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Influence of Unequal Flute Spacing on the Nature of the Mill's Work and Technological Effects of the Process

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Abstract: The article discusses the influence of unequal flute spacing of the end mills' cutting edges on surface roughness as well as on forces generated during the processing. Presented study results apply to stainless steel 2H13 (X20Cr13).

Keywords: unequal flute spacing, milling, surface roughness, forces

1. Introduction

Ever higher quality requirements for processed details in combination with a focus on reducing production costs significantly affect the selection of the right technology. To meet these requirements new solutions are searched both in terms of material engineering and micro and macro geometry of the cutting edges. These activities directly translate into increased stability of processing, a significant increase in the durability of tools, improving the quality of the produced parts while increasing efficiency [1, 3].

Demand for high-quality products involves more and more often the use of modern, difficult- to-cut construction materials. Particularly a stainless steel has gained in popularity over the past sixteen years [4]. Its production has increased nearly 140% [4] and that is probably just the beginning. This is due to the advantages of the material such as resistance to corrosion and chemicals, as well as the resistance to temperature changes and long life cycle [4, 5, 10].

Depending on the type of stainless steel, machining can be accompanied by problems associated with a tendency for strain hardening and the creation of built-up during the cut. High ductility promotes the formation of long chips, which can pose a threat for the tool and the surface. A small heat conductivity affects its discharge from the cutting area contributing to a considerable temperature rise [6, 7, 8]. The main factor that determines the quality of the processed surfaces and the performance of the cutting process, particularly hard-to-cut materials, is the correct selection of cutting tools [8, 9, 10].

The aim of the studies presented in the publication was to determine the influence of unequal flute spacing of the end mills' cutting edges on the technological effects of the milling process. Continuous load recording and surface roughness measurements allowed for the unambiguous definition of the usefulness of such a solution in the industrial conditions.

2. Test stand and research methodology

Two Ø8 mm diameter cutters made of solid carbide has been examined. Both mills are made of the same material, have the same geometry, the same number of flutes, diameter and length (Table 1). The difference lies in the use of unequal flute spacing. The cutters are made of material with a hardness of 1620 HV, belonging to a group of carbide K20-K40. Table 1 shows basic information about these tools.

Table 1. *Technical information about examined tools [2].*

Cutter number	1	2
Tool material	VHM K20-K40	
Diameter [mm]	8	
Number of blades	6	
Total length [mm]	63	
The length of the working part [mm]	19	
The sprain angle of the chip flutes [°]	45	44, 45,46
Corner	Chamfer 0,1×45°	

Figure 1 shows the characteristics of the specificities of the cutters with unequal flute spacing, while Figure 2 shows the tested cutter with the sprain angle of the chip flutes of 45°.

Figure 1. Variable sprain angle of the chip flutes [2].

The material used in the research was high-chromium stainless steel with martensitic structure 2H13 (X20Cr13 according to DIN). Before the milling the sample was milled with milling cutter to standardize the roughness of surface, which allowed to simulate the finishing processing in next step. Surface roughness before milling with tested tools was Ra 0,4 μm.

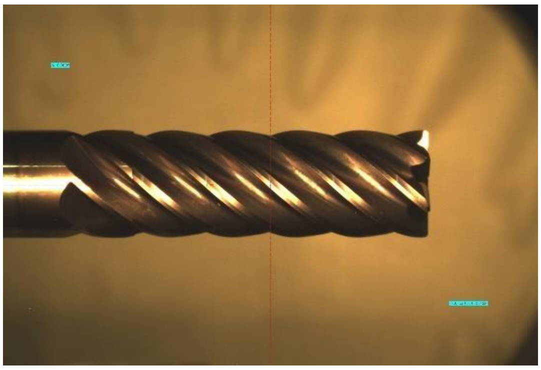


Figure 2. Tested cutter no 1.

The experiment was carried out on the milling machine Hass TM-1 p (Figure 3). Tools were set to the ER collet, cooling with Blascout 2000 Universal emulsion was used. Moreover, cutting width was a_e= 0.5 mm when the depth equaled a_p= 15 mm. Cutters worked concurrently with a combination of cutting speeds of 140, 130, 120, and 110 m/min and feed of 0,15, 0,1 and 0,05 mm/rev.

Figure 3. Hass TM-1P.4

In the course of processing the measurement of cutting forces in continuous mode was made with the help of the piezoelectric triple component dynamometer Kistler 0257A. The appearance of the dynamometer and the manner of its mounting on the machine are shown in the following photos.

