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Influence of the machining parameters on the geometry of surfaces formed by face-milling with a milling head

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Abstract

The process of surface generation is complex and depends on numerous factors. The geometry of a surface is described by the sum of all irregularities of the actual surface, i.e. deviations in form, waviness and roughness. This study focuses on determining the influence of selected cutting parameters on the surface geometry of three materials. The laboratory face milling tests were conducted using a milling head with round-nose tools.

Keywords: cutting, roughness, waviness, straightness, face milling.

Wpływ parametrów skrawania na strukturę geometryczną powierzchni frezowanej czołowo głowicą frezową

Streszczenie

Proces powstawania struktury geometrycznej powierzchni (SPG) jest bardzo złożony i wpływa na niego wiele czynników. Strukturę geometryczną powierzchni opisuje zbiór wszystkich nierówności powierzchni rzeczywistej tj., odchyłki kształtu, falistości, chropowatości. Podjęto próbę określenia wpływu wybranych parametrów skrawania na strukturę geometryczną powierzchni dla różnych materiałów obrabianych. Przeprowadzono badania laboratoryjne frezowania czołowego głowicą frezową z ostrzami o zaokrąglonym narożu.

Słowa kluczowe: skrawanie, chropowatość, falistość, prostoliniowość powierzchni, frezowanie czołowe.

1. Introduction

Machining is still the most common of the manufacturing technologies. Although the dimensions and the outer layer of a product or machine part change, it is envisaged that machining will be employed increasingly whenever precision or high precision is required [1].

The advances in the design of numerically controlled machine tools and the application of better cutting materials cause that the accuracy of the machining process, especially turning and milling, is higher. Products do not require any superfinishing, which may have a direct effect on their function [2, 3].

In the last few years, numerically controlled machine tools have been used more and more frequently for face milling and similar operations. The applications include simple flat surfaces, certain dies and even rotor vanes. The face milling process combined with the numerical control and the CAD/CAM programs ensures high efficiency, very high dimensional and form accuracy and low roughness even in the case of curvilinear surfaces [4].

The surface quality is one of the most important features of a product. It accounts for the product durability, friction, wear, quality of the mating parts as well as the functional and aesthetic properties [5].

Every object subjected to machining shows deviations from its ideal nominal form. Producing geometrically ideal surfaces is not possible, and producing close to geometrically ideal surfaces is becoming more and more expensive. Deviations from the geometrically accurate surface can have a significant effect on the product subsequent characteristics, e.g. wear resistance, stick and slip lubrication properties, fatigue strength, corrosion resistance, etc..

As can be seen, surface formation by face milling with milling heads is a complex problem. The findings show that to determine the factors affecting surface quality is extremely important. Emphasis should be placed on establishing the effect of the machining parameters on the surface formation.

This paper presents selected test results concerning the influence of selected machining parameters on the surface quality in face milling with round-nose tools.

2. Laboratory tests concerning face milling with a milling head

2.1. Objectives, materials and methods

The aim of the study was to establish the effect of selected machining parameters on the roughness, waviness and straightness of face milled surfaces. The tests were conducted at the laboratories of the Kielce University of Technology.

The study was divided into three stages. The first part, i.e. the machining, was performed at the Laboratory of Numerically Controlled Machine Tools. The MASTERCAM program was employed to prepare the specimen geometry and generate the CNC machining programs. The programs were transmitted to a CNC Triac 200 milling machine, which was used for the machining process. Three materials were tested: steel 15, steel 45 and MO58 brass. The specimens were cut with a DOLFAMEX 220.17-40 milling head [6] equipped with three BAILDONIT TPKN 1603 PP-R carbide inserts. The coolant applied during the process was Castrol Syntilo RHS.

The machining parameters are given in Table 1. The machining process was performed by changing either the feed or the cutting speed (the so-called one-factor-selection program).

Tab. 1. Zestawienie parametrów skrawania zastosowanych podczas badań
Tab. 1. Machining parameters during the tests

MACHINING CONDITIONS FOR THE ANALYZED SPECIMENS	
feed rate f_z [mm/tooth]	0.04; 0.08; 0.12; 0.16; 0.20; 0.24; 0.28
cutting speed v_c [m/min]	80; 120; 160; 200; 240; 280
cutter diameter d [mm]	40

A change in the cutting speed was achieved by adjusting the rotational speed of the spindle, while a change in the feed was achieved by adjusting the feed rate per minute.

