# 3D visualisation of worn surfaces – first approach

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***Abstract:*** *The paper presents the first approach results in 3D scanner application in evaluation of surface layers wear. Abrasive wear test in abrasive box was realised. Powder hard-deposit materials of various chemical composition based on NiCrBSi were tested in this test, with relative abrasive wear resistance determination. Wear was evaluated using 3D scanner as well. Wear area visualisation of particular samples obtained in 3D scanning is indirectly proportional relative to examined materials wear. A quantification was not performed in this first approach.*

***Key words:*** *3D scanner, wear test, wear resistance, NiCrBSi alloys.*

## INTRODUCTION

Tribological knots are zones of relative motion of two or more functional parts in touch, with simultaneous effect of additional factors [1-4]. This results in wear of these parts. The wear results in undesirable surface change or dimension change of functional parts, it is necessary to pay continual attention to this area [5, 6]. Because the problem is very complicated and complex, when solving it, it is necessary to analyze all significant effects, to determine basic causes and based on its analysis propose problem solution.

Testing is an inseparable part of systematic problem solving, meaning a set of measurements allowing better understanding of the researched problem. Measuring is the significant part of the testing, defined as quantitative evaluation of object properties using measuring devices [1, 7].

Various measuring techniques and wear extension expression parameters used for wear rate measurement. Absolute wear parameters can be determined using direct measurement. This parameters are related to change of specimen geometry (linear dimensions change, cross-section change, volume change), to specimen weight change or to amount of worn material loss. Wear rate can be expressed indirectly using relative parameters.

Wear rate (wear as a function of time to wear as a function of trajectory) or wear coefficient and similar belong to relative parameters [1, 4, 5, 8].

It is important to consider changes character of specimen in wear conditions when selecting measuring equipment, along with wear size, chosen method accuracy as well as results application in practice. When interpreting results, it is necessary to reflect the wear parameters obtained are not material constants, but these are dependent on operational variables and structure of tribological system considered [8].

Variety of methods and devices exist for each wear type, using those wear process and results can be researched in detail. The wear test classification is presented in [8, 9].

Non-contact methods are used for detection and evaluation of dimensions and its change more often in presence. 3D scanning is one of these methods [10]. An application the method for wear observation and measurement of functional parts is rare so far, so the method described presents a contribution to development in this area.

## EXPERIMENTAL PROCEDURE

Wear development observation was realised using test specimens for abrasive wear resistance test in device with grinding box. The device principle is presented in Figure 1.

Hard-facing materials based on NiCrBSi supplied by VUZ PI SR were applied onto base material of testing specimens from steel grade C45. Basic parameters of hard-facing materials are presented in Table 1. Torch NPK 1 was used for application of powder hard-facing materials using oxygen-acetylene flame. The flame was neutral. The deposit layer thickness was 2 to 3 millimetres. The final specimen shape was obtained in grinding. Test specimen shape and dimensions after hard-facing material deposition is presented in Fig. 2 (hard-facing material deposit application zone is indicated by dash line). Testing parameters are presented in Table 2. Three specimens were tested for each hard-facing material.

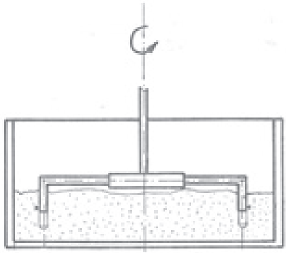


*Fig.1. Design of testing device for abrasive wear resistance test in grinding box*

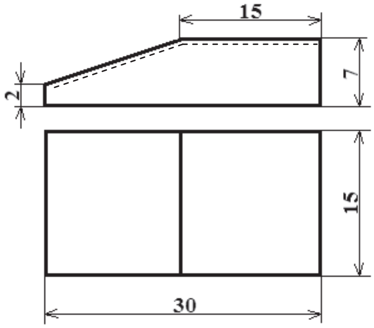



*Fig.2. Shape and dimensions of the specimen for abrasive wear resistance test in grinding box*

