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EXAMINATION OF 2D AND 3D SURFACE ROUGHNESS PARAMETERS OF FACE MILLED ALUMINIUM SURFACES

Material removal with a rotating cutting tool has a series of special characteristics due to the movement relations. For face milling, looped cycloids occur, which also affects the roughness characteristics of the machined surface. This article analyses how the values of 2D and 3D roughness parameters change in symmetrical milling of flat surfaces of aluminium parts in planes parallel to the feed direction.

1 INTRODUCTION

Face milling is a high performance, widely used operation for machining flat surfaces. In recent years Wiper and CBN inserts have been introduced, which makes it possible to produce fine surfaces and efficient face milling of hardened surfaces. In the past, the goal was to achieve maximum performance, and the required surface integrity of the machined surface was also highlighted. In addition to good surface quality, to achieve the proper productivity, high-feed processes are beginning to emerge. To increase the feed rate v_f (mm/min), there are research goals and aspirations that aim at achieving values of a_p/f_z lower than 1 by increasing the feed per cutting edge and reducing the depth of cut a_p [1, 2].

There is no doubt that the changed feed rate significantly influences the shape of the cross-sectional area of the chip, the cutting forces and the surface roughness of the machined surface too. In the literature, the features of face milling, the characteristics of surface texture and the effect of cutting data on the roughness of the milled surface are widely discussed [1-4]. Parameters of technological parameters and surface integrity are examined [5]. Various models [1, 6, 7] can be used to calculate (estimate) surface roughness in face milling.

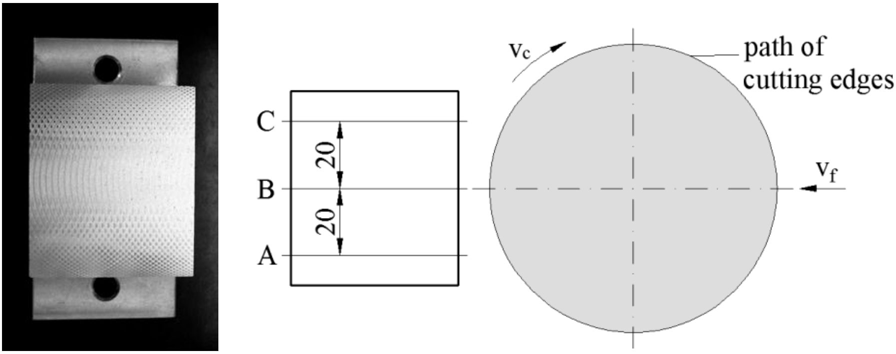
The characteristic feature of the face milling is that the rotating and feed direction movement of the tool causes the tool path to be a series of looped cycloids and chip removal is not limited to the number of cutting edges and the number of inserts, but also affected by the number of cutting edges (in cut simultaneously), tilting angle of the tool, tool position to the workpiece (displacement relative to each other), the width of the workpiece, etc.

Examining roughness is also of paramount importance because it is well-known that increasing the feed rate increases the surface roughness. Therefore, when planning the manufacturing of parts, it is necessary to take into account the maximum feed rate for which the roughness requirements are still satisfied.

The results of roughness experiments performed at different feed rates are published in this paper. In the studies we analysed the 2D and 3D roughness parameters, carrying out the analysis in different planes.

2 EXPERIMENTS

The aim of the experiments is to analyse the topography of the surfaces in planes parallel to the feed direction. The planes were taken from the centre line at 20 mm and the surface roughness was examined at five different feed rates (Figure 1).



a) b)

Figure 1 – The face milled surface and the measuring planes
a) Characteristic traces of the face milled surface
b) The places of roughness measurement on the milled surface

2.1 Experimental conditions

The machining (milling) experiments on aluminium alloy were carried out with inserts when the tool cutting edge angle $\kappa_r = 90°$. The cutting data are summarized in Table 1.

