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ANALYSIS OF INFLUENCE OF THE SHAPE OF CUTTING INSERT ON CHANGE OF THE PARAMETER VALUE DESCRIBING THE DEVIATION OF THE PROFILE OF SURFACE ROUGHNESS

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Abstract

The article presents the influence of the shape of the cutting insert on the surface roughness of the material after medium-fine turning machining. The analysis of measurements of the R_a parameter describing the arithmetic mean deviation of the surface roughness profile from the centre line of the profile by the mechanical and contact method was made using the Hommel Etamic Waveline 20 profile (Gdynia Maritime University). The tests were carried out on three stainless steel X2CrNiMo17-12-2 / 1.4404 shafts with a diameter of 80 mm, subjected to medium-precision turning machining at a length of 270 mm, using three cutting inserts made of tungsten carbide shaped T – triangular, C – rhombic, W – trigonal manufactured by Pafana. Values of used parameters are turning speed V_c = 150 m/min, depth of cut a_p = 2 mm and feed f = 0.2 mm/rev. The parameters have been selected according to the manufacturer's recommendations. The tests were carried out three times, five measurements on the length of the turned part of the rollers. The first test was made after collecting one layer of material, the second test was carried out after collecting five layers of material, and the third test was made after collecting nine layers of material. The article describes the differences between the used tiles and their effect on surface roughness, presents the results of the research, charts of measurements with averaged values and descriptive statistics of the R_a parameter were presented. It was noted that for all measurements of the R_a parameter, the smallest values were obtained using a W-shaped cutting insert. The R_a parameter using the C and T shaped plates increases with each subsequent measurement. The largest value of the R_a parameter is obtained using the T.

Keywords: *surface roughness, turning machining, cutting insert, technological quality, contact profilometer*

1. Introduction

The treatment of the surface layer affects the surface roughness of the workpiece, depending on the type of machining, tools, and workpiece material. The surface roughness of a material after cutting with a defined geometry blade depends on many factors, including the cutting edge geometry, machining parameters and the grade, structure and properties of the workpiece material [3]. The basic element of the surface roughness profile after turning is the shape of the cutting edge trace [3]. There are many variations of cutting inserts, differing in size, contour, shape of the rake face and cutting edges [1].

Stainless steels have become well known due to their exceptional corrosion resistance, attractive appearance, and durability of the surface of the elements [2]. There is still a need for a better understanding of the properties of this material in all kinds of processing. Stainless steels cause many difficulties when turning. They show a greater tendency to strengthen, low thermal conductivity and greater blade abrasion during machining [4].

The steel selected for testing was AISI 316L according to the American standard and according to European standard, as X2CrNiMo17-12-2 / 1.4404. This steel belongs to the group of austenitic steel [5]. Austenitic stainless steels are used, among others, for elements working in the seawater environment. The chemical composition shown in Tab. 1 provides them with austenite structure stable over a wide temperature range. Tensile strength of 316L steel is R_m = 500-700 MPa [5].

Tab. 1. The chemical composition of steel used in research [5]

Chemical composition [%]					
C	Cr	Ni	Mn	Mo	Fe
≤ 0.03	17.5	11.5	≤ 2.0	2.3	Balance

2. Geometry of indexable inserts and their influence on surface roughness

The machining process creates mechanical and thermal stresses in the tool, as a result of which, among others, such phenomena as formation and disappearance of the accent on the edge of the tool and wear of the blade [10]. The indexes selected for testing are made of sintered carbides, which have favourable cutting and strength properties, high hardness, resistance to wear and good strength properties [1].

The indexable inserts and their geometry are described by many assigned surfaces, planes, edges, angles and radius values, among others:

- the basic plane P_r – this is the plane passing through the considered cutting edge point, perpendicular to the assumed direction of the main motion,
- cutting edge plane P_s – this is the plane passing through the considered point of the cutting edge, tangent to the cutting edge and perpendicular to the base plane P_r,
- flanking surface A_α – is the part of the blade against which the already shaped surface of the workpiece moves,
- corner angle ε_r – this is the angle between the planes of the cutting edge P_s and P'_s,
- insert angle α_n – this is the angle between the straight perpendicular to the base plane and the contact surface A_α,
- corner radius r_ε – this is the radius of curvature of the corner determined in the basic plane P_r [1].