*Table 1.*

*Parameters of powder hard-facing materials based on NiCrBSi supplied by VÚZ-PI [11]*

| Material designation | Basic chemical composition (wt.%) | | | | | | | | | Hardness HRC | Granularity (μm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | Si | B | Fe | Cr | W | Cu | Mo | Ni | | |
| VUZ NP 52 | max. 0.5 | max. 5.0 | max. 3.5 | max. 5.0 | 8.0 14.0 | - | - | - | balance | 48 – 54 | max. 100 + 5 |
| VUZ NP 58 | max. 0.6 | max. 4.5 | max. 4.0 | max. 10.0 | max. 15.0 | max. 2.5 | max. 2.5 | max. 2.5 | balance | 54 – 59 | max. 100 + 5 |
| VUZ NP 60 | max. 0.6 | max. 5.0 | max. 3.9 | max. 5.0 | max. 16.0 | - | - | - | balance | 56 – 62 | max. 100 + 5 |
| VUZ NP 62 | max. 0.9 | max. 5.5 | max. 4.0 | max. 5.0 | max. 20.0 | - | - | - | balance | 58 – 65 | max. 100 + 5 |
| VUZ NP 60 WC 20 | max. 0.6 | max. 5.0 | max. 3.9 | max. 5.0 | max. 20.0 | 20 % $W_2C$ | - | - | balance | 75 – 82 ($W_2C$) | max. 125 + 45 |
| VUZ NP 60 WC 45 | max. 0.6 | max. 5.0 | max. 3.9 | max. 5.0 | max. 20.0 | 45 % $W_2C$ | - | - | balance | 75 – 85 ($W_2C$) | max. 125 + 45 |

*Table 2.*
*Test parameters for determination of relative abrasive wear resistance of materials in grinding box*

| Parameter | Value |
|---|---|
| Radius of specimen rotation | 140 mm |
| Spindle RPM | 85 $min^{-1}$ |
| Speed of testing specimen motion | 1.25 $m.s^{-1}$ |
| Test duration | 4 h |
| Total grinding trajectory length | 18000 m |
| Specific load to specimen | 0.1 MPa |
| Sand type | silicone |
| Sand granularity | 0.6 – 1.2 mm |

Specimen weights were measured using scale Precisa 205 A with accuracy $10^{-4}$ g. Weight loss determined as a difference of the specimen weight before and after test $\Delta m$ was used as a parameter for specimen wear evaluation.

Relative wear resistance values were calculated using formula:

$$\Psi_{abrbn} = \frac{\Delta m_E}{\Delta m} \quad (1)$$

where $\Psi_{abrbn}$ – relative wear resistance in grinding box, -,

$\Delta m_E$ – average weight loss of reference testing specimens, g,

$\Delta m$ – average weight loss of testing specimens of material tested, g.

Specimen of shape and dimensions according to Fig. 2 made from steel grade C45 were used as a reference specimen.

Non-contact digital methods based on 3-dimensional scanning of observed specimens using structured light were used for wear evaluation. 3D scanner DAVID Laserscanner SLS-1 (DAVID Vision Systems GmbH., Germany) was used for scanning, composed by data projector and digital camera for picture taking DAVID-CAM-3M. Scanner operating and picture processing was controlled by software DAVID-Laserscanner Pro Edition. Measuring equipment configuration is presented in Fig. 3.

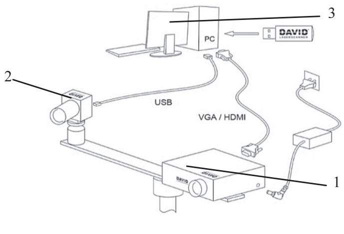



*Fig. 3 Measuring system with 3D scanner [12]*
*1 – data projector, 2 – CCD camera, 3 – computer with software*

Calibration wall was replaced by specimen after calibration, fixed in a vise. The scanning process was controlled by software. Sets of horizontal and vertical stripes of light structure with varying width were projected onto scanned object. The camera scanned its distortion on the specimen surface. The specimen was rotated around its axis in exactly set revolve angles during sequencing. Because of relative simple shape of specimen for grinding box test, only three pictures were necessary to create picture of the whole specimen body. The particular results were joined into one 3-dimensional virtual object after scanning all three views.

It was possible to determine the shape change of specimens from the resulting 3D virtual object, because the scanning of all specimens, including the reference specimen, was realised before and after the wear tests. These shape changes expressed as colour maps when the virtual 3D shapes before and after test were superposed. Zones of the highest wear rate can be identified based on the colour changes.

## RESULTS

Fig.4 presents graphical expression of the relative abrasive wear resistance for tested materials.

Shape after wear was measured in case of specimens for the test in the grinding box. Only one of three specimens was scanned. Resulting three-dimensional shapes, created by joining of specimens scanned before and after tests in the grinding box, are presented in Fig.5.