Table 1 – Data of cutting experiment

No.	a_p[mm]	n [1/min]	v_c [m/min]	f_z [mm]	f [mm]
1	1.5	10000	1980	0.06	0.72
2				0.09	1.08
3				0.12	1.44
4				0.15	1.80
5				0.18	2.16

Additional conditions for machining were as follows:

Machine tool: Perfect Jet MCV-M8 (H) vertical milling machine

Tool: Lach Diamant D-MB-X3-063-08-Z12/P face milling cutter with 12 soldered PCD inserts, D_s=63 mm, κ_r=90°

Workpiece: Grade AlSi9Cu3(Fe), width of cut surface: 58 mm, length: 50 mm

Figure 1 shows the specimen on which the measuring planes are also marked and the motion relations. Investigations in different planes are important because the surface roughness varies in different points of the face milled surface and in different measurement directions. The surfaces of the specimens were examined by the following measuring equipment.

Measuring machine: AltiSurf®520 3D surface roughness measuring machine

Measuring software: AltiMap Premium 6.2

2.2 Results and discussion

Experimental data for roughness values in 2D and 3D were examined. From the resulting profile diagrams, those for the two largest feed rates are shown in Figures 2 and 3.

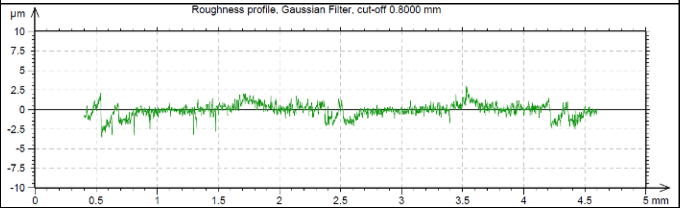
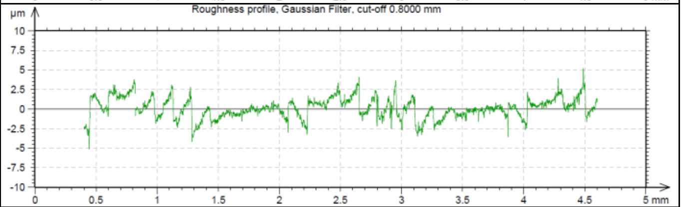
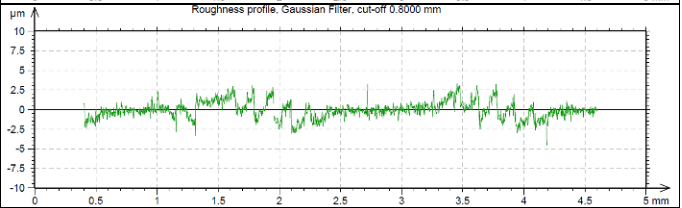
No	Roughness [μm]	Profile-diagram (f_z = 0,15 mm)
A	R_a=0.619 R_z=5.090	
B	R_a=1.042 R_z=10.046	
C	R_a=0.784 R_z=5.995	

Figure 2 – Surface roughness for specimen 4

The roughness examinations were analysed for face milling with 1 insert in the 2D and 3D systems. Among the parameters measured in the 2D system, the R_a, R_q and R_z values were analysed. In the 3D system we also measured their equivalents: S_a, S_q and S_z. (Among the measured roughness parameters, the numerical values of R_a, R_z, R_q, S_a, S_z, S_{10q} are given.) In the 2D system, a profile diagram was taken, and the 3D system was a topographic illustration. The face milling parameters and the measuring results can be found in Table 2.

From the measuring results, it can be seen that by increasing the f_z, the average roughness value of R_a doubled in both the middle and the parallel planes within the examined feed rate range. In the case of face milling, the theoretical values of the roughness parameters are reduced from the symmetry plane and are of the same value in the same distance planes in both sides. By reviewing the values in Table 2, it can be established that there is a difference between the roughness values of the A and C planes. The primary explanation for this is that on one side of the symmetry plane is up-milling and the down-milling on the other side.

