common areas and calculate the "average" positions. After this establishment, it can also compile other comparisons. One option is the set-up of the digital models coordinate systems in the same position and the execution of the alignment. This option is mainly used for parts with "cube" and similar shape. In the case of rotating parts (like the ball nose end mill), the coordinate system positioning (rotation) in the same direction is difficult. This possibility was also tested. Coordinate systems were placed in the same point, the axis Z passed through the rotation axis of the tool. The problem was the setting of axis X and Y. Their direction was unable to reconcile on the two digital models.

Figure 8 (right) presents another possibility of models' alignment. In this case, the alignment of two models was realized in respect of the part of the model. This feature is called "Local best fit". For the purpose of the comparison, it was easily accessible.

The alignment with the feature „Local best fit" needed to select only part of the model, according to which the two models will be aligned and compared. It is mainly used when comparing the cutting edges or large parts, which needs to check only one area. For both ball nose end mills was especially interesting to compare the cutting edges. Therefore, the selected areas were the cutting edges. As it is evident from Figure 8, the color maps are different. The largest variations are in the shank area. This phenomenon could occur for two reasons. The first is that the object has been scanned „per parts" from the cutting part

to the end of shank, which could lead to an imperfect digitization accuracy. A second possibility is that the ball nose end mill has already been used and the shank is slightly angled.

But we were mainly wondering how the cutting edges differ. On Figure 9 and Figure 10, there are shown only the tool's cutting edges at both established positions.

On all the images (nearly circle), the dark spots (except of cutting edge) are caused by sticked and later digitally filled reference points. The scale of deviation was set at ± 0.02 mm.
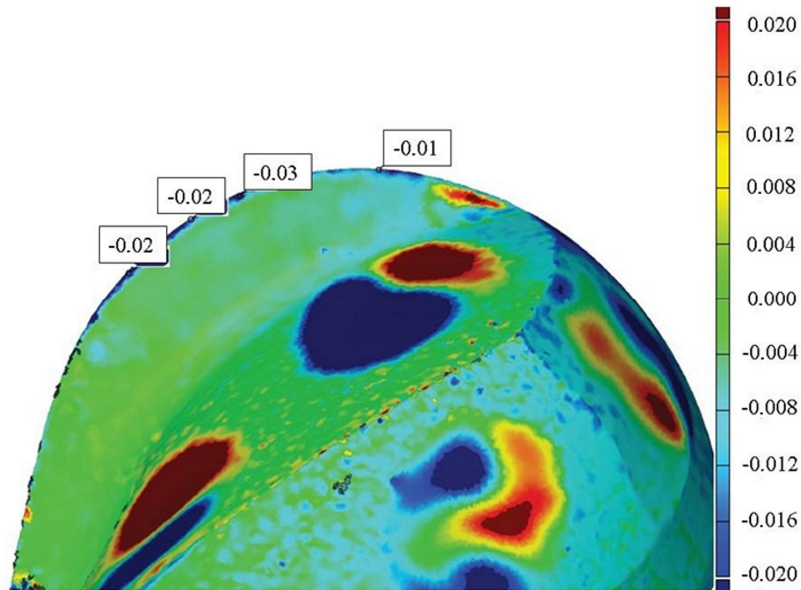

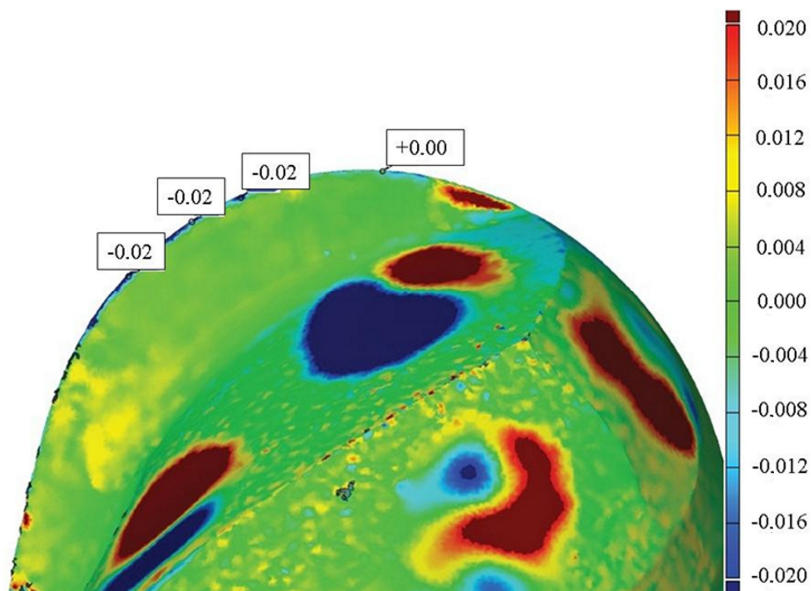Fig. 9. The Color deviation map (Prealignment)

Fig. 10. The color deviation map (Local best fit)

In both Figures 9 and 10, it can be seen that on the cutting edge deviation values are in minus figures. This means that on the cutting edge of the ball nose end mill is some material loss. The values vary in the different points, establishes („Prealignment" vs. „Local best fit") of 0.01 mm at the tip of mill and on the cutting edge field do not differ at all. The cutting edge on both digital models, however, was in consequence of scanning partly rounded, it could cause an uncertainty in the evaluation.

5. CONCLUSION

The digitization of the ball nose end mills required 3D scanning aimed at small volumes. The goal was to scan both tools and compare the shape of the digital models. For a for better camera recording, the cutting edges were adjusted by spraying. The shape comparison of both digital models took place with an evaluation of the deviation color maps. It was found that on the used ball nose mill is a slight loss of material on the cutting edge. The smallest measuring volume of the GOM ATOS system (MV 38) offers a wide range of applications for 3D scanning of the cutting edges. Despite the positive results, there are still gaps in the quality processing of the sharp edges. The cutting edge radius rises, which can not be removed by improving conditions for 3D scanning. It will be interesting to see in the future, in what direction the optical 3D scanning technology will proceed in this area, because the inspection of small cutting tools is becoming a wider problem. In the practical part, it was found that even in the absence of CAD model, there can be two independent scans of unused and used tools to carry out relatively accurate comparisons and measurements. It would be interesting to carry out the same measurements by GOM ATOS III TripleScan with camera resolution of 8 megapixels.

ACKNOWLEDGEMENT

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