THE POSSIBILITIES TO REDUCE SURFACE ROUGHNESS IN PRE-ASSEMBLY FACE MILLING WITH WIPER INSERTS

Możliwości obniżenia chropowatości powierzchni w przedmontażowym frezowaniu czołowym z wykorzystaniem płytek typu Wiper

Adam FRĄCZYK ORCID: 0000-0002-3056-3141

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Abstract: In the paper, the results of the comparative studies of the surface roughness, as obtained after face milling, with the application of standard cutting inserts and Wiper inserts, have been discussed. The presented results of the studies show in what technological conditions it is possible to obtain the best effects of reducing the surface roughness.
Keywords: face milling, surface roughness, cutting plates, Wiper inserts

Streszczenie: W artykule przedstawiono wyniki badań porównawczych chropowatości powierzchni, uzyskanych po obróbce frezowania czołowego, przy wykorzystaniu standardowych płytek skrawających oraz płytek typu Wiper. Zaprezentowane rezultaty badań pokazują, w jakich warunkach technologicznych obróbki można uzyskać najlepsze efekty obniżenia chropowatości powierzchni.
Słowa kluczowe: frezowanie czołowe, chropowatość powierzchni, płytki skrawające, Wiper

Introduction

Milling is one of the most frequently employed methods of machining. Nowadays, owing to a wide application of CNC machine tools and modern too materials, we may replace grinding with milling as a finishing in technological process of manufacture. To this end, we should optimally choose the technological machining parameters to the applied tool and the treated material. On the grounds of, *inter alia*, literature analysis [4, 6, 7, 9, 16] it may be observed that there are many studies concerning the effect and optimization of the technological machining parameters on the quality of the treated surface in the case of different metal alloys.

The utilization of smoothing Wiper inserts in the machining process, recommended by tool producers, is another method for improvement of the treated surface quality.

The mentioned aspect inclined the author of the paper to check to what degree the application of Wiper inserts affects the lowering of the surface roughness parameters in the case of treatment of two different species of steel.

The methodology of the studies

To examine the advantages resulting from the application of Wiper inserts, two types of steel were subjected to treatment: low-alloy steel S355JR (acc. to PN-18G2A) and tool alloy steel for hot work X40CrMoV511 (acc. to PN-WCLV).

The machining was carried out in 3-axial vertical milling machine CNC Mori Seiki DURA VERTICAL 5080.

Face milling cutter by Mitsubishi Materials marked as ASX445-063A05R, with number of edges=5, was used as a tool. The mentioned device employs cutting inserts with a positive geometry and rake angle 20°; the major cutting-edge angle is 45°. According to the producer's information, the mentioned head has a universal application – it is intended for rough and finishing (end) face milling of the alloys of light metals, cast iron, carbon steel and alloy steel, stainless steel and hardened steels [11].

On the conducted experiment, two types of inserts produced by Mitsubishi were used. The standard cutting inserts marked as SEMT13T3AGSN-JM, VP15TF type and the smoothing inserts of WIPER type – WEEW13T3AGER8C were applied. The both types of the inserts had a coverage (Al, Ti) N [12]. In the case of smoothing Wiper inserts, it is sufficient to install one insert in the milling head on order to improve the quality of the treated surface. It is important to ensure that the feed per revolution is not greater than the width of the smoothing edge of the insert [10].

The treatment was performed in two variants of technological parameters:

- Variable feed per tooth f_z, constant cutting speed V_c, constant depth of cutting α_p,
- Variable cutting speed V_c, constant minute feed f, constant depth of cutting α_p.

Tab.1. Variants and technological parameters of machining

Variant I of the machining			Variant II of the machining		
a_p [mm]	f_z [mm/z]	V_c [m/min]	a_p [mm]	f [mm/min]	V_c [m/min]
	0.05				80
	0.1				120
0,4	0.15	160	0,4	606	160
	0.2				200
	0.3				240

For the needs of the experiment, it was decided to extend the range of the feed by value of f_z =0.05 mm/tooth in relation to the parameters, recommended by the producer. The comparison of the parameters, employed in the studies has been presented in Table 1.

Additionally, the following assumptions were adopted for each treatment:

- Down milling operations,
- Incomplete milling at the width α_e =0.6 D,
- Cooling of the tool with the compressed air.

