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The impact of the texture and the roughness of the surface on the results of tests executed with the use of a triangular laser head

Streszczenie. *W artykule zaprezentowano wyniki badań dokumentujące wpływ chropowatości i kierunkowości struktury powierzchni na wyniki pomiarów realizowanych z zastosowaniem laserowej głowicy triangulacyjnej. Jako powierzchnię projekcji plamki lasera wykorzystano czoła trzech stalowych trzpieni obrobione poprzez toczenie, szlifowanie oraz elektrodrążenie. Każda z powierzchni charakteryzuje się odmiennym rodzajem tekstury wynikającym z kierunkowości śladów obróbki oraz odmienną wartością chropowatości.*

Abstract*. The article presents the results of tests investigating the influence of the roughness and the texture of the surface on the results of measurements taken with the use of a triangular laser head. As test samples the heads of three steel plungers that were subject to turning, grinding and electrical discharge machining were used. Each surface is characterised by different texture resulting from the directional character of traces left by the machining tool and a varied value of roughness. (****Wpływ tekstury i chropowatości na wyniki pomiarów z wykorzystaniem laserowej głowicy triangulacyjnej****).*

Słowa kluczowe: triangulacja laserowa, chropowatość powierzchni, tekstura, rozrzut wskazań
Keywords: laser triangulation, surface roughness, texture, dispersion of indications

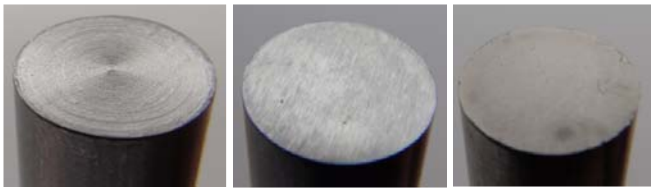
Introduction

The use of a triangular laser head is one of noncontact measurement methods [1, 2, 3, 4]. The positioning of the test surface is estimated with the use of a set of right-angled triangles. A laser diode emits a light beam used for the measurement, which once formed by the optical system runs in the direction of the surface of the test object, and forms on it a small spot with the diameter of ca. several dozen to several hundred μm. The image of the spot is projected by the optical system onto the photodetector system [5]. When the distance between the laser head and the test sample is changed, the image of the spot moves along the photodetector, which plays the role of a pattern length. The electronic system automatically adjusts the sensitivity threshold of the head to the type of a tested surface diffusing the light (the way the light is diffused differs depending on the kind of a test sample). The resulting electric signal is digitally processed, and the microprocessor system of the head checks its correctness. As a result of this control, the influence of such interferences as background intensity changes, changes in the temperature of the surrounding, or the higher order reflections [6, 7] can be measured.

Laser head producers guarantee certain parameters of accuracies for a given reference surface (usually white, smooth and matte ceramics). In the case of reflective surfaces or surfaces of varied texture, the obtained value can, however, be significantly different from the actual value measured. As a result, even the slightest roughness of the surface amounting to several micrometres can interfere with the laser beam, which leads to incorrect measurement results.

Test objects

The tests were performed on three types of flat surfaces made of stainless steel. The test samples in form of 9 mm discs were subject to surface treatment processes including turning, grinding and electrical discharge machining. Each of the surface treatment methods used is characterised by a different directional character of traces left by the machining tool on the processed surface. In the case of turned surfaces this directionality has a form of concentric rings, whereas on grinded surfaces the machining tools leave parallel scratches. The traces left on spark-eroded surfaces are not directed. Every surface used is characterised by different sparkle and surface roughness. The roughness of turned surfaces equals 1.12 μm, spark-eroded surfaces – 0.32 μm, and grinded surfaces – 0.22 μm. Each test sample has a natural colour characteristics for the treatment used (Fig. 1).



a) b) c)

Fig.1. Test samples: a) turned surface, b) grinded surface, c) spark-eroded surface

The test samples are the heads of plungers adjusted in a way enabling their cooperation with the test stand (Fig. 2).

Fig.2. Plunger

At the end of the plunger there is a ball tip that ensures a point of contact with the model adjusting element.

Test stand

The tests were performed on a test stand onto which a triangular head was mounted perpendicularly to the test sample with the use of a stiff support (Fig. 3).