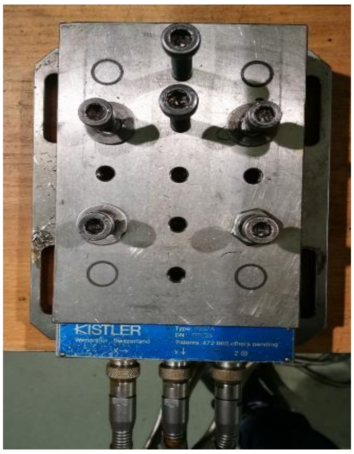


Figure 4. Piezoelectric dynamometer

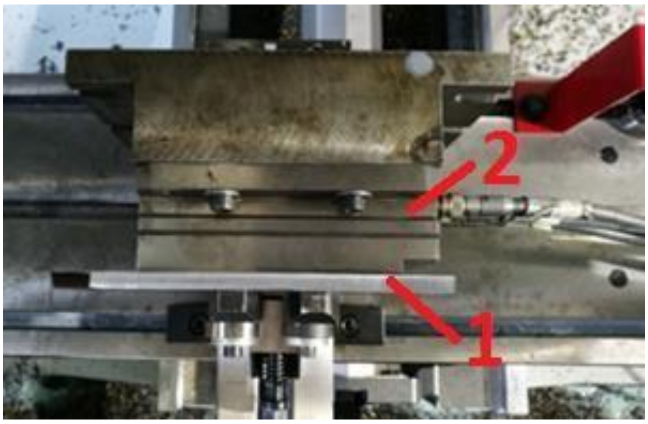


Figure 5. The mounting of the sample and dynamometer (1- sample, 2- dynamometer).

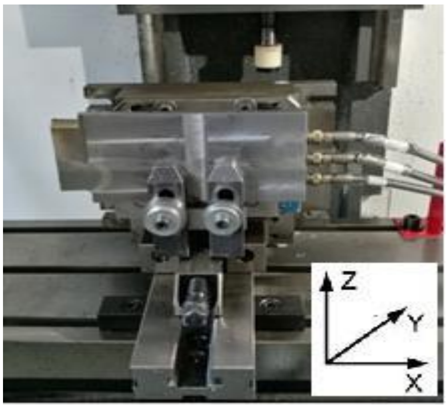


Figure 6. The mounting of the sample and dynamometer.

Figure 7. The measurement profilometer Hommel Tester T1000.

After the milling process was finished the samples' surface roughness was tested with portable measuring profilometer Hommel Tester T1000 (Figure 7).

3. Research results

The research tried to answer the question whether changing the flute spacing of cutter can impact significantly on the technological effects of the process by damping the vibrations caused by the work of the individual blades.

The influence of cutting parameters on the surface roughness

It has been decided to present surface roughness with the help of parameters Ra and Rz widely popularized in the industry. Individual results are the average of three conducted measurements. The following chart shows the effect of technological parameters on achieved values of altitude parameters.

