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MEASUREMENT OF CUTTING TOOLS WITH VISIONAL METHOD

POMIARY NARZĘDZI SKRAWAJĄCYCH METODĄ WIZYJNĄ

A b s t r a c t

The paper presents the characteristics of methods of measurement of cutting tools used in computer numerically controlled milling machines. An analysis of an active vision method for measuring tools, with reference to the case of a milling head, has been conducted. Sample measurement results and analysis of using a non-contact method for the measurement of a milling head have been presented.

Keywords: *active vision*, *measurement of cutting tools*, *non-contact measurements*

S t r e s z c z e n i e

W artykule przedstawiono charakterystykę metod pomiaru narzędzi skrawających stosowanych na frezarkach sterowanych numerycznie. Przeprowadzono analizę zastosowania metody wizji aktywnej do pomiaru narzędzi na przykładzie głowicy frezowej. Zaprezentowano przykładowe wyniki pomiaru i analizę zastosowania metody bezstykowej do pomiaru głowicy frezowej.

Słowa kluczowe: *wizja aktywna*, *pomiar narzędzi skrawających*, *pomiary bezstykowe*

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1. Methods of measurement of cutting tools

For a machining process to be carried out properly, a number of important factors must be fulfilled. One of the most important is accurate measurement of the cutting tools used in the machining process. Correctness of cutting tools measurement is a condition for obtaining the desired size and quality of work piece surface. This is particularly important in the case of rotating and indexable tools – such as milling tools. The length and diameter of milling tools (cutters, milling heads, drills, centre hole drills, etc.) can be defined in two ways: by an external tool setting system (Fig. 1) or directly on the machine (Fig. 2). It should be noted that not all of the tools used in the milling process require measurement of length and diameter. For example, for drills, only length is determined. Usually, measurement of tool length and diameter in a numerically controlled milling machine is carried out using a probe once the tool is placed in the machine spindle, using predefined programmes. An example of tool measurement in a HAAS VF1 milling machine, using a Renishaw tool probe, is shown in Fig. 2 [6].

Fig. 1. Kalimat A/C/E – a device for measuring cutting tools [4]
Rys. 1. Kalimat A/C/E – urządzenie do pomiaru narzędzi skrawających [4]

Fig. 2. Measurement of the cutter in a HAAS VF1 with a Renishaw tool head [5]
Rys. 2. Pomiar frezu na obrabiarce VF1 firmy HAAS za pomocą głowicy narzędziowej firmy Renishaw [5]

2. Measurements with vision systems

In the industry, there are several areas in which 3D vision systems can be used, for example:
– measurement of objects (length, width and height),
– measurement of surface area or volume of an object,
– quality control of surface finish,
– identification.

Using 3D vision systems for industrial processes reduces the costs and improves the quality of production. Manual control operation may be replaced by a vision system capable of determining the dimensions and structure of the object surface to allow detection of faulty objects. Such a solution also eliminates the need for complex systems of sensors, thereby reducing costs and saving time. In 3D object modelling, there are many parameters that must be taken into account depending on what task is performed by the vision system and how accurate a model is to be achieved. Below, several of such parameters are discussed:

1. Geometric shape and size of the object. Depending on the shape and size of the object and the distance between the object and the sensor, various methods of 3D measurement can be used. For the measurement of larger objects (e.g. buildings), the technique used may be the *time of flight* method. For smaller objects, the most commonly used technique is passive or active vision.
2. Surface structure and colour of the object. Image processing techniques are very sensitive to changes in the quality of the surface of materials and their structure. This is due to the phenomenon of reflection, dispersion and absorption of light at the surface of the object, which takes place in a different way for each material and surface structure.
3. Working environment. The environment in which a given vision system operates is very important. The most important element is the lighting conditions. With weak and irregular illumination, a vision system, particularly one based on passive vision techniques, struggles to identify data reference points on the image.
4. Duration of calculations. Another important parameter is the computation time needed to reconstruct the scene or to measure in three dimensions. Such calculations require a large CPU computing power. In the case of two-dimensional vision system, the response time is less than a second. 3D measurements increase the amount of data to be processed and, consequently, the calculation time.

To create a 3D model of an object, a certain number of surface points obtained by sampling is required. The points set out in three dimensions are obtained through the use of several methods of measuring. Then, on the basis of the points collected, a triangle or polygon mesh is created, representing surface geometry.

The process of creating a 3D model can be divided into the following stages:

1. View planning and sensor position. Imaging of all sides of the object requires observation of the object from different perspectives. Hence, the positioning system must consist of a movable sensor, a moving object, or both elements moving simultaneously in a particular combination.
2. Scanning and recording. When the sensor is in the right position, the image is recorded and the data obtained from it is saved in a coordinate system.
3. Consolidation of the model and execution of the algorithms of image processing and the algorithms implementing the programme for the measurement of selected parameters of the scanned object.