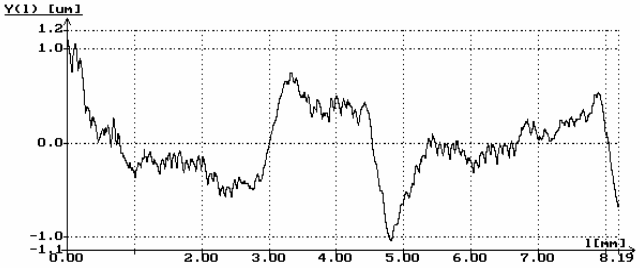
The second part of the study concerned roughness. The measurement was conducted with a PM-03 profilometer [8]. The following parameters were measured: *Ra (arithmetic mean profile deviation from the mean line), Rq (mean square profile deviation from the mean line)* and *Rm (maximum height of unevenness)*. The power spectral density function (PSDF) was also analyzed.

Then, the tests were conducted by means of a Taylor Hobson Talysurf 4 profilometer operating with a program called SUFORM [7]. It was a complex measurement of about a dozen roughness, waviness and straightness parameters. The results including sets of coordinates, a load capacity curve and a power spectrum were represented graphically as a set of diagrams corresponding to the registered roughness profile.

Some of the results are presented below in the form of diagrams. The diagrams include curves illustrating the correlations between the surface unevenness heights (the roughness profilogram) and the corresponding diagrams of the power spectral density function (PSDF), the lateral roughness *Ra*, the waviness *Wa* (*arithmetic mean of the waviness profile ordinates*), the straightness *Pa* (*arithmetic mean of the primary profile ordinates*) at the changeable feed per tooth f_z and the cutting speed v_c. The diagrams include columns of errors specifying the scatter of results, errors of form, waviness, roughness and the identified lines corresponding to the values of the feed per revolution and feed per tooth.

2.2. Results and discussion

Figures 1 and 2 show a lateral profilogram and the corresponding diagrams of the standardized unilateral power spectral density function. The spectral lines in the diagram of the power spectral density function show which part of the power coincides with a given value of frequency.

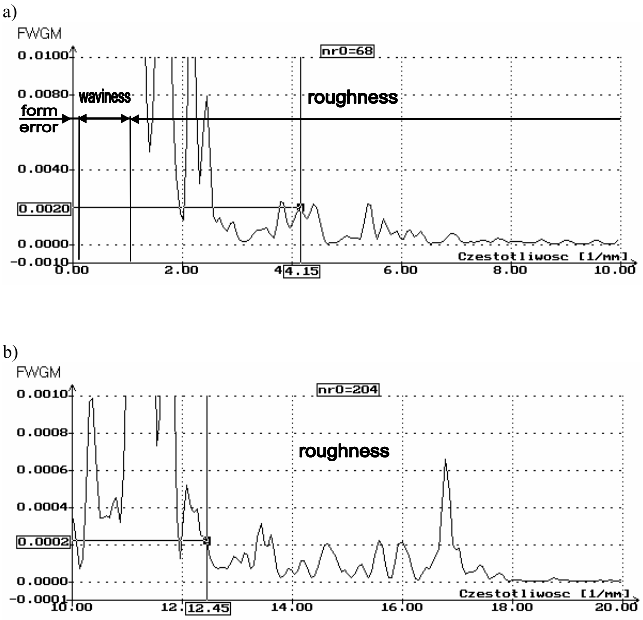


Ra=0.6867 *Rq*=0.8233 *Rm*=3.0575

Rys. 1. Profilogram poprzeczny. Warunki obróbki: f_z=0,08 mm/ostrze, v_c=200 m/min, a_p=0,20 mm, średnica frezu d=40 mm, materiał obrabiany stal 45, frezowanie czołowe

Fig. 1. Lateral profilogram. Milling conditions: f_z=0.08 mm/tooth, v_c=200 m/min, a_p=0.20 mm, cutter diameter d=40 mm; material - steel 45, method - face milling

In Figures 2a and 2b presenting the power spectral density function after standardization. we identified spectral lines corresponding to the feed per revolution (Figure 2a), spectral lines corresponding to the feed per tooth (Figure 2b) and spectral lines of their subsequent harmonic components (specially marked in both diagrams). The spectral line with a frequency of 4.15 in Figure 2a corresponds to the feed per revolution *f* equal to 0.24 [mm/rev]. They are located in the roughness range, which shows that for the given machining parameters the feed affects the surface roughness. In Figure 2b, where the power spectral density function is amplified, the marked line with a frequency of 12.45 corresponds to the feed per tooth f_z equal to 0.08 [mm/tooth].