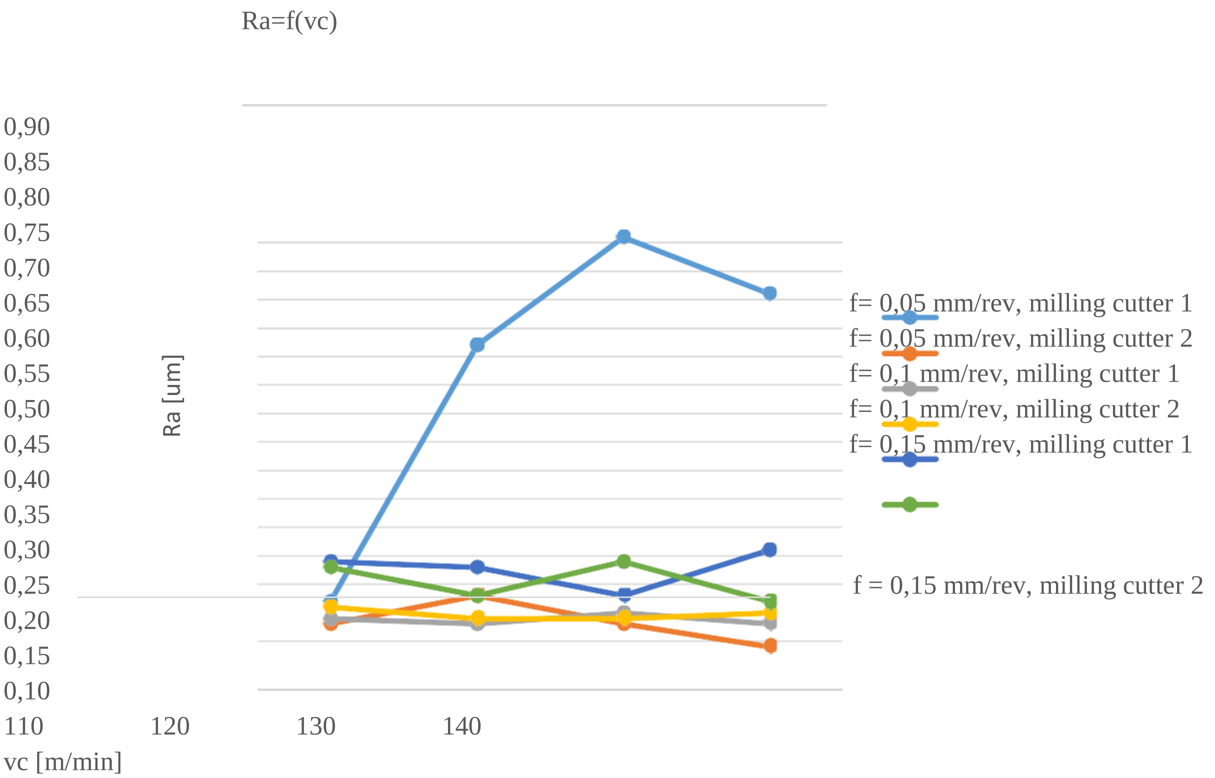


Figure 8. Chart presenting roughness parameter Ra in the function of cutting speed