The measurements of the roughness were carried out using the contact profilometer Mitutoyo SJ-210 (Fig.1). The conditions of the measurements were based, *inter alia*, on the recommendations of standards PN-ISO 4288 and PN-ISO 3274:

- The employed filter – ISO 11562,
- Length of travel – l_t = 4.8 mm
- Sample length (Cutoff) – λ_c = 0.8 mm,
- The measuring range – 360 μm,
- Velocity of the needle travel – V_t = 0.50 mm/s

Fig. 1. A view of Mitutoyo SJ 210 profilometer

To determine the necessary number of the measurements n, the preliminary studies were carried out. There were adopted: significance level α = 0.05 and the number of preliminary measurements n_0 = 10; the level of estimate error was assumed as d = 0.1. For the adopted values, the coefficient t_α = 2.262 [12] was read out. Then, the arithmetical mean $\bar{y}$ of *Ra* and *Rz*, standard deviation *S* were calculated and the number of measurements n from the following relationship was estimated [8, 12]:

$$n = \frac{t_\alpha^2 \times s^2}{d^2} \leq n_0$$

where:
n_0 = size of the preliminary test,
t_α = value of T-Student variable,
s^2 = variance from the preliminary test,
d – maximum estimate error, equal to the measurement error

Tab. 2. The results of the measurements of the preliminary tests

n_0	Steel S355	
	Ra [mm]	*Rz* [mm]
1.	1,521	8,545
2.	1,741	8,378
3.	1,813	8,265
4.	1,673	8,234
5.	1,579	7,965
6.	1,685	8,251
7.	1,668	8,344
8.	1,643	8,434
9.	1,454	8,314
10.	1,585	8,515
$\bar{y}$	**1,636**	**8,325**
S	**0,15090**	**0,165538**
S^2	**0,011043956**	**0,027402944**
n	**5,65**	**14,021**

Tab. 2 shows the results of the preliminary measurements of roughness of steel S355 subjected to the machining by head, equipped in standard cutting inserts with the following parameters: cutting speed V_c = 160 m/min., feed per tooth f_z = 0.05 mm/tooth.

On the grounds of the conducted statistical analysis, based upon the results of the preliminary measurements for parameter *Rz*, the number of the measurements was adopted with a certain reserve *n* = 16.

The results of the tests

Fig. 2 – 9 show the change in parameters 2 D of the surface roughness *Ra* and *Rz* as a function of changes in feed F_z and cutting speed V_c for standard cutting inserts and Wiper inserts. Standard deviation was given as dispersion.

The results of the surface roughness measurements for steel S355JR as illustrated in Fig. 2-5 indicate the improvement of the quality of the surface after cutting with the Wiper insert.

During the milling with the feed f_z = 0.5 mm/tooth, the difference in the surface roughness, resulting from the application of Wiper insert is practically invisible. We should however remember that the mentioned value of feed f_z is not recommended by the producer of the inserts. The highest differences in the surface roughness were obtained during the treatment with the feed f_z = 0.1 mm/tooth. It may be observed that the surface roughness as obtained after the treatment with the use of Wiper insert demonstrates a slightly declining trend together with the increase of the value of feed f_z.

The increase of the cutting velocity V_c causes a reduction in the surface roughness of steel S355JP; it is especially visible after the machining with the standard inserts and at higher cutting speed V_c >140 m/min – Fig. 4÷5.

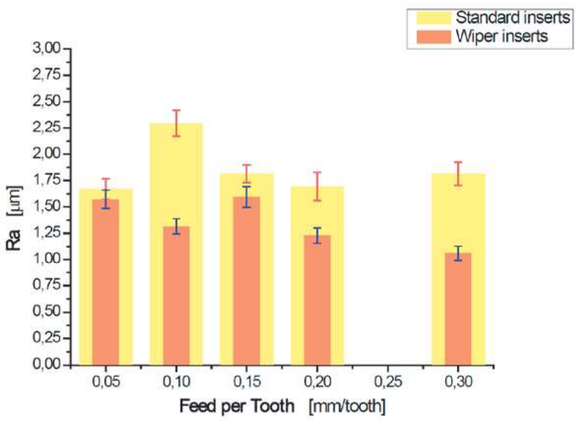

Fig. 2. The changes in the roughness parameter *Ra* for steel S355 in function of feed f_z after milling with standard inserts and Wiper inserts

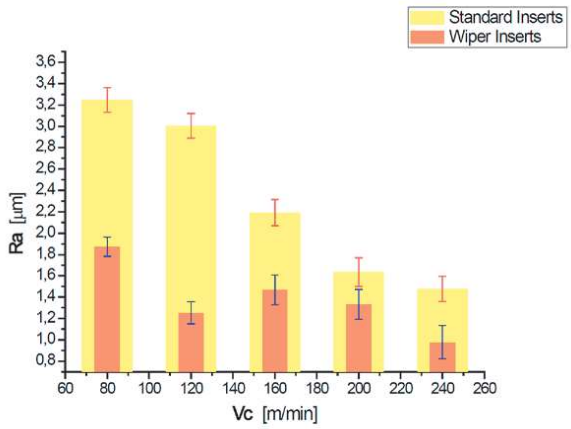

Fig. 4. The changes in the roughness parameter *Ra* for steel S355 in function of cutting speed V_c after milling with standard inserts and Wiper inserts