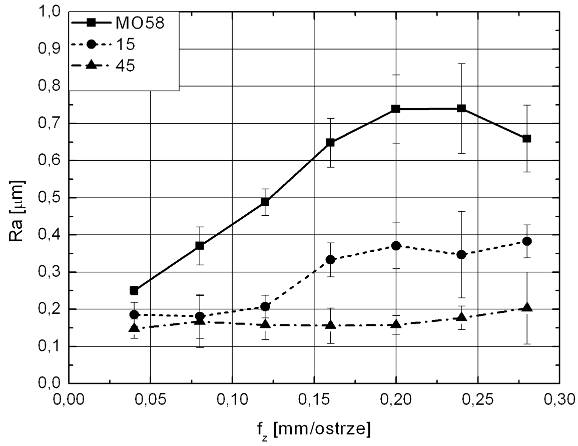


Rys. 2. Wykres znormalizowanej jednostronnej funkcji widmowej gęstości mocy. Warunki obróbki - jak na rys. 1: a) profilu ze zidentyfikowanym prążkiem odpowiadającemu posuwowi na ostrze; b) wzmocniony wykres znormalizowanej jednostronnej funkcji widmowej gęstości profilu ze zidentyfikowanym prążkiem odpowiadającemu posuwowi na obrót

Fig. 2. Diagram of the standardized unilateral power spectral density function. Milling conditions like in Figure 1; a) profile with the identified spectral line corresponding to the feed per tooth; b) amplified diagram of the standardized unilateral power spectral density function;, profile with the identified spectral line corresponding to the feed per revolution

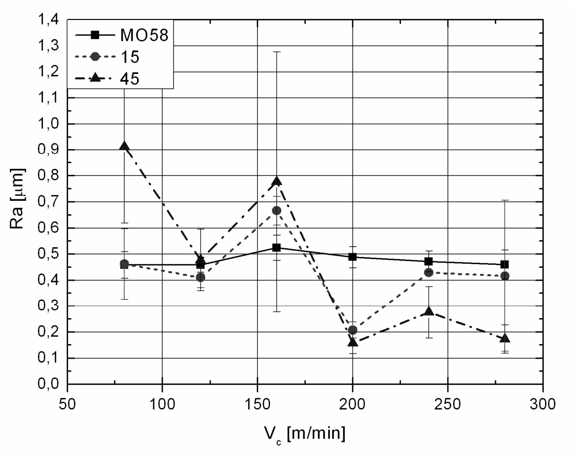
Analyzing Figure 3, one can see that when the feed per tooth f_z rises, the parameter *Ra* for MO58 brass rises, too. For steel 15, it increases slightly and for steel 45 it stays steady. The roughness *Ra* for steel 45 was the lowest. For steel 15 it was higher, and for MO58 brass it was the highest.

Figure 4 shows that there is no visible influence of the cutting speed on the roughness *Ra*. For MO58 brass specimens, the roughness *Ra* remains nearly constant, and for steel 15 and 45 it alternately falls and rises, with the slightly downward trend being predominant.



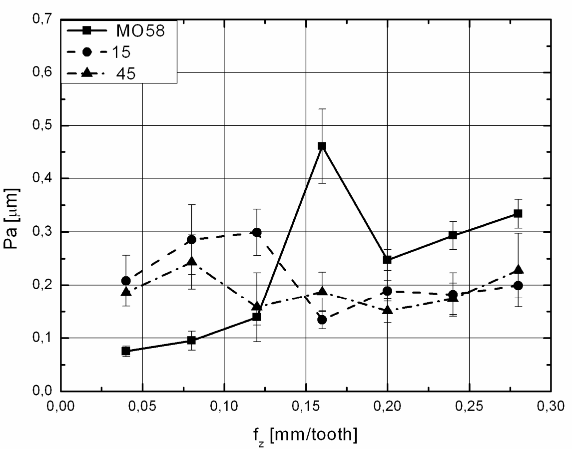
Rys. 3. Wpływ posuwu na chropowatość Ra powierzchni dla mosiądzu MO58, stali 15 i 45. Warunki obróbki: v_c = 200 m/min, a_p = 0.2 mm

