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COMBINATION OF WHITE LIGHT INTERFEROMETRY AND FRINGE PROJECTION FOR MEASUREMENTS OF CUTTING TOOL INSERTS

KOMBINACIJA INTERFEROMETRIJE BIJELOM SVJETLOŠĆU I PROJEKCIJE RUBA ZA MJERENJE IZMJENLJIVIH REZNIH PLOČICA

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ABSTRACT

A conventional measuring instruments for purpose of cutting inserts control, based on contact or optical principles, evaluate tool characteristics one or maximally two dimensionally and are affected by large operator influences and long control time. Shape and wear characteristics of the cutting tool insert could be completely determined only by three dimensional values that the newly developed system by Chair Quality Management and Manufacturing Metrology gives in one measuring cycle.
The system should integrate measuring process and CAD coupling ensuring by the measurement results repeated positioning accuracy and precision clamping on the tool holder as well as wear monitoring that ensure production application of only functionally capable inserts. For creating the cloud of measuring points system combined white light interferometry and fringe projection with two separate instruments whose accuracy should be based on the standard tolerances values for the cutting tool inserts.
The work presents first measuring results of a standard shape values for new and used cutting tool inserts.

1. INTRODUCTION

Despite increase in developments of more complex tool forms and the definition of their three-dimensional wear currently only two dimensions tactile or optically measuring systems are used for obtaining the cutting tool inserts characteristics. Tool shape as well as its production or application deviations could be acquired only punctually along a measuring line. Tools wear can be estimate only qualitatively in its entire dimension. Selection of measuring points for determination of shape or wear characteristics as well as tool alignment relative to the measuring instrument are usually done by user, leading to the subjectively influenced results and time consuming processes [5]. To ensure that only functionally capable tool inserts are used in the production line, their function related shape and wear characteristics should be checked by the tool manufacturer as well as by the user with flexible and functional system.

2. SHAPE AND WEAR CHARACTERISTICS OF CUTTING TOOL INSERTS

Shape of the cutting tool inserts is described by standard values defined by DIN 4967, DIN 4968, DIN 4969, DIN 4987 and DIN 4988 standards [7, 8]. They are used as the defaults in construction and for the control of production required tolerances of the limiting dimensions and shape characteristics. Important characteristics of the cutting insert shape are control size m, tip angle ε_r, nose radius r_ε and, as well, rounded cutting edge radius r_β for the inserts with the rounded cutting edges, Fig. 1.

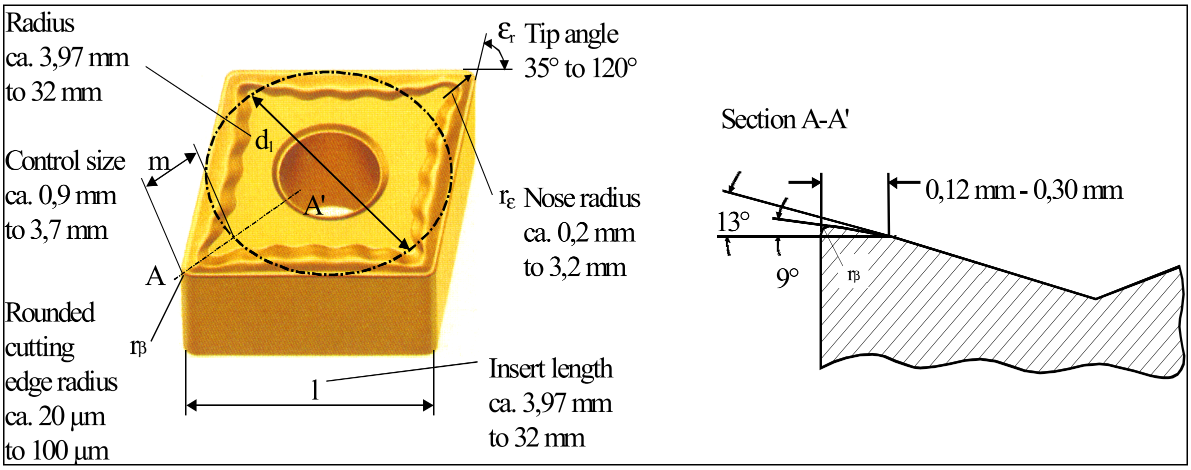

FIGURE 1. SHAPE VALUES FOR A RHOMB FORMED CUTTING INSERT ACCORDING TO DIN 4967

On the cutting edges of the used cutting inserts are remarkable different influences named as wear forms caused by mechanical, thermal and chemical debits of the cutting process and their characteristics are directly affected by process parameters like cutting speed, cutting deep, forward feed as well as with tool service time [3]. Wear characteristics of the used cutting tool are given by Fig. 2.

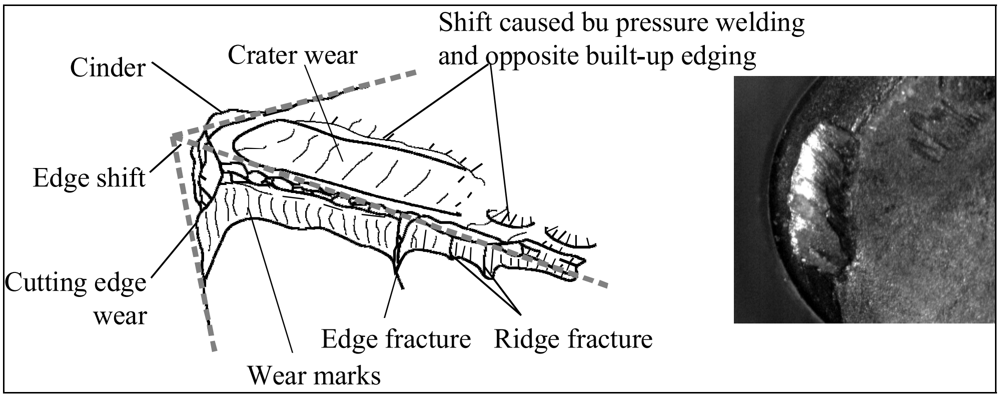

FIGURE 2. WEAR OF A CUTTING TOOL INSERT

With the aim of wear measurements the most important characteristics of cutting tool inserts, land wear in the tool flank and the crater wear in inserts land face must be quantitatively defined. Measurements of the wear are direct measurements on the tool conventionally performed by tool marker’s microscope, light section microscope, profile projection or surface profile measuring instruments. Direct measurement of a tool wear is often difficult in production and sculptured surfaces provided on the tool as well as chip flow makes it even tougher. Simple wear characteristics, which could be measured conveniently, often do not give a total picture of the changes that have taken place on the cutting edge leading to the inefficient cutting and bad surface finish.

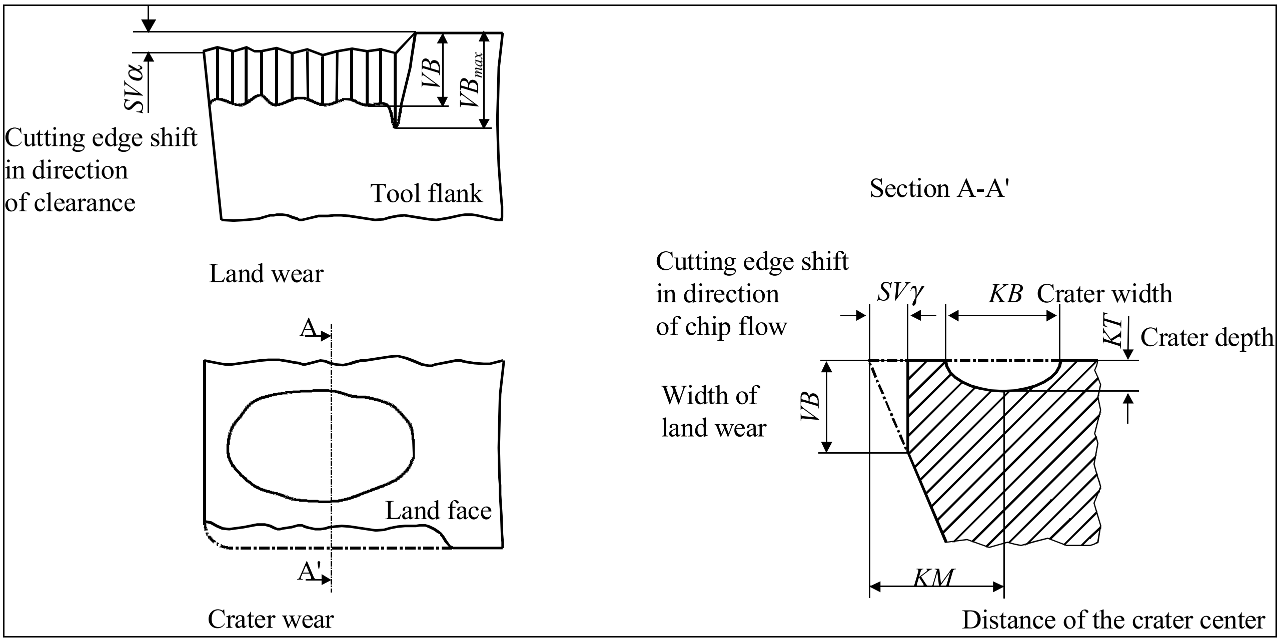

FIGURE 3. LAND AND CRATER WEAR CHARACTERISTICS OF A CUTTING TOOL INSERT

3. OPTICAL 3D-FORM MEASUREMENT OF CUTTING TOOL INSERTS

3.1. Basis

An ideal measurement system for form inspection of tool inserts should appeased following requirements:

- it must have high resolution and low measurement uncertainty conforming a condition of the measurement gold rule for cutting toll inserts tolerance values
- it must have flexibility for various measurement tasks and ability to accommodate various types of inserts
- it must be functionally oriented performing objective 3D-data evaluation [6].

Introduction of newly developed system that combines fringe projection and white light interferometer for 3D-form measurement promises to meet all mentioned demands. Measuring process is performed by evaluation of a cutting tool insert from different views and with different resolutions. Cutting tool insert is represented by a 3D-cloud of measuring points transformed in a common coordinate system. This automated and user independent process, fast and completely determine parameters for defining shape and wear of cutting tool inserts.

3.2. Fringe projection system

For obtaining the shape of a cutting tool insert device developed at the Chair Quality Management and Manufacturing Metrology use a fringe projection system based on DMD (Digital Mirror Device) array. A white light source, e.g. the halogen lamp illuminate DMD array that projects fringes in a regular order over the projection optics on the measuring object. According to the shape topography of a measured object deformed projected fringes are observed by a CCD matrix camera under a triangulation angel of 20° to 50°. System combined phase shifting and grey coding for submitting the indispensably vertical resolution. By phase shifting is projected a serial of fringes order that are shifted one to the other for a defined phase angel according to the equation [2]:

$$I(x,y) = I_0(x,y) + [1 + V(x,y) \cos\Phi(x,y)] \tag{1}$$

where $I(x,y)$ is the intensity curve of the fringe patterns registered by the image taking camera, $I_0(x,y)$ is the background intensity, $V(x,y)$ is the amplitude and $\Phi(x,y)$ is the phase position of the observed intensity curve. Additional grey coding sequence enables explicit identification of the fringes for extension the vertical measuring field.

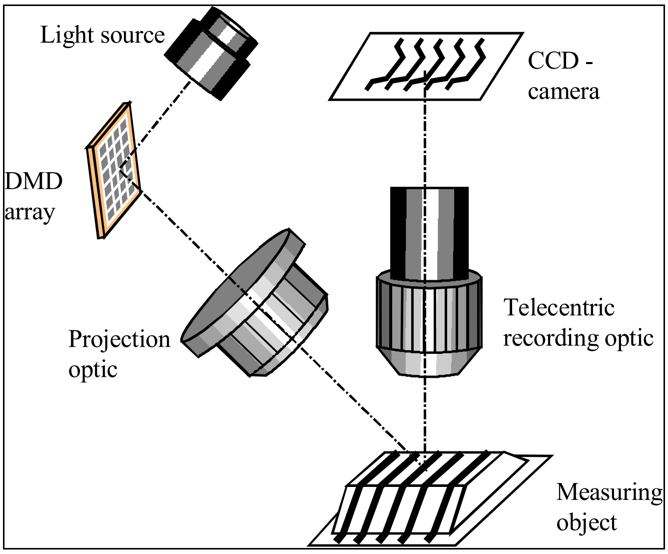

FIGURE 4. PRINCIPLE OF A FRINGE PROJECTION SYSTEM

3.3. White light interferometer

Control of the cutting insert wear is performed by white light interferometer for measurement on optical rough surfaces. This system named as coherence radar is based on Michelson interferometer in which in the object arm one mirror is changed by measuring object [1]. System is moved by a linear stage along the optical axis crossing the reference plane of the object and causing the intensity modulation of the corresponding pixel of the CCD camera. Position of the linear stage for which is generated maximum of intensity modulation in interference correlogram for each pixel is stored as a vertical coordinate.

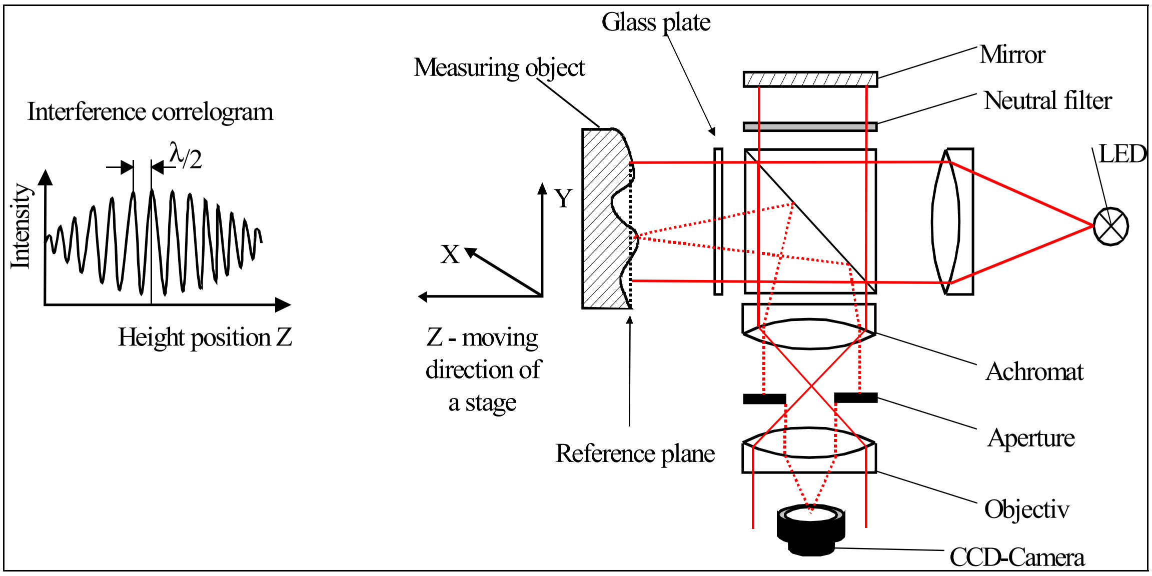

FIGURE 5. PRINCIPLE OF A WHITE LIGHT INTERFEROMETER

4. EXPERIMENTAL RESULTS

4.1. Measurement strategy

Fringe projection system and coherence radar digitalise complete surface of a cutting tool insert. Fringe projection system codes the area of a lateral size 4 mm x 4 mm by 11,000 measuring points. Coherence radar codes the area of a lateral size 2.1 x 2.1 mm with 256,000 measuring points. Position information of a work piece positioning system in the moment of digitalisation and part of based plate are used as transformation parameters for defining the work piece coordinate system in a space. Based on those parameters evaluation of the form characteristics from the 3D data points should be done by substitution of digitised surface of the insert by ideal geometric elements (e.g. sphere, cylinder, cone, plane or free form surface element). For the form evaluation it is sufficient if these substitute geometry elements approximate the observed segments of the insert and are limited to those, which are essential to obtain the results. Obtained surface geometry represents actual shape of a cutting tool insert. Actual shape should be fitted in the CAD model of a cutting tool insert by whom is given reference shape of insert. With comparison of actual and reference shape are obtained information about the production form deviations of a new insert. Actual model could be later used as a base for determination of a wear values caused by manufacturing application of a cutting tool insert. Direct comparison of a CAD reference model and actual form of a used cutting insert are not possible while tolerances for inserts characteristic standard parameters are smaller than possible deviations caused by production of a new cutting tool insert. Tolerances deviation according to DIN 4967 standard are for control size from ±0.005 mm to ±0.38 mm, nose radius ±0.1 mm and tip angle ±0.5° [7].

4.2. First results of shape measurement of a cutting tool insert

First shape form measurement is done for cutting area of a new cutting tool insert in rhomb form. It is measured in one view and point cloud data are processed by SDRC Imageware Surfacer software packet. Surfacer is used for a number of different CAD applications including free form modelling, high quality and first class surfacing, and reverse engineering. It is used in a three-dimensional CAD environment with major goal of returning curves and/or surfaces to the CAD system. Simplified reference model of a cutting tool insert is made by Pro/Engineer CAD software according to standard values given in DIN 4988 [8]. Pre processing of measuring point clouds is done by eliminating weakly contrast points, median filtering that smooth errors by taking the statistical median of a specified sampling cloud with the effect of eliminating outliers from the point data. In instant point transformation parameter for fitting the actual shape in CAD reference model is given manually. Results presented by Fig. 6. shows deviation of actual shape from the reference one by grey coded values. There is remarkable good fitting in area of a tool flank and on the cutting edge with deviation smaller than 15 µm. Because of a simplified CAD reference model of a cutting tool insert deviations in area of chip flow surface show dissatisfactory deviation of 0.15 mm. In the grey code presentation is remarkable position of chip flow surface and chip breaker.

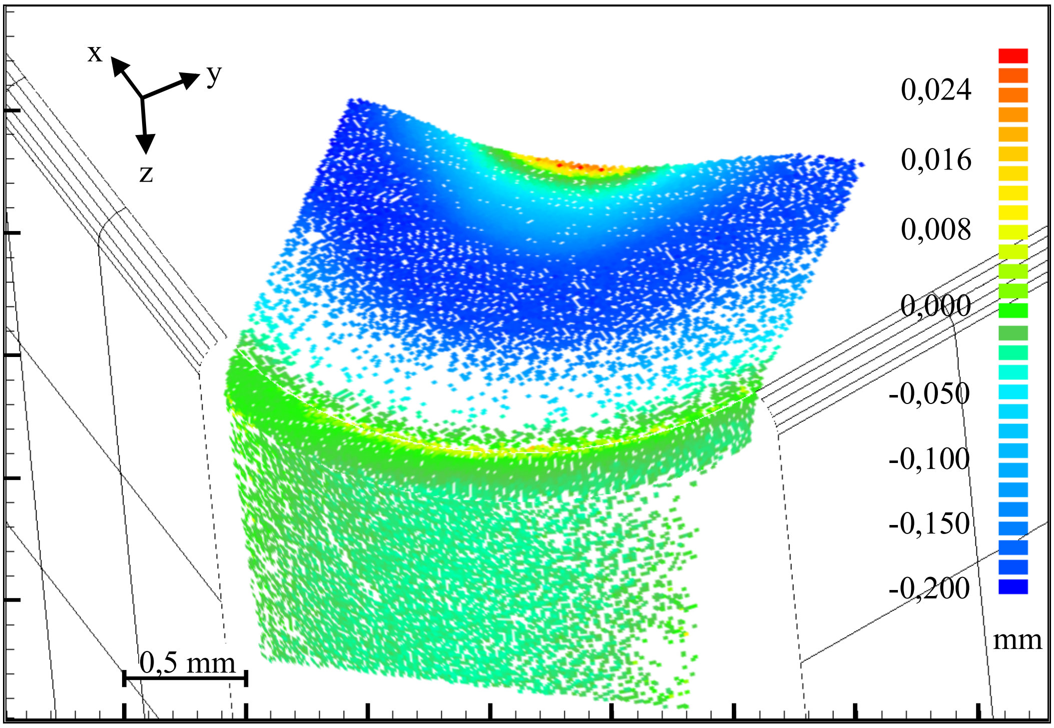

FIGURE 6. COMPARISON OF ACTUALL AND REFERENCE SHAPE OF A CUTTING TOOL INSERT

4.3. First results of wear measurement of a cutting tool insert

Wear monitoring is presently done by comparison of characteristic values in the section of a cutting tool insert obtained from actual shape model of new and used cutting insert. On the presented results in the Fig.7. is remarkable deviation of nose radius from 171.67 µm to 377.76 µm between profile sections of a chip flow surface on a new and used cutting tool insert. In the same time tip angle do not alter. Progression of cutting edge shift in the direction of tool clearance of a used cutting tool insert could be watched on the chip flow surface. On the concrete example same parameter is presented on the evaluated picture of section B-B'. Comparing section A-A' of new and used cutting tool insert can be determine progression of land wear width e.g. as difference of values 307.9 µm and 265.4 µm as well as crater depth which still do not exist on the concrete example of used cutting tool insert. Parameters for 3D definition of cutting tool wear are still in the phase of introducing and they are going to uniquely estimate cutting insert tool wear.

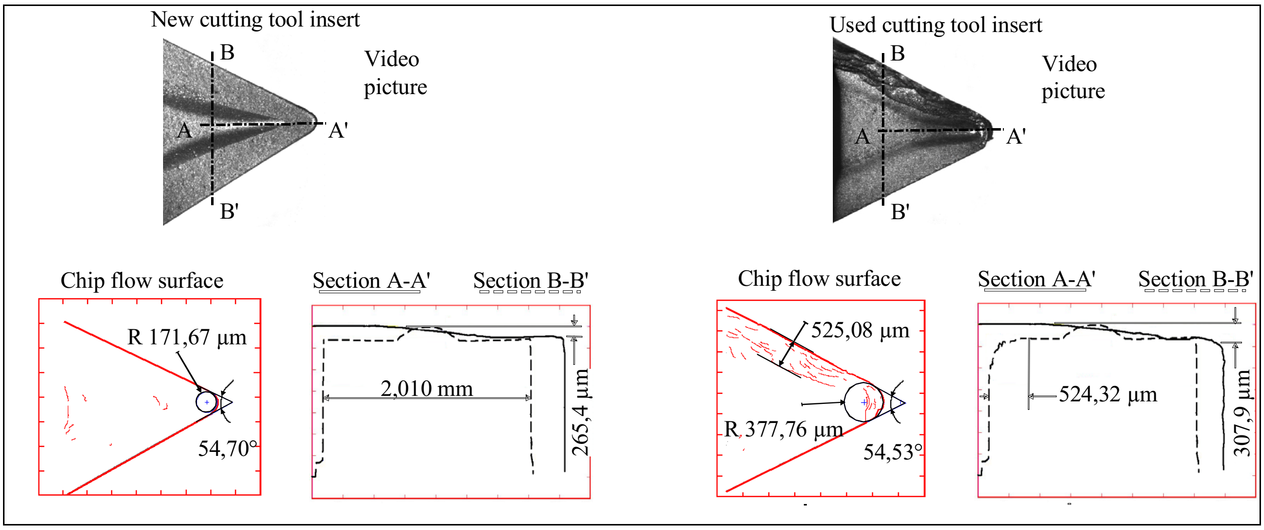

FIGURE 7. WEAR MONITORING ON CUTTING TOOL INSERTS

5. CONCLUSION

Optical 3D measurements are completely suitable for measurement of shape and wear of cutting tool inserts. Already performed measurements with two optical systems show satisfactory reproducibility and good correlation with conventionally used measurement. The results and measuring data visualization are optimised for maximally expressive presentation of the obtained information. The efficiency of the entire measuring system could be examined on the basis of repeating measurements of selected used or new cutting tool inserts. The evaluation of tool status is resolve by shape and wears characteristics and their irregularities are calculated from the nominal model values. It is possible to make decision about the further capabilities of cutting tool insert accurately and without user influence.

6. REFERENCES

[1] Ammon, G.; Haeusler, G.: New Modifications of the Coherence Radar. In: Proceedings of the Fringe, International Workshop on Automatic Processing of Fringe Patterns, Bremen, 1997. P. 15-17.

[2] Frankowski, G.; Reissner, H.: Fast Optical 3D Measurement of Functional Surfaces with Digital Stripe Projection Based on Micromirrors, In: 10th International Colloquium on Surfaces, TU Chemnitz, 2000. P. 74-85.

[3] Leopold, J.: Werkzeuge für die Hochgeschwindigkeitsbearbeitung, Carl Hanser Verlag, München, 1999.

[4] Schmitz, S.: Dreidimensionale Gestaltmessung von Wendeschneidplatten mit Streifenprojektionssystemen und Phasentriangulation, Lehrstuhl QFM (Qualitätsmanagement und Fertigungsmesstechnik;2), Erlangen, 1998.

[5] Weckenmann, A.; Radhakrishnan, V.; Schmitz, S.: Fringe Projection Method for Measuring Geometry and Wear of Cutting Tool Inserts In Proceedings - ASPE 1999 Annual Meeting, American Society for Precision Engineering, Monterey, CA, 1999. P. 473-476.

[6] Weckenmann, A.; Schimke, W.: Messen der 3D-Gestalt von Wendeschneidplatten, In VDI Berichte Nr. 1530 - Sensoren und Messsysteme 2000, S. 359 - 370, VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik, 2000. 10. VDE/VDI/GMA Tagung Sensoren und Messsysteme 2000, Ludwigsburg, 2000. P. 359-370.

[7] Norm DIN 4967 Wendeschneidplatten aus Hartmetall mit Eckenrundungen, mit Senkbohrung, Teil 1, 1987.

[8] Norm DIN 4988 Wendeschneidplatten aus Hartmetall mit Eckenrundungen, mit zylindrischer Bohrung, 1987.