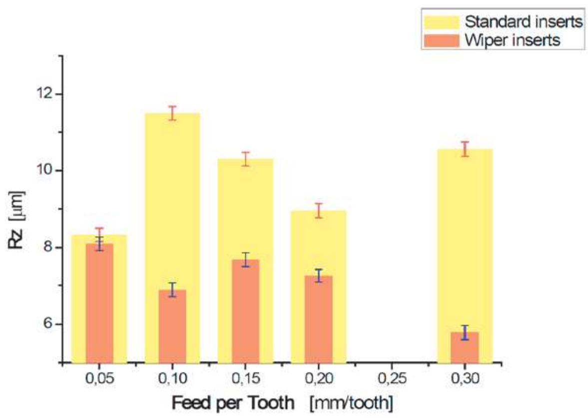

Fig. 3. The changes in the roughness parameter *Rz* for steel S355 in function of feed f_z after milling with standard inserts and Wiper inserts

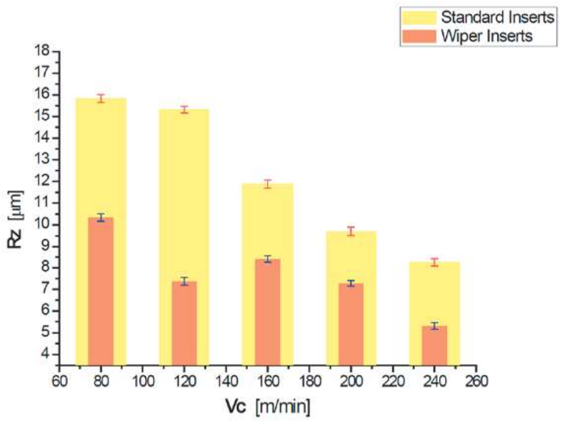

Fig. 5. The changes in the roughness parameter *Rz* for steel S355 in function of cutting speed V_c after milling with standard inserts and Wiper inserts

In the case of the machining of steel X40CrMoV511, the advantages resulting from the application of Wiper inserts are most visible – Fig. 6-8. The increase of the feed f_z in the case of the standard inserts use leads to a distinct increase of the parameters *Ra* and *Rz* – Fig. 6-7. The situation is different in the case of treatment with Wiper insert. Together with the increase of feed fz, the increase of the roughness parameters is practically not recorded. The most significant differences between the obtained parameters were found for feed f_z = 0.2 mm/tooth. After cutting with the Wiper insert, there was obtained five times lower parameter *Ra* as compared to the surface, treated by the standard inserts.

The effect of cutting speed of steel X40CrMoV511 on the surface roughness after the machining is visible in Fig. 8÷9. Together with the increase of cutting speed V_c, a small declining tendency of parameters *Ra* and *Rz* is observed.

The situation visible in Fig. 2-3 requires a separate explanation as well as in Fig. 6-7 where the increase of feed fz caused a decline in the roughness. It results probably from the fact that at lower feed velocities, the roughness becomes independent on the feed velocity and is only a function of the radius of the insert rounding and the type of the treated material [3]. It causes a higher micro-roughness, i.e. the overlapping uneven roughness on the produced grooves when removing the chips. In the area of edge, relatively more plastic flowing of the machining material is generated. Similarly when the feed is high and the corner of the insert has a small radius, the roughness of the surface is mainly dependent on the feed. The mentioned plastic flowing of the material is directed opposite to the direction of the feed and leads to formation of higher unevenness [1]. A similar phenomenon was presented in the paper [2] where a lower surface roughness occurred at higher feed due to "a clear cut" of the material and a relative lack of plastic deformations in the area of the blade work. The discussed theory may be supported by the fact that in the case of Wiper inserts, having a completely different cutting edge and the corner, the mentioned above phenomenon is practically not observed – Fig. 6-7.