Fig. 3. Feed rate vs. surface roughness Ra for MO58 brass and steel 15 and 45. Milling conditions: v_c = 200 m/min, a_p = 0.2 mm



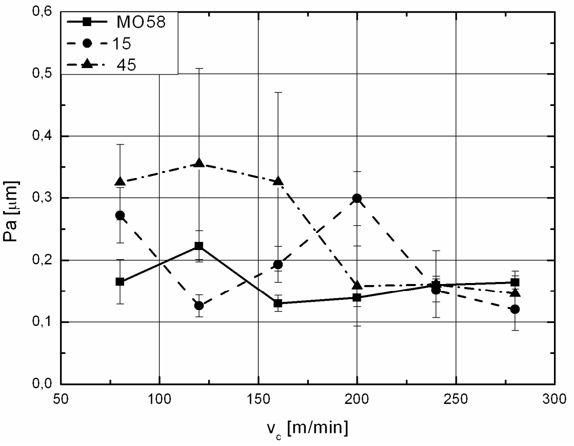
Rys. 4. Wpływ prędkości skrawania na chropowatość Ra powierzchni dla mosiądzu MO58, stali 15 i 45. Warunki obróbki: f_z = 0.12 mm/ostrz, a_p = 0.2 mm

Fig. 4. Cutting speed vs. surface roughness Ra for MO58 brass and steel 15 and 45. Milling conditions: f_z = 0.12 mm/tooth, a_p = 0.2 mm



Rys. 5. Wpływ posuwu na liniowość Pa powierzchni dla mosiądzu MO58, stali 15 i 45. Warunki obróbki: v_c = 200 m/min, a_p = 0.2 mm

Fig. 5. Feed rate vs. surface straightness Pa for MO58 brass and steel 15 and 45. Milling conditions: v_c = 200 m/min, a_p = 0.2 mm



Rys. 6. Wpływ prędkości skrawania na liniowość Pa powierzchni dla mosiądzu MO58, stali 15 i 45. Warunki obróbki: f_z = 0.12 mm/ostrz, a_p = 0.2 mm

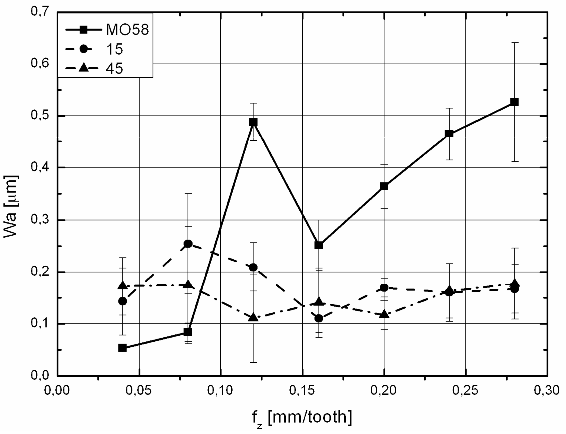
Fig. 6. Cutting speed vs. surface straightness Pa for MO58 brass and steel 15 and 45. Milling conditions: f_z = 0.12 nmm/tooth, a_p = 0.2 mm

From Figure 5 it is clear that a change in the feed per tooth f_z has an effect on the surface straightness. An increase in the feed rate results in an increase in the parameter *Pa* for MO58 brass. For steel 15 the influence is not clearly defined. In the case of steel 45, the impact is small. The value of the parameter *Pa* for steel 45 changes slightly, by about 0.1 µm.

As one can see in Figure 6, the influence of the cutting speed on the straightness *Pa* is different and depends on the material. For MO58 brass, an increase in the cutting speed leads first to a slight increase and a fall of the parameter *Pa*, and then to a slight yet gradual increase. For steel 15 the effect of the cutting speed on the surface straightness is not clear. For steel 45, there is a visible drop in the parameter *Pa* when the cutting speed rises.

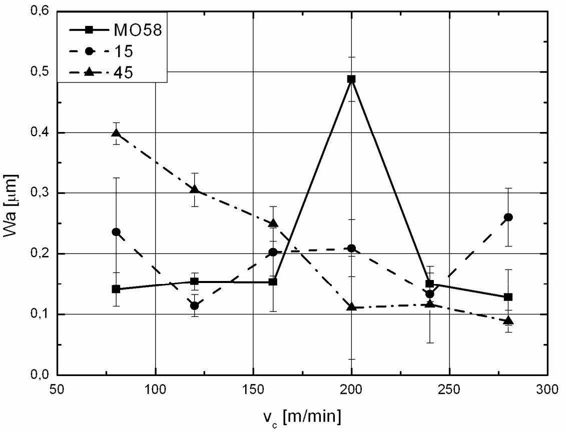
The last two Figures, 7 and 8, show the influence of the feed and the cutting speed on the surface waviness, *Wa*. In Figure 7, we can see that the feed considerably affects the surface waviness of the MO58 brass specimens. In the case of steel 15 and 45, the influence is small. Steel 15 is reported to be slightly more sensitive to a rise in the feed.

As can be seen from Figure 8, an increase in the cutting speed has the most favourable effect on steel 45, which is due to the fact that only for this material did we observe a fall in the value of the parameter *Wa*. For steel 15, it was found that the influence of the cutting speed was not clear; the parameter *Wa* fluctuated around 0.2 µm. The results obtained for MO58 brass showed that when the cutting speed equalled 200 m/min, the value of the parameter *Wa* was the highest. For the other values of the speed range, *Wa* remained steady at about 0.15 µm.



Rys. 7. Wpływ posuwu na falistość Wa powierzchni dla mosiądzu MO58, stali 15 i 45. Warunki obróbki: v_c = 200 m/min, a_p = 0.2 mm

Fig. 7. Feed rate vs. surface waviness Wa for MO58 brass and steel 15 and 45. Milling conditions: v_c = 200 m/min, a_p = 0.2 mm



Rys. 8. Wpływ prędkości skrawania na falistość Wa powierzchni dla mosiądzu MO58, stali 15 i 45. Warunki obróbki: f_z = 0.12 mm/ostrz, a_p = 0.2 mm

Fig. 8. Cutting speed vs. surface waviness Wa for MO58 brass and steel 15 and 45. Milling conditions: f_z = 0.12 mm/tooth, a_p = 0.2 mm

3. Conclusions

The following conclusions were drawn from the analysis and the test results:

1) The feed rate had a significant effect on the surface quality of brass specimens. After increasing the feed, one could observe a rise in Ra, Wa, and Pa. For steel 15 and 45, the influence was equally high. The best surface quality for steel was obtained when the feed was approximately 0.15 mm/tooth.
2) The effect of the cutting speed on the parameters describing the surface geometry is not that clear. The analysis shows that the brass specimens were less affected than the steel ones. However, when the cutting speed was about 200 m/min, the parameter Wa was the highest. For steel 15 no clear trend was observed. Analysing the samples made of steel 45, one could see that the higher the cutting speed, the lower the parameters Ra, Wa and Pa, to a different degree though.
3) The spectral lines show the ranges of feed in which the surface irregularities form. The diagrams of the power spectral density function of a surface profile confirm that there is some indirect relationship between the machining parameters and the geometry of surfaces whenever the machining process involves vibrations.
4) The diagrams of the spectral power density function show lines with a frequency corresponding to the value of the feed per tooth and the feed per revolution. The lines of the subsequent harmonics provide us with information on the ranges of feed for which the machining process results in the formation of surface roughness, waviness or in a form error.

The work was presented at the IV. International Congress on Precision Machining – ICPM 2007, Sandomierz-Kielce, September 2007

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Artykuł recenzowany

INFORMACJE

Studia Podyplomowe

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Organizacja i Akredytacja Laboratoriów

Studia prowadzone są na Wydziale Elektrycznym Politechniki Śląskiej w Gliwicach, w systemie zaocznym w każdą sobotę lub w co drugi weekend (do wyboru) przez dwa semestry. Zajęcia prowadzone są przez nauczycieli akademickich ze stopniem co najmniej doktora oraz przez zaproszonych Gości o uznanym dorobku i autorytecie. Studia obejmują 200 godzin dydaktycznych. Rozpoczęcie Studiów nastąpi po skompletowaniu odpowiedniej liczby kandydatów na dany rodzaj studiów.

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