The plunger was mounted in a special grip, one of the elements of the support, which enabled its shift along the measurement head. The distance between the test sample and the laser head was determined with the use of gauge blocks constituting a support for the ball tip of the measurement plunger. For each of the distances measured, an appropriate pile of gauge blocks, on which the ball tip of the plunger was based, was placed. The measurements were taken with the use of a triangular laser head by PEPPER+FUCHS. The working range of this head is 100mm, the minimum measurement distance – 30mm and the measurement distance – 70mm. The length of light emitted by the laser used in the head amounts to 650nm, and the head resolution is 0.1% of the measurement range at its 0.25% linearity. The dimensions of the spot projected by the laser head are: 1.5 mm x 3 mm at the beginning of the measurement range, and 1.5 mm x 3.25 mm and its end.

a) b) c)

Fig.3. Test stand: a) side view, b) front view, c) view of the laser spot on the surface of the plunger

The test stand was equipped with a controller and the user panel, which enabled the process automation and data record in a digital form.

Test methodology

The main objective of the tests was to determine the repeatability of measurement results for the same type of material but with differently processed surfaces characterised by different roughness and texture. As a repeatability measurement, the dispersion value of measurement deviations recorded for selected measurement distances was chosen.

Totally, for each of tested surfaces, 1600 measurements were taken. The tests were conducted in the shift range of 1-60mm characterised by a changeable stroke of the measurement distance, which amounted to 1mm for the 1-5 mm shift, and 5mm for the 5-60mm shift. The results of measurements were projected on the user panel and transferred to the PC cooperating with the test stand, which enabled their automatic record and archiving in a suitable field of the measurement spread sheet.

For every distance between the test sample and the head, 10 measurements were taken. After each of them, the plunger was cyclically turned around its own axis at the angle of ca. 6°. The turn allowed for the laser spot to be projected onto the surface with changeable topography. The plunger was turned to eliminate any systematic errors connected with the observation of the reflection of the laser spot.

Test results

Based on the recorded results, the measurement deviations for each of the measurements taken were estimated. The term "measurement deviation" was used with reference to the difference between the measured value and the real value of the measured quantity. The measurement results in question are presented in the graphs of measurement deviations estimated for every measurement distance taken into consideration (Fig. 4, Fig. 5, Fig. 6). In order to improve their readability, the graphs show only border lines of top and bottom deviations and a line representing the course of average deviation value changeability estimated based on 10 measurements taken for each measurement distance.

