Evaluation of the dimensional-shape accuracy and surface stereometry of the radiator formed by precision VHM micro milling cutter

Ocena dokładności wymiarowo-kształtowej i stereometrii powierzchni radiatora ukształtowanego mikrofrezem precyzyjnym VHM

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The paper presents the possibilities of application the individual measurement methods for evaluation of the dimensional-shape accuracy and surface stereometry of the radiator milled with precision VHM micro milling cutter with DLC coating.
KEYWORDS: milling, dimensional-shape accuracy, surface texture, optical measurements, coherence correlation interferometry

Modern equipment requires new construction and technological solutions. One of the problems is to ensure the effective removal of heat generated during operation. To receive this energy, among others, radiators made of materials with high thermal conductivity such as aluminum and copper, are used.

In the case of small appliances, the size of the radiator must be adjusted to the size of the heat generator, while at the same time, ensuring the efficient discharge of excess air into the atmosphere.

A radiator, for the purpose of testing the effectiveness of heat removal, was prepared using a treatment micro milling cutter VHM with DLC coating [2] (fig. 1). The radiator has dimensions of 30×30 mm and a groove depth of 0.4 mm and a groove width of 0.4 mm.

Fig. 1. VHM precision micro milling cutter with DLC coating and the radiator produced by it

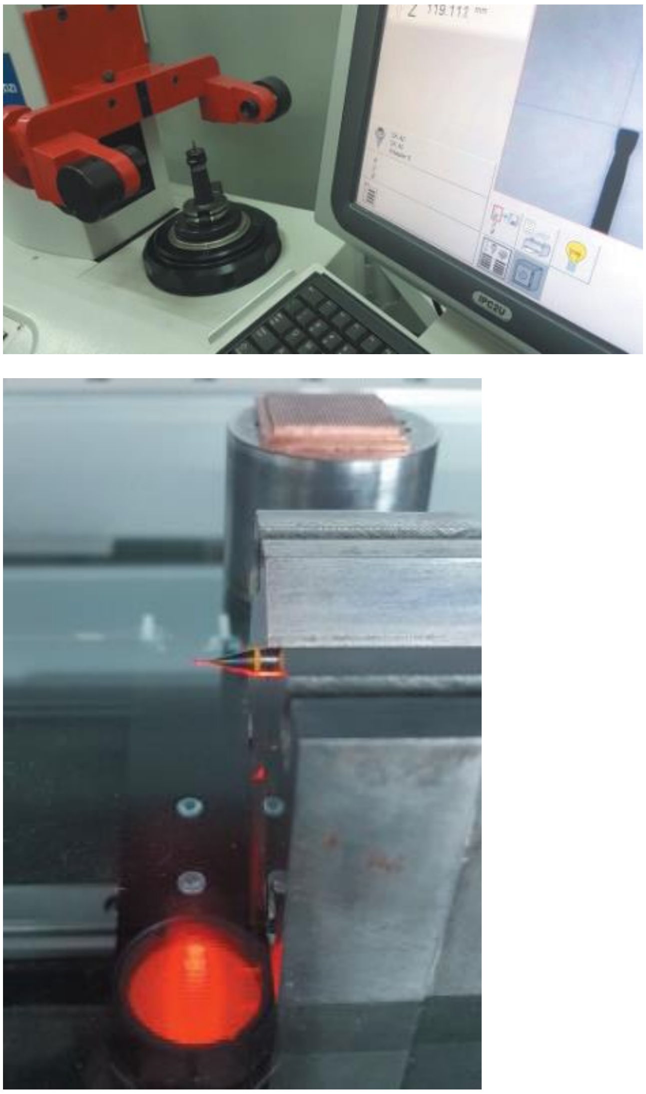

Fig. 2. Measurement of VHM micro milling cutter diameter: a) with KALIMAT-C station, b) with multi-sensor coordinate measuring machine O-Inspect

Prior to machining, micro milling cutter measurements were made with the KALIMAT-C station and with the O-Inspect multi-sensor coordinate measuring machine (fig. 2). The mean diameter of the tool was 0.418 mm.

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The Hermle B 300 vertical milling center was used to produce the radiator. The top surface of the radiator was milled with a milling head ⌀63 mm with a feedrate of 800 mm/min and a depth of cut of 1 mm. Grooving using the VHM precision micro milling cutter with a DLC coating was performed with a maximum spindle rotation of 15000 rpm and a feedrate of 72 mm/s and a cutting depth of 0.015 mm. Total milling depth was 0.4 mm. This shaped radiator was subjected to dimensional and form analysis and surface texture, which consisted of:

- groove width measurement,
- groove depth measurement,
- measurement of the surface texture of the top surface of the radiator
- measurement of the surface texture of the bottom of the radiator groove.