Triangular plate – shape symbol T, corner angle of the tile $\varepsilon_r = 60^\circ$, angle of application of the tile $\alpha_n = 0^\circ$, diameter of the circle inscribed 9.525 mm, thickness 4.76 mm, radius of the corner $r_\varepsilon = 0.8$ mm [1, 7]. Breaker STK. Material – FM30S sintered carbide.

Trigonal plate – shape symbol W, corner angle of the tile $\varepsilon_r = 80^\circ$, angle of application of the tile $\alpha_n = 0^\circ$, diameter of the circle inscribed 12.70 mm, thickness 4.76 mm, radius of the corner $r_\varepsilon = 0.8$ mm [1, 7]. Breaker STK. Material – FM30S sintered carbide.

Rhombic plate - shape symbol C, corner angle of the tile $\varepsilon_r = 80^\circ$, angle of application of the tile $\alpha_n = 7^\circ$, diameter of the circle inscribed 9.525 mm, thickness 3.97 mm, radius of the corner $r_\varepsilon = 0.8$ mm [1, 7]. Breaker SSP. Material – FM30S sintered carbide.

The theoretical height of inequalities (1) R_t, which is the result of an ideal kinematic-geometric representation of the contour of the blade in the turned material, is given by the formula [1]:

$$R_t = \frac{f^2}{8 r_\varepsilon}, \tag{1}$$

where:
f – feed [mm/rev],
r_ε – radius of the corner [mm].

The value of R_t is the same in all three cases of the tiles used, because the feed rate used $f = 0.2$ mm/rev, and the corner radius of the tiles $r_\varepsilon = 0.8$ mm, are the same. The roughness of the machined surface, which arises in real turning conditions, may differ from the theoretical roughness, because in addition to the ideal, kinematic-geometric projection of the blade in the work material, it is influenced by such factors as:

- jagging of the cutting edges of the blades,
- tool wear,

- the phenomenon of creating growth,
- lateral flow of the material (flash) at the interface of the machined surface with an auxiliary cutting edge,
- system vibrations,
- tool edge and tool spindle bending,
- heterogeneity and defects of the processed material [1].

3. Methodology of the research

The tests were carried out on three 316L stainless steel shafts with a diameter of 80 mm, subjected to medium-precision turning machining at a length of 270 mm, each using a different cutting insert made of FM30S sintered carbide:
- T – triangular,
- C – rhombic,
- W – trigonal,

manufactured by Pafana.

The values of the parameters used for turning machining are:
- turning speed V_c = 150 m/min,
- depth of cut a_p = 2 mm,
- feed f = 0.2 mm/rev.

The parameters have been selected according to the manufacturer's recommendations. The treatment was carried out on a universal lathe CDS6500X1000 using a semi-synthetic emulsifier concentrate for Emulex Synti HD metal processing by Veco. The analysis of measurements of the parameter R_a describing the arithmetic mean deviation of the surface roughness profile from the centre line of the profile by mechanical and contact method using the Hommel Etamic Waveline 20 profilometer, located at the Faculty of Mechanical Engineering of the Maritime University of Gdynia. The tests were carried out three times for five measurements on the length of the turned part of the rollers (270 mm) in the direction of turning, which allowed obtaining a more accurate image of the surface roughness of the material after machining. The first test was carried out after collecting one layer of material, the second test was carried out after collecting five layers of material, and the third test was made after collecting nine layers of material. The blade is made of diamond and is pressed against the surface with a constant force several mN and moved along the surface, and changes in its position in the direction perpendicular to the direction of travel, depend on the dimensions and shapes of irregularities [8, 9]. The radius of rounding the tip of the blade mapping the surface profile is 2 µm. The value of the length of the surface subjected to the test at each measurement is 4.80 mm.

With the contact technology, it is important that the contact pressure be obtained by measuring pressure. This pressure causes elastic deformation both in the measured object and in the used measuring tool [8]. Often the blade used in these methods may damage a delicate surface during the measurement, contaminate, or change its physical properties [8].

4. Results and analysis of research

The parameter R_a and surface profile were determined for each one-time surface length tested. An example of the surface profile generated during the tests on the Hommel Etamic Waveline 20 profilometer is shown in Fig. 1.

The results of the first measurement of the R_a parameter are presented in Tab. 2. After the first measurements, it can be seen that the smallest value of the R_a parameter of 1.072 µm was obtained using a trigonal cutting insert (W). The largest parameter value is 1.604 µm obtained using a triangular cutting insert (T).