It results from Fig.5 the wear generated in tests achieved rather small values. The wear appeared mainly on the boundary line between sloped and horizontal surface and on the horizontal specimen surface. The sloped surface zone wear was minimal. An aim proposed – cutting edge wear evaluation – was not achieved in full range.

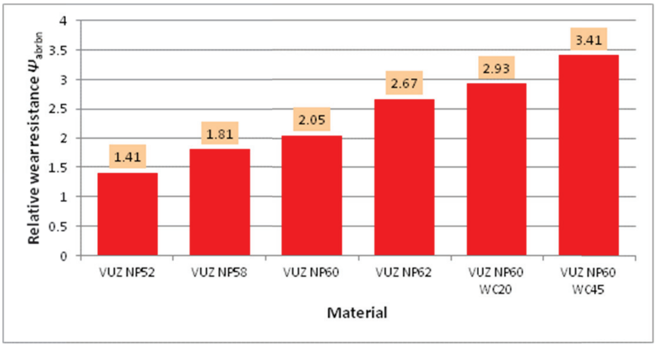
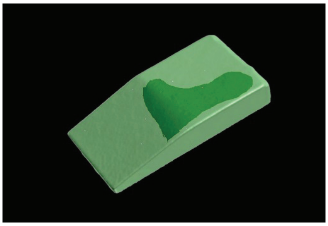



*Fig.4. Relative wear resistance in grinding box of hard-facing materials observed*

The wear is located on the right part of the specimens, caused likely by design of the testing device and load method of the specimens in the test.

Relative to the wear areas size (green as green fields in Fig.5) results its indirect proportion to value of relative wear resistance in grinding box (Fig.4).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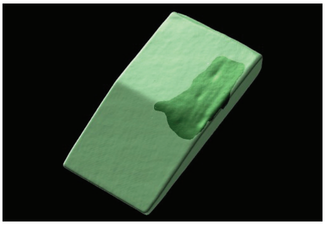
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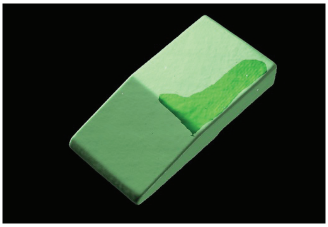
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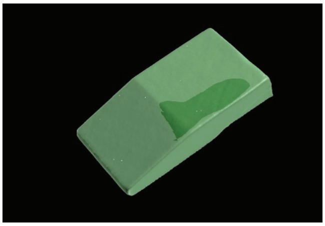
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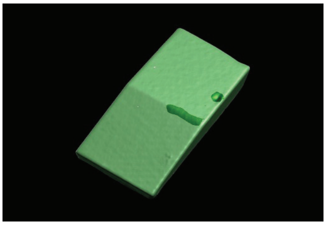
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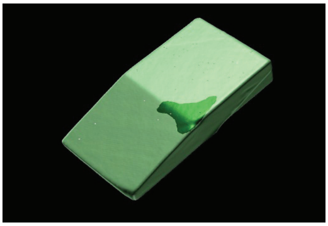
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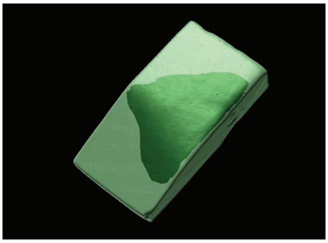
g)

*Fig.5. Three dimensional virtual figures of specimens of material:*
*a) VUZ NP52, b) VUZ NP 58,*
*c) VUZ NP 60, d) VUZ NP 62,*
*e) VUZ NP 60WC20, f) VUZ NP 60WC45,*
*g) reference*

**CONCLUSIONS AND FUTURE WORK**

Based on results achieved, these conclusions follow:

- Using 3D scanner system and method proposed, it is possible to find occurrence and distribution of the wear on the surfaces of the functional parts, and even rather small wear can be detected,
- An accuracy and resolution are a function of the scanning iterations (and laser scanning method too, for example),
- Indirect proportion was found between worn areas size and relative wear resistance of the particular researched hard-facing materials,
- Wear resistance of the observed hard-facing materials based on NiCrBSi depends on their chemical composition, particularly on C and Cr content, eventually on the WC particles content,
- The method proposed will be completed by wear quantification.

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**This paper has been reviewed.**