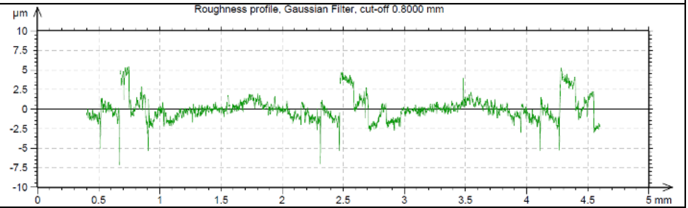
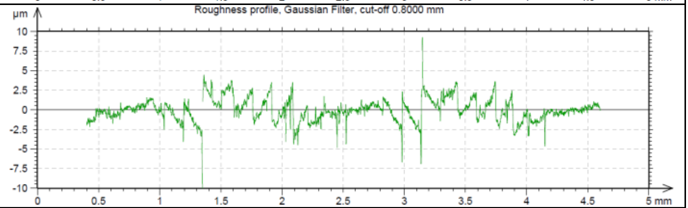
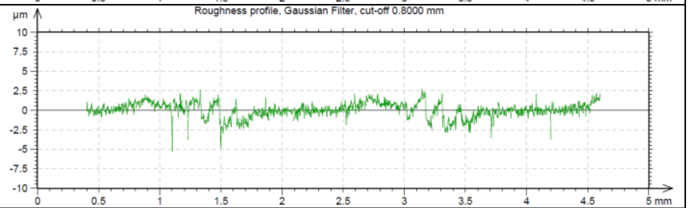
No	Roughness [μm]	Profile-diagram (f_z = 0,18 mm)
A	R_a=1.071 R_z=10.509	
B	R_a=1.001 R_z=9.405	
C	R_a=0.811 R_z=6.635	

Figure 3 – Surface roughness for specimen 5

In line with our previous experience [8], the R_a and R_q parameters are similar in relation to each other, and their value is almost the same. Therefore, the usage of only one, the more general R_a is needed. The other finding is that neither R_a nor R_q reflects the change of roughness with sufficient sensitivity. It can be seen in Figures 2 and 3 that R_z responds more sensitively and more accurately to the change in roughness. This is why R_z. is more frequently used in factories. Looking at Table 2, it can be stated that all roughness characteristics change in a similar way.

Table 2 – Summary of measured parameters of the surface roughness

No.	f_z [mm]	Side	R_a [μm]	R_z [μm]	R_q [μm]	S_a [μm]	S_z [μm]	S_q [μm]
1	0.06	Entry side	0.558	4.404	0.751	1.409	9.644	1.700
		Middle	0.499	3.777	0.667	1.423	11.954	1.863
		Exit side	0.576	4.325	0.755	1.516	10.536	1.854
2	0.09	Entry side	0.423	3.226	0.554	1.301	12.317	1.700
		Middle	0.532	3.647	0.668	1.258	11.082	1.678
		Exit side	0.475	3.193	0.607	1.341	13.293	1.744
3	0.12	Entry side	0.408	4.157	0.581	1.175	13.828	1.564
		Middle	0.492	3.226	0.612	0.937	17.262	1.222
		Exit side	0.384	2.751	0.501	1.142	13.029	1.496
4	0.15	Entry side	0.619	5.090	0.837	1.010	19.288	1.339
		Middle	1.042	10.046	1.565	0.942	20.132	1.245
		Exit side	0.784	5.995	1.018	0.955	21.173	1.285
5	0.18	Entry side	1.071	10.509	1.425	1.027	20.657	1.365
		Middle	1.001	9.405	1.284	1.086	23.876	1.479
		Exit side	0.811	6.635	1.044	0.974	21.144	1.306

The tendency in the 2D profiles seems to be an increase in the number of deep grooves growing by increasing the by feed per cutting edge (f_z). This is unfavourable for fatigue applications, but it is beneficial from the point of view of capability for oil.

In addition to the profile diagrams taken from the machined surface, the topographic figures also provide useful information. Here we show the topographic figures belonging to the two highest feed rates of the 5 cases examined. The 3D profile figures are characterized by a distinct convexity which is proportional to the feed rate value. The micro-geometric shape of the sur face can be said to be regular.