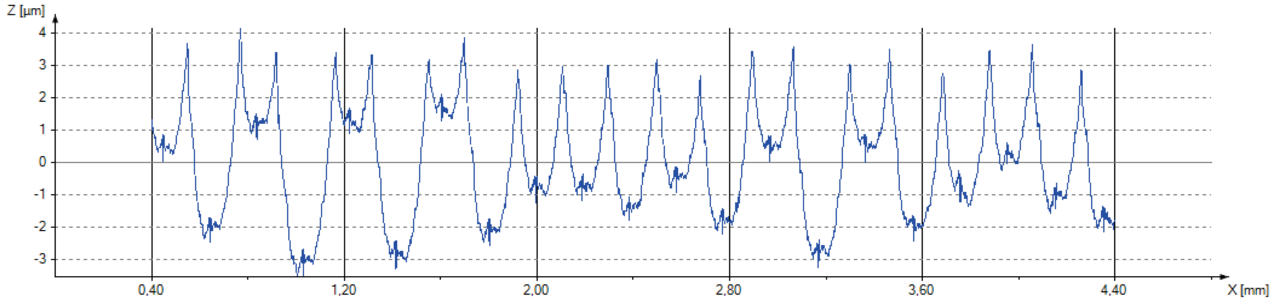

Fig. 1. Surface roughness profile made on the Hommel Etamic Waveline 20 profilometer

Tab. 2. The results of the first measurement of parameter R_a

Measurement 1 [µm]			
Measurement position	Rhombic insert (C)	Trigonal insert (W)	Triangular insert (T)
1	1.570	1.422	1.587
2	1.594	1.085	1.604
3	1.480	1.107	1.493
4	1.400	1.072	1.388
5	1.410	1.084	1.479

The average values of the parameter R_a, obtained during the first measurement, are placed in Fig. 2. The graph in Fig. 2 accurately depicts the differences in the value of parameter R_a after collecting one layer of material from each shaft, using the same turning parameters and other cutting inserts.

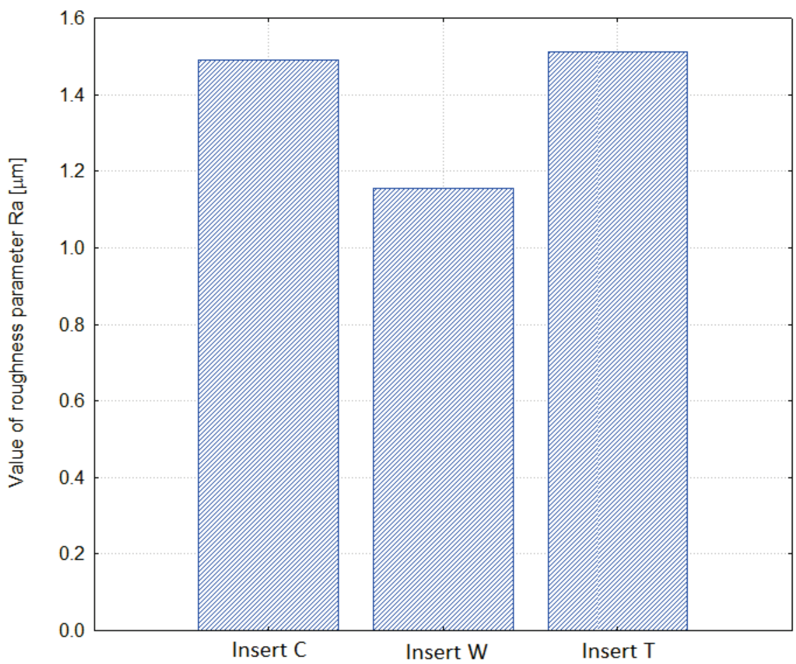

Fig. 2. The graph of the first measurement results with the averaged values of the parameter R_a

The results of the second measurement of the mean arithmetic deviation of the surface roughness profile from the centre line of the profile are presented in Tab. 3. The smallest value of the R_a parameter of 1.132 µm was obtained using a trigonal cutting insert (W). The highest measurement value is 2.026 µm and it was obtained using a triangular shaped cutting insert (T). The values of parameter R_a using all plates increased compared to the first measurement.