Measurement methods

Development in recent years of new techniques for measuring the surface texture of the classification system presented in PN-EN ISO 25178-6:2011 [6], which defines the class of line-profiling methods and areal-topography methods, has significantly increased the ability to evaluate different types of surfaces. The most common method is to measure with a contact profilometer with a stylus tip [5]. This method is used both in industry and in laboratory conditions. During measurements of micro grooves, however, the apex angle of the cone of stylus tip is decisive, which limits the penetration depth of the groove, and thus the lateral mapping of the groove (fig. 3).

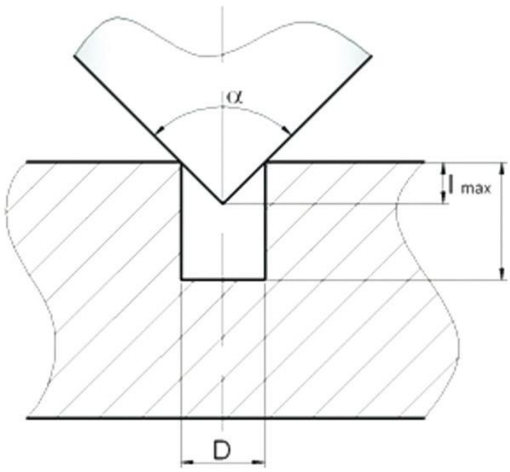

Fig. 3. Diagram of the measurement with a stylus tip

Measurement of the radiator using the contact profilometer FormTalysurf PGI with a stylus tip with the cone angle α = 90° and the radius r_{tip} = 2 µm is shown in fig. 4.

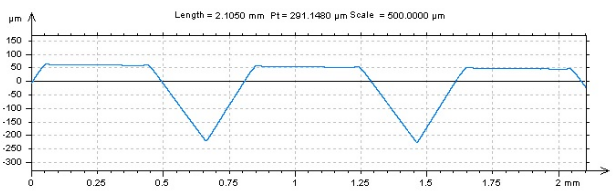

Fig. 4. The result of the radiator measurement using the contact method

As a result of groove measurement by this method, we obtain an incorrect depth value and incorrectly reproduced its form.

For the analysis of surface treated with DLC coating, an optical method was chosen based on the collection of interferential band images and their location during vertical scanning, combining the vertical scanning technique with optical interferometry [1, 3]. This method of measuring the deep grooves of the radiator is a numerical aperture of the lens that limits the ability to measure on sloping slopes. The application for surface measurements with steep slopes lens with too little aperture results in areas with immeasurable points, marked as white spots on the topography of the surface.

In order to verify the results obtained, measurements based on the confocal method were also performed. The resolution of the head depends on its vertical range: from a few nanometers for heads with the smallest vertical range up to 300 nm for heads with the largest range.

Measuring instruments

For measuring and dimension-shape analysis, two instruments were selected:

- Optical profilometer Talysurf CCI (fig. 5), using a coherent correlation interferometry method with a Z axis measurement range of 2.2 mm and a resolution of 10 pm, in which the image analysis is based on a 1024×1024 dot matrix equipped with a set of lenses with magnification of ×10, ×20 and ×50, allowing the area to be measured to suit the lens used: 1.66×1.66 mm; 0.83×0.83 mm; 0.33×0.33 mm. As the lens increases, the horizontal resolution and numerical aperture of the lens increase as well, increasing the possibility of measuring the surface with large slope angles. An analysis of larger areas is possible with the option of combining individual measurements.

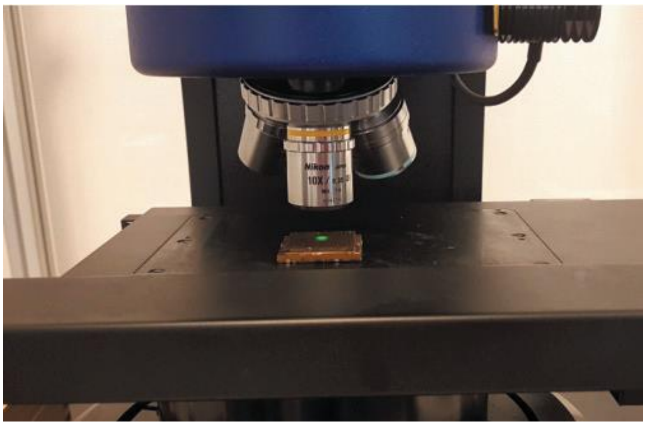

Fig. 5. Talysurf CCI Lite optical profilometer using coherent correlation interferometry

- Multi-sensor coordinate measuring machine O-Inspect (fig. 6) equipped with three measuring heads (contact, optical and confocal). The confocal head uses a white light spot with a diameter of 20 µm. Its vertical range is 10 mm.