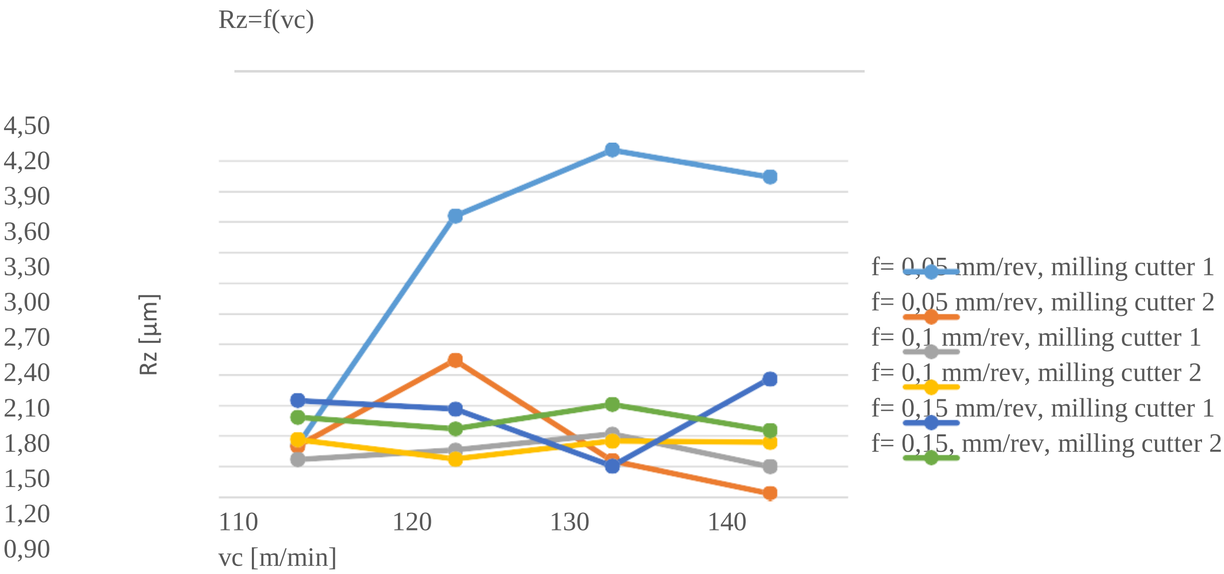


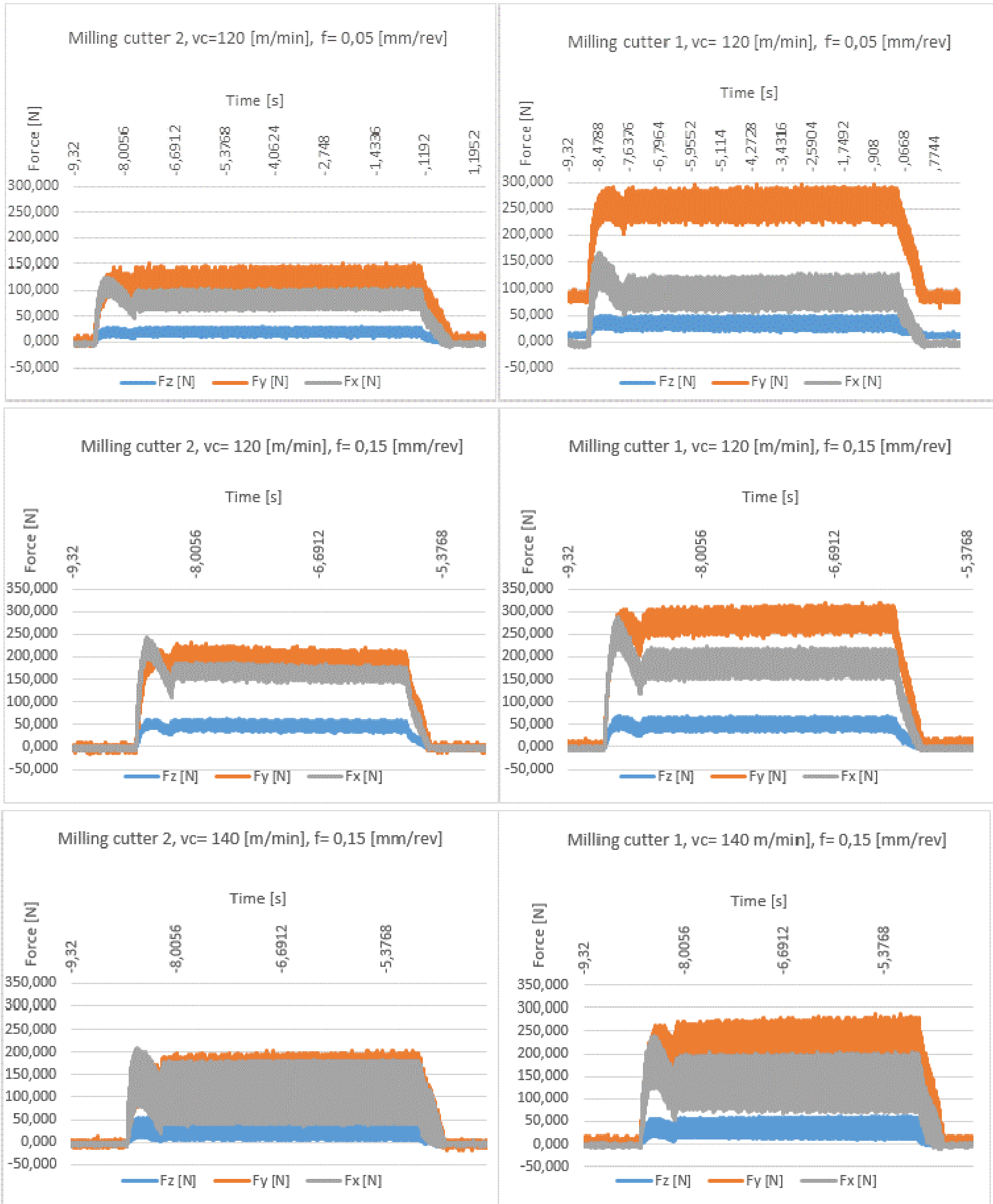
Figure 9. Chart presenting roughness parameter Rz in the function of cutting speed

By analyzing above charts one may notice that the parameters of the Ra and Rz in most tested cases are very similar to each other after cutter treatment both with and without unequal flute spacing.

It is suspected that elicitation of very close results is associated with use of relatively low feed speed and very fixed machine-tool-workpiece system. Only in the case of processing with feed of 0,05 mm/rev. both of these parameters are much higher after the cutting without unequal flute spacing (Ra higher by 542% and Rz higher by 429% at cutting speed of 130 m/min).

a. Influence of cutting parameters on course of force

The diagrams below show selected courses of cutting force while cutter work.



By analyzing the presented charts one may notice that at the beginning of the forces measurements appears a sudden increase (in particular in the direction of the X axis). Then there is a sharp decline and stabilization. This is connected with the cutter work strategy. In the initial stage of work the cutter enters the material to the desired value of the parameter a_e and only after reaching this value starts to move towards the X axis direction. As expected, in each case the axial component (Z axis) is characterized by the lowest force values and they are identical for both of the tested tools. The values of the feed component (X axis) in the case of both tools are at a similar level, but you can notice a significant values dispersion in the case of tools with fixed flute spacing. In turn, the thrust cutting force (Y axis) every time is characterized by a substantially lower values in the case of unequal spacing tool. Differences in the recorded values equal almost 50% - in the case of processing at cutting speed 120 m/min, and a feed of 0,05 mm/rev thrust cutting force was on average 125 N for tools with unequal flute spacing and 250 N for fixed flute spacing.

4. Conclusions

In the analysis of the influence of the unequal flute spacing of cutting edges on the surface roughness only in one case considerable improvement roughness was noted (during treatment with 0,05 mm/rev). Processing with the other set of technological parameters showed no significant differences.

Measurement of cutting force components showed significant differences between the two cutters. Compared to a cutter with unequal flute spacing, during milling with a fixed flute spacing cutter every time there appear larger forces in the Y direction which may have significant impact on the achieved durability of tools. This makes it possible to use unequal flute spacing cutters on less powerful machines, as well as not very rigid machines or in the case of unstable cutting conditions (e.g. thin-walled parts processing or an unstable way of fastening).

The lack of any correlation between surface roughness and cutting forces may result from the use of the "safe" technological parameters (in particular from low feed speed), a very good technical machine condition and a stable way of detail fastening.

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