Tab. 3. The results of the second measurement of parameter R_a

Measurement 2 [µm]			
Measurement position	Rhombic insert (C)	Trigonal insert (W)	Triangular insert (T)
1	1.783	1.523	2.026
2	1.710	1.427	1.934
3	1.619	1.318	1.956
4	1.475	1.132	1.955
5	1.477	1.149	1.912

The averaged values of the R_a, parameter obtained during the second measurement are placed in Fig. 3. The graph in Fig. 3 precisely illustrates the change in the mean value of the arithmetic deviation of the surface roughness profile from the centre line of the profile after collecting five layers of material from each shaft, using the same turning parameters. A larger difference in the parameter value between the triangular (T) and rhombic (C) cutting inserts is noticeable. The value of the R_a parameter still using the triangle-cutting insert (W) is smaller compared to the triangular (T) and rhombic (C) cutting inserts.

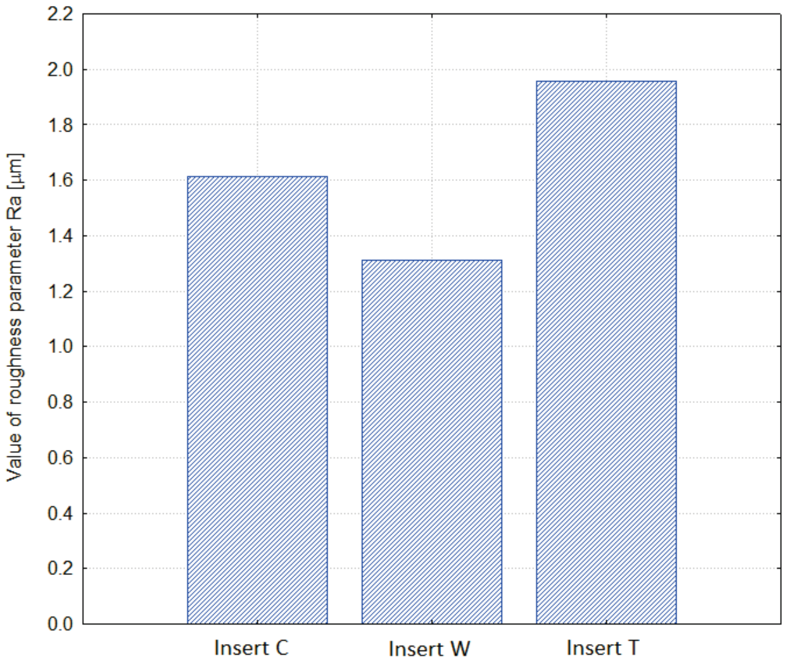

Fig. 3. The graph of the second measurement results with the averaged values of the parameter R_a

The results of the third measurement of the mean arithmetic deviation of the surface roughness profile from the centreline of the profile are presented in Tab. 4. The smallest value of the R_a parameter of 0.931 µm was obtained using a trigonal cutting insert (W). The largest measurement value of 2.334 µm obtained using a triangular cutting insert (T). After the third turning treatment, where nine material layers were collected using the same turning parameters, the R_a parameter values increased by using triangular (T) and rhombic shaped (C) cutting inserts, while using a trigonal cutting insert (W) the values decreased.

The average values of the R_a parameter obtained during the third measurement are placed in Fig. 4. It is noticeable that the R_a parameter changes after collecting the next nine layers of material from each shaft using the same turning parameters. The difference in the value of parameter R_a between the surfaces of the rollers after the use of cutting inserts of a different shape significantly increased. In the case of using a tribological cutting insert (W), the roughness values are reduced and are much smaller than the other values. In order to determine differences in the results of measurements of the average arithmetical deviation of the surface roughness profile from the centre line of the profile, the basic descriptive statistics performed in the Statistica program were used. Descriptive statistics are included in Tab. 5. It was noted that, for all measurements of the R_a parameter, the smallest values were obtained using a trigonal cutting insert (W). The R_a parameter using the rhombic shaped (C) and triangular (T) cutting insert increases with each subsequent measurement.

Tab. 4. The results of the third measurement of parameter R_a

Measurement 3 [µm]			
Measurement position	Rhombic insert (C)	Trigonal insert (W)	Triangular insert (T)
1	1.799	1.129	2.334
2	1.744	1.195	2.299
3	1.639	0.948	2.178
4	1.653	0.931	2.145
5	1.712	0.952	2.116

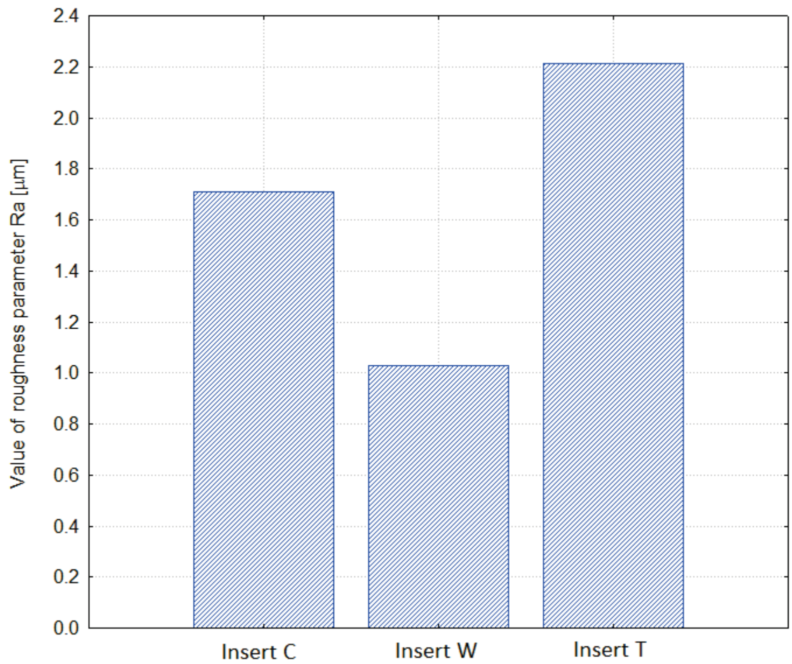

Fig. 4. The graph of the third measurement results with the averaged values of the parameter R_a

5. Conclusions

The article presents the results of research on the influence of the shape of the cutting insert used during medium-fine turning of 316L stainless steel on the R_a parameter, describing the arithmetic mean deviation of the surface roughness profile from the centreline of the profile. During turning machining with identical conditions and turning parameters that were used during machining, plates of various shapes were used. The tests showed a difference in the obtained values of the R_a parameter.

After analysing the results, it was found that, for all measurements of the R_a parameter, the smallest values were obtained using a trigonal cutting insert (W). The R_a parameter using the rhombic shaped (C) and triangular (C) cutting insert increases with each subsequent measurement. The highest value of the R_a parameter was always present using a triangular cutting insert (T). The largest difference in the value of the parameter R_a between the cutting insert (W) and the cutting insert (T) is 1.403 µm.

Tab. 5. Descriptive statistics of the R_a parameter

Variable	Shape of the cutting insert	N important [–]	Descriptive statistics of the R_a parameter				
			Avg. [µm]	Min. [µm]	Max. [µm]	Standard deviation [µm]	Standard error [%]
Measurement 1	Insert C	5	1.4908	1.4000	1.5940	0.089181	0.039883
	Insert W	5	1.15400	1.0720	1.4220	0.150348	0.067238
	Insert T	5	1.5102	1.3880	1.6040	0.087890	0.039306
Measurement 2	Insert C	5	1.6128	1.4750	1.7830	0.137736	0.061597
	Insert W	5	1.3098	1.1320	1.5230	0.170827	0.076396
	Insert T	5	1.9566	1.9120	2.0260	0.042776	0.019130
Measurement 3	Insert C	5	1.7094	1.6390	1.7990	0.065896	0.029470
	Insert W	5	1.0310	0.9310	1.1950	0.122096	0.054603
	Insert T	5	2.2144	2.1160	2.3340	0.096547	0.043177

The tiles used were made of the same material; they also have the same radius of the corner. The difference that may affect the test results is the geometric value of the cutting insert, which is the diameter of the inscribed circle. In the case of a trigonal cutting insert (W), it is larger than the other two cutting inserts by 3.225 mm. The cutting insert with a triangular shape (T) after using which the highest measurement values were obtained differs from the other two inserts cutting the angle of the plate corner, which in its case is $\varepsilon_r = 60^o$ and in the cutting insert of the trigonal (W) and rhombic (C) shape this is $\varepsilon_r = 80^o$.

On this basis, it can be stated that the choice of the shape of the cutting insert is important and affects the surface roughness of the workpiece.

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