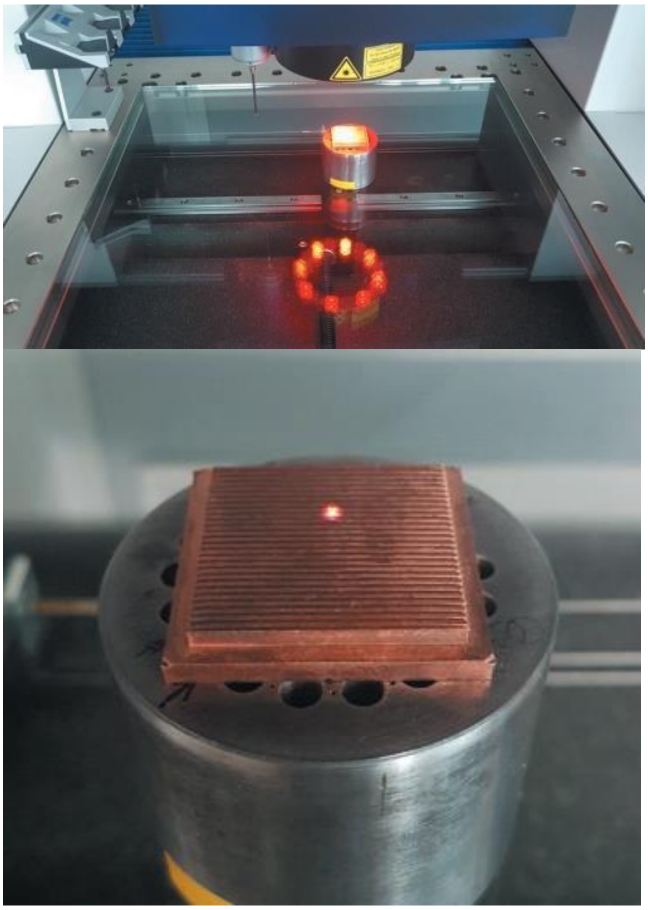

Fig. 6. Multi-sensor coordinate measuring machine O-Inspect equipped with three measuring heads

Measurement of groove width and depth

The measurement of the surface stereometry of the radiator using the Talysurf CCI Lite profilometer is shown in fig. 7.

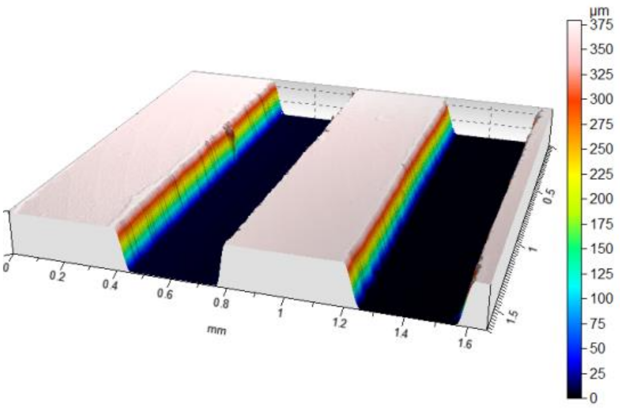

Fig. 7. Isometric image of the radiator surface

To determine the width of the groove, a single profile (fig. 8) was isolated from the stereometric image.

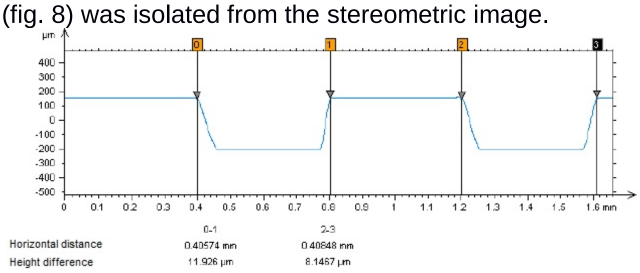

Fig. 8. Determining the width of the groove on the profile

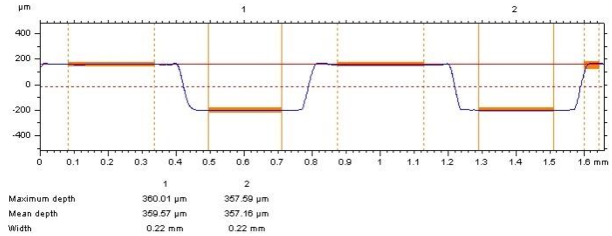

Fig. 9. Results of measurements of radiator groove depth

Measurement of the radiator groove depth was carried out on the average profile generated from the 3D measurement of the workpiece (fig. 9).

Results obtained with the optical profilometer were compared with a measurement made using a multi-sensor coordinate measuring machine O-Inspect equipped with a confocal head (fig. 10).

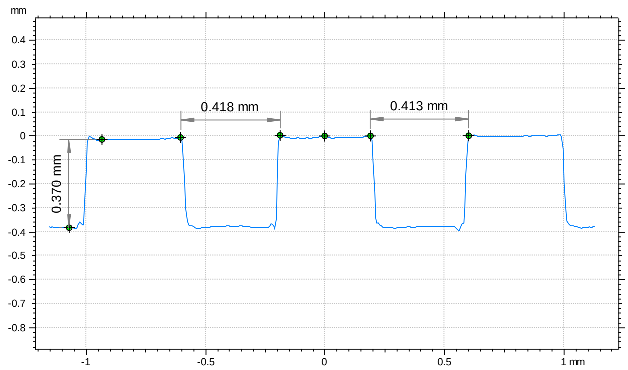

Fig. 10. Determination of groove width and depth with multi-sensor coordinate measuring machine O-Inspect

On the basis of the results, it can be concluded that measurements made by coherent correlation interferometry give very similar widths and depths to confocal measurements [4]. The difference for the groove width is 8 µm, which is 2% of the measured value, and for the depth of 8 µm, which is also 2% of the measured value.

Measurement of surface texture

In order to check the surface of the radiator, the top surface (fig. 10) was processed after machining with the milling head and groove base (fig. 11) after micro-processing and the spatial parameters of the surface were determined. Amplitude parameters for the upper surface are approximately 2 times higher than the values of these parameters for the bottom of the groove. The upper surface is oriented, periodic and determinate while the bottom of the groove is random, isotropic.

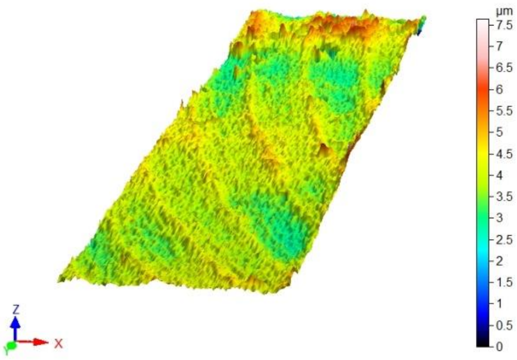

Fig. 11. Isometric image of the top surface of the radiator

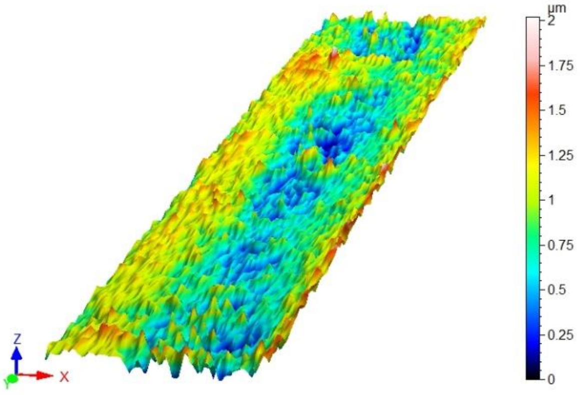

Fig. 12. Isometric image of the surface of the bottom of the groove

TABLE. Parameters of surface texture

Parameters	Upper surface	Lower surface
Sq, µm	0,597	0,311
Ssk	-0,016	-0,181
Sku	4,700	2,800
Sp, µm	3,760	1,180
Sv, µm	3,880	0,844
Sz, µm	7,640	2,020
Sa, µm	0,452	0,252

Conclusions

The research was focused on the selection of optimum methods and measuring instruments for dimension and shape evaluation and the state of surface texture after machining the grooves with a dimensions 0.4×0.4 mm VHM micro milling cutter with DLC coating. For surfaces with such geometry, the contact profile method is inadequate and the groove geometry is unreliable. The coherent correlation interferometry method for dimensional and shape evaluation and surface texture provides reliable results. These were confirmed by means of a confocal head. The only way to measure the stereometry of the radiator surface is by optical methods. The top surface of the radiator and bottom surface of the groove are characterized by different properties resulting from the type of machining used.

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