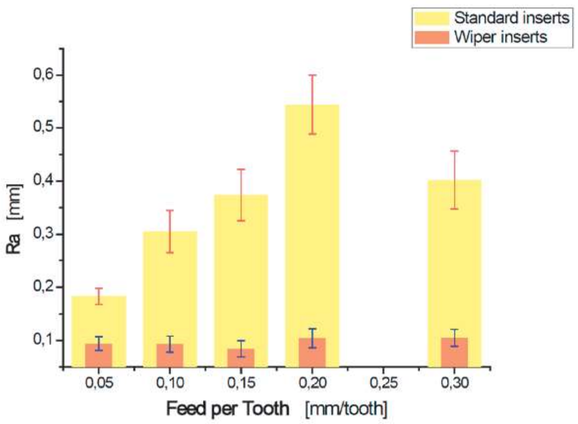

Fig. 6. The changes in the roughness parameter *Ra* for steel X40CrMoV511 in function of feed f_z after machining with standard inserts and Wiper inserts

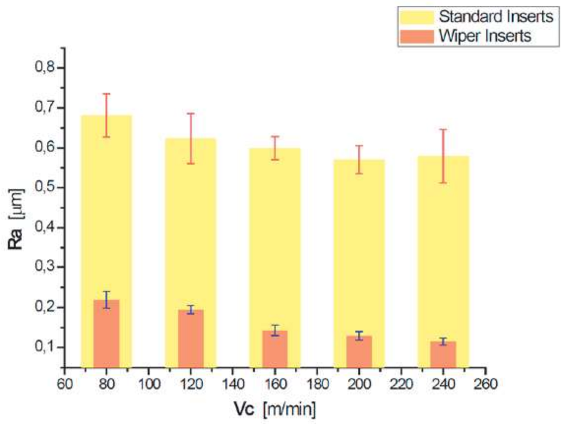

Fig. 8. The changes in the roughness parameter *Ra* for steel X40CrMoV511 in function of cutting velocity V_c after machining with standard inserts and Wiper inserts

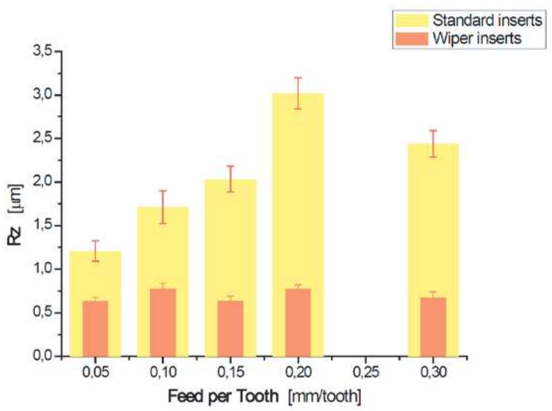

Fig. 7. The changes in the roughness parameter *Rz* for steel X40CrMoV511 in function of feed f_z after machining with standard inserts and Wiper inserts

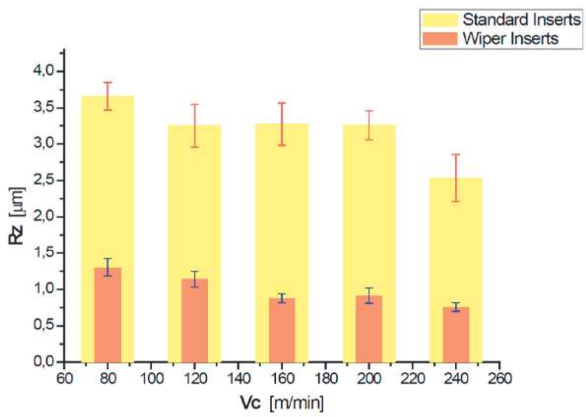

Fig. 9. The changes in the roughness parameter Rz for steel X40CrMoV511 in function of cutting speed V_c after machining with standard inserts and Wiper inserts

It should be remembered that vibrations, generated during the treatment are the reason for the changes in the surface roughness. They may cause "flattening" of the traces after the machining due to the relative vibrations of the tool's work [14].

Summary and concluisions

The conducted tests allowed carrying out the general verification of advantages coming form the application of smoothing inserts during the process of face milling as affected by the variable technological parameters V_c and f_z. On the grounds of the above, it is possible to formulate the following conclusions:

1. The application of cutting Wiper inserts in the process of face milling allows obtaining the lower surface roughness as compared to the machining with the standard inserts.
2. The decline in the surface roughness after the machining with the application of a single Wiper insert is dependent on the type of the steel. A considerable improvement of the surface quality is observed after the machining of the alloy steel.
3. In the case of using Wipert inserts, the increase in the feed value allows maintaining a low value of roughness what may be manifested in the increase of productivity, especially in the conditions of series and mass manufacture of the products.
4. The increase of the feed value in certain circumstances of the blade work may also lead to the lowering of the roughness of the surface after machining.

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Dr inż. Adam Frączyk
Department of Materials and Machine Technology
University of Warmia and Mazury in Olsztyn, Poland
e-mail: adam.fraczyk@uwm.edu.pl

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