A convexity corresponds to one rotation of the tool. It is obvious that in the parallel planes the direction of the groove is different and because the axis of the milling cutter was perpendicular to the surface, the traces caused by the edge also appeared there too.

In our experiments we worked with commercial milling heads and commercial inserts. Even at the highest feed rate – in the examined interval – we have received smaller R_z values than, for example, the value prescribed for the milled machined surface of a gearbox made of this material.

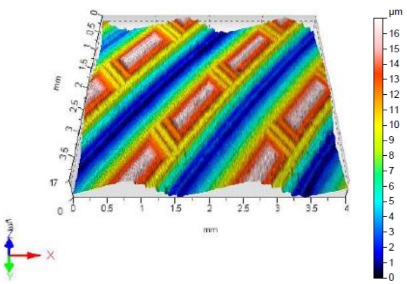
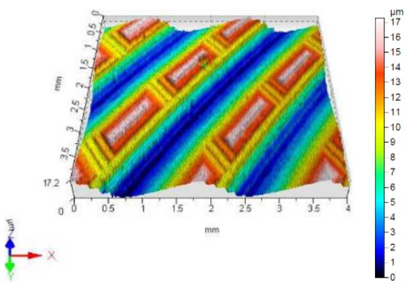
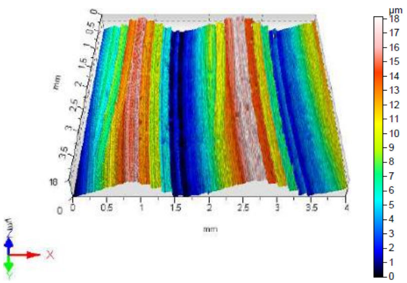
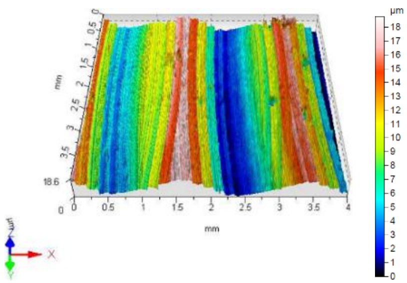
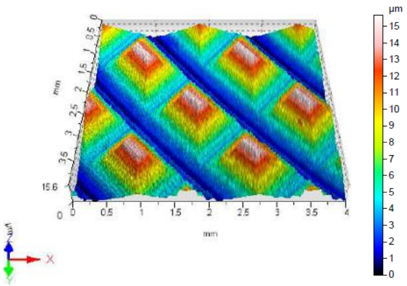
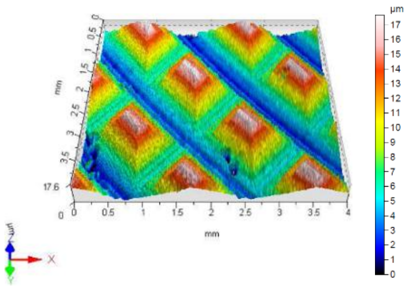
Sign	4 (f_z = 0.15 mm)	5 (f_z = 0.18 mm)
C		
B		
A		

Figure 4 – 3D topography of the milled surface

When removing a constant value cross sectional area, increasing the feed per tooth of the cutter (chip thickness is increasing as well), the cutting force decreases, and the mechanical power necessary for chip removal decreases, too [9]. Starting from this, by further increasing the feed rate, the increase in the cutting force will be slower, so the extent of the cutting force will be less than the limit of the increase of the feed rate. Rather, roughness values may limit the choice of the feed values.

3 CONCLUSION

In this paper, the roughness of the face milled surface was analysed with a face milling cutter. It was found that the roughness values in the planes parallel to the plane of symmetry differ. Although the theoretical values of the roughness values are the same in equal planes, they differ in the machined surface. This can be partially explained by the fact that the plane of symmetry is up-milling one side and down-milling the other side.

In the examined interval, with increasing feed per tooth of the cutter (f_z) roughness values gradually decrease. At the same time, the roughness value is significantly lower than the allowable values for such surfaces, which allows for further feed increase.

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