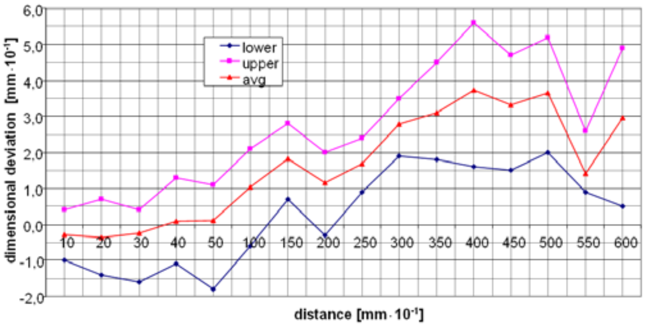


Fig.4. Distance measurement deviations for a grinded surface

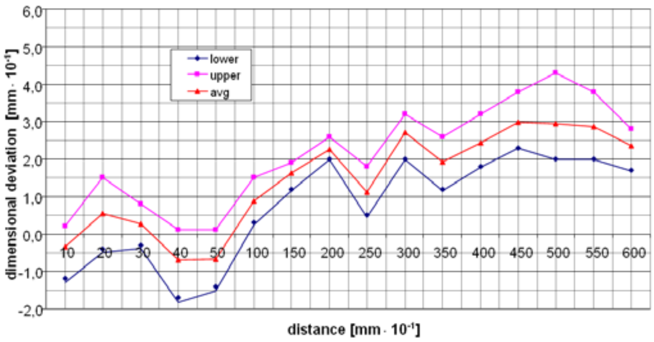


Fig.5. Distance measurement deviations for a spark-eroded surface

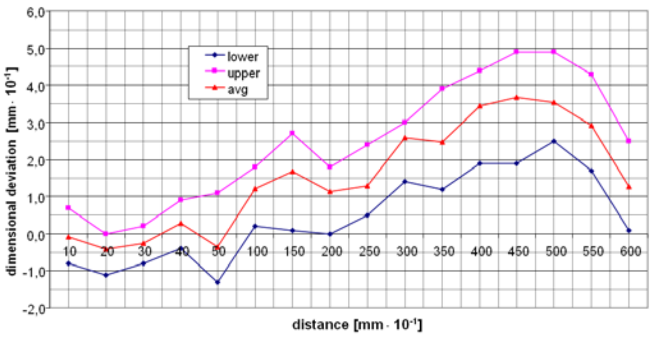


Fig.6. Distance measurement deviation for a turned surface

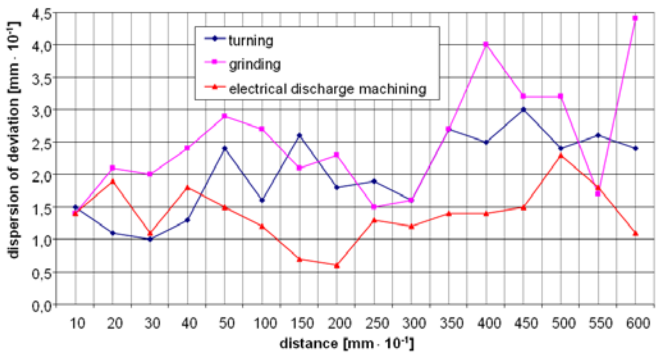


Fig.7. Measurement deviation dispersion

In order to compare the results of measurements conducted for the three test samples, the dispersion of deviations recorded for each measurement distance was estimated (Fig. 7).

The dispersion of deviations is described by the difference between the top and the bottom measurement deviation.

The course of changeability of the difference between the real and the defined value of measured quantity is visible in the measured characteristics. The compensation of this difference is a separate issue connected with an appropriate and an individual calibration of the measurement head that can be achieved through the recording of the course or the determination of the proper functional relationship.

Analysis of the results

A statistical analysis was conducted for the determined values of the dispersion of measurement results. Within this analysis the following were undertaken: the estimation of the average value of the standard deviation and the estimation of the changeability coefficient (Tab. 1).

Table 1. Statistical parameters of the measurement deviation dispersion

	Grinding	Turning	Electrical discharge machining
Average value $\overline{X}$ [µm]	2.51	2.02	1.39
Standard deviation S	0.84	0.60	0.41
Changeability coefficient [%] $v_s = \frac{S}{\overline{X}}$	33.46	29.7	29.49

The estimated value of the dispersion of measurement results $\overline{X}$ and the standard deviation S indicates that the results characterised by the lowest dispersion were recorded for the test sample that had previously been subject to electrical discharge machining. The spark-erosion machined surface positively influences the value of the changeability coefficient, which in this particular case, has the lowest value.

The grinded surface is characterised by the greatest value of the deviation dispersion and the highest value of the dispersion changeability coefficient at the same time.

Summary

Based on the tests and analyses conducted it can be stated that the directionality of the surface structure and its roughness significantly influence the determined distance value and the accuracy of measurements taken with the use of a triangular laser head. The greatest dispersion was recorded for a grinded surface with the unevenness of 0.22 µm, whereas the lowest for an spark-erosion machined surface with the roughness of 0.32 µm. The intermediate dispersion value was obtained for a turned surface with the roughness of 1.12 µm. As the lowest roughness is not equivalent with the lowest dispersion, it can be stated that the main parameter determining the accuracy of measurement is, in the case of tested samples, the directional character of their machining. The results obtained for the turned and grinded surfaces have a much higher dispersion than those recorded for the spark-eroded samples. This can be so, due to the clear directional character of traces left by the machining tool. In the case of an electrical discharge machining the surface does not have texture of a directional character and is described by an unstructured and an accidental system of traces left by the machining tool.

It can therefore be stated that the surface constituting the measurement base for the triangular measurement head should be characterised by non-directional texture.

The tests showed that the measurement accuracy of triangular laser heads depends on the condition of the surface onto which the light beam is projected, and the results recorded for metal surfaces with different roughness and directionality of treatment processes can significantly differ.

REFERENCES

[1] Hofmann F., Degórski P.: Technika pomiaru bezkontaktowego Ekspozycja w czasie rzeczywistym. ELEKTRONIKA PRAKTYCZNA 3/2011

[2] Peterson J., Peterson R.: Laser triangulation for liquid film thickness measurements through multiple interfaces. Applied Optics, Vol. 45, Issue 20, pp. 4916-4926 (2006)

[3] Giesko T., Zbrowski A., Czajka P.: Laser profilometers for surface inspection and profile measurement. Problemy Eksploatacji 2007 nr 1, str. 97-108

[4] Mazurkiewicz A. edit.: Innovative Technological Solutions for Sustainable Development.. Institute for Sustainable Technologies – National Research Institute Press. Radom 2010, ISBN 978-83-7204-955-1

[5] Eugeniusz E.,Woźniak A.: Nowe trendy w budowie bezstykowych głowic pomiarowych stosowanych w maszynach współrzędnościowych. MECHANIK nr 1/2005, s.32-36

[6] Daneshpanah M., Harding K.: Surface sensitivity reduction in laser triangulation sensors. Proc. SPIE 8133, Dimensional Optical Metrology and Inspection for Practical Applications, September, 2011

[7] Dorsch R, Häusler G, Herrmann J.: Laser triangulation: fundamental uncertainty in distance measurement. Applied Optics, Vol. 33, Issue 7, pp. 1306-1314 (1994)

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