As previously mentioned, 3D vision systems allow measurement in three dimensional space. In the image provided by the camera, one can determine selected features of the object, such as its geometric dimensions and position on the plane. The central question is how to obtain information about the third dimension. Therefore, before discussing 3D vision systems, methods of measurement should be mentioned. Sensors that measure the actual distance from the object, without direct physical contact, may be classified as distance-measuring non-contact sensors.

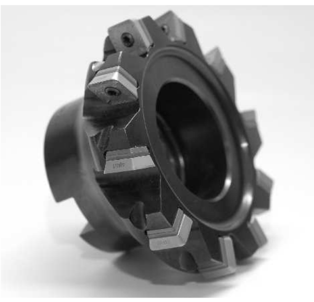
The paper will discuss a 3D vision system based on the principle of laser triangulation. In general, the principle of operation of the system can be described as follows: a light beam is directed at an object at a certain angle, and the surface on which the beam is projected is observed from a different angle by a light detector. Changing the height of the object changes the position of the reflected light beam on the detector. By observing the reflected light, one can, with the help of an algorithm, measure the height of the object. Systems equipped with a camera and a projector lamp are referred to in the literature as *active vision*. The term “structured lighting” is defined as the projection of coded light patterns (points, grid lines, complex shapes) onto the tested object. The main advantage of structured lighting is that the observed features of the object can be highlighted in the image. As a result, both the detection and separation of image elements becomes easier.

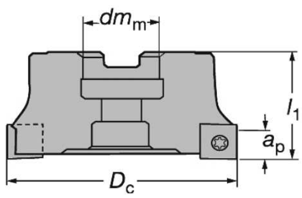
Upon commencement of a measurement task, a number of operating parameters of the work bench and of the operation of the vision system itself need to be determined. The most important parameters include:

1. Field of View, which describes the size of the measuring field on the 3D vision system converter. Correct setting of the measuring field allows the highlighting of details on the object which had been selected for inspection. It also permits control of the operating speed of the system and eliminates the adverse effects of laser light reflection against object edges and planes.
2. Selection of laser and laser power to match the material and quality of surface finish. The way the object is lit has a decisive impact on the quality and resolution of the captured image.
3. Drawing of the reference plane, i.e. the plane of the measuring table, and angles arising from errors in the alignment of the camera and the inspected object.

3. The use of vision method for measuring the face mill

To analyse the use of a vision measuring system, a R290-100Q32-12H ten-cutting edge milling head manufactured by Sandvik Coramant has been selected (Fig. 3).

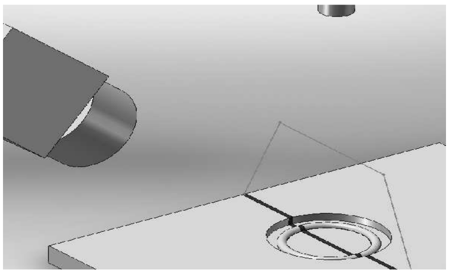




D_c = 100 mm
dm_m = 32 mm
l_1 = 50 mm
$a_{p\_\max}$ = 10.7 mm
Max_rpm = 12 000
Insert_Size = 12
κ_r = 90°

Fig. 3. R290-100Q32-12H Sandvik Coramant milling head [2]
Rys. 3. Głowica frezowa typ R290-100Q32-12H Sandvik Coramant [2]

The face mill was placed on a work bench where a 3D vision system had been installed. Bench configuration settings were chosen in such a way as to be able to reconstruct the shape of the frontal area in 3D space. The aim was to determine the applicability of 3D vision systems as standard lathe equipment for the measurement of cutting tools. Such a system would be responsible for checking the tool in terms of the correct mounting of inserts and measurement of the length and diameter dimensions of the tool in the milling machine. Below, Fig. 4 shows a diagram of set-up of a 3D vision system for inspection of selected parameters of the milling head.



Laser plane is perpendicular to the surface of the milling head face.

The vision system watches the surface of the face at an angle allowing the mapping of all elements of the head.

Fig. 4. Diagram of 3D vision system set-up
Rys. 4. Schemat ustawienia stanowiska systemu wizyjnego 3D

As a result of scanning the face of the milling head, a 3D image was obtained as shown in Fig. 5. The image was built out of points collected on the object with the following resolution.

$$\Delta X \approx 0.125 \text{ [mm/pixel]} \quad (1)$$

$$\Delta Y \approx 0.125 \text{ [mm/pixel]} \quad (2)$$

$$\Delta Z \approx 0.04 \text{ [mm/pixel]} \quad (3)$$

Resolution of 1280×1000 pixels and image size of 160×125 mm, corresponding to that resolution, were obtained. The 3D image is shown in the figure below.

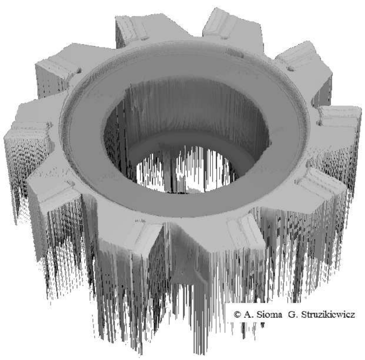


Fig. 5. 3D image of head face
Rys. 5. Nieprzefiltrowany obraz 3D powierzchni czołowej głowicy

In order to measure the height of assembly of 10 inserts, a baseline reference plane was determined on the milling head. In relation to the designated plane, measurement of points forming the cutting edge of the insert was carried out. The plane was determined from the points constituting the 3D model. To determine the surface area, the plane of the face of the milling head base roller was taken into consideration. Using appropriately selected image transformation algorithms, the 3D image of the head and the 3D image of the reference plane were merged. A view of the plane and the head face is presented in Fig. 6.

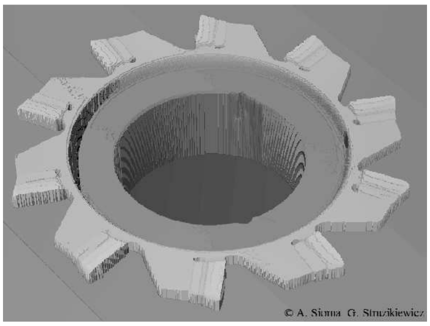


Fig. 6. 3D image of head face
Rys. 6. Obraz 3D powierzchni czołowej głowicy

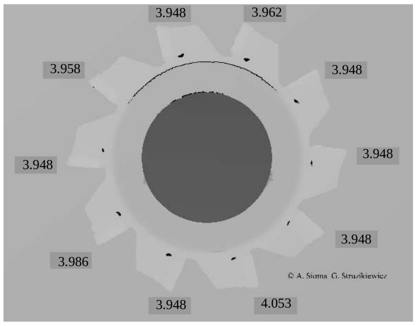


Fig. 7. Results of measurement of the height of assembly of cutting inserts edge expressed in [mm]
Rys. 7. Wyniki pomiaru wysokości montażu krawędzi płytek skrawających wyrażone w [mm]

On such an image, measurements of the height of all edges of cutting inserts, using an algorithm prepared by the authors, were carried out. The measurements enabled determination of average values and the maximum value based on the points forming the cutting edge of a cutting insert. The obtained values presented in Fig. 7 show the maximum height of individual blades in millimetres.

Analysis of the results allows assessment of the accuracy of mounting of the inserts in the milling head jacks. It can be noticed that one of the inserts is mounted about 0.1 [mm] higher in relation to the other inserts, which can significantly affect the quality and the accuracy of dimensions and shapes of the work piece plane.

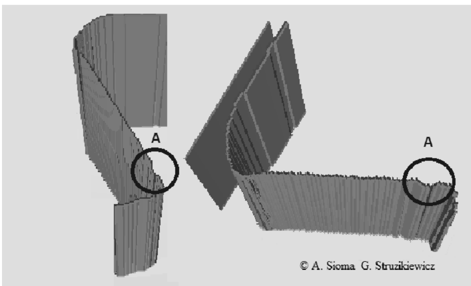


Fig. 8. Analysis of the edges of cutting inserts
Rys. 8. Analiza krawędzi płytek skrawających

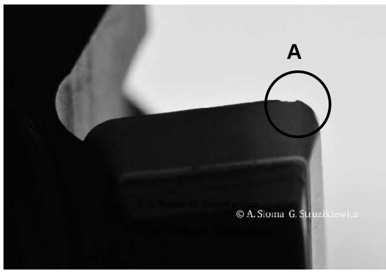


Fig. 9. Photograph of the edge of a cutting insert with visible chipping
Rys. 9. Fotografia krawędzi płytki skrawającej z widocznym wykruszeniem

The next step of head inspection was to check the condition of the inserts' cutting edges mounted on the head, with particular attention to chippings, cracking, abrasive wear or built-up. Such inspection may be carried out prior to the mounting of a milling head in the milling machine tool shop. It can also be performed in order to verify the degree of head wear between machining operations carried out on the successive semi-finished products. This makes it possible to check the wear of cutting tools and simultaneously of the quality of surfaces produced with the tested head. The picture below shows the edge of one of the inserts where a chipping was detected. The chipping is described as detail A and is presented in two views to assess the chipping and the site of its occurrence. The obtained results of measurement using a vision system were confirmed with an optical microscope.

A photograph of the chipping was also taken using a macro lens to compare the 3D image of the edge with a 2D image of the same, which was taken using a sensor with resolution of 12 MPixels (Fig. 9).

4. Conclusions

The analysis confirms the applicability of 3D vision systems for quality control of both the dimensional parameters of a milling head as well as the parameters describing damage and wear of the edges of cutting inserts mounted in the head. The bench requires selection of a suitable test system configuration and selection of vision system sensor resolution that enables inspection of objects within the assumed dimension range. Inspection of the head can be conducted prior to mounting in the machine as well as after mounting, as an inter-operational check. This requires installation of a vision system in the working space of the machine in such a way that the tool can be set for measurement frontally and/or laterally with respect to the vision system. Measuring information can be then used as feedback for the machine's control system.

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