A Study of Surface Roughness Affected by Radial and Axial Depth of Cut in Side Milling Operation

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Abstract

In the process of metal cutting operations, unstable cutting condition causes many effects on surface quality of finished products. In addition to size of cutter, clamping system and hardness of the work-piece, forces exert on cutting tools dramatically change quality of surface. In this paper, experiments were conducted by two cases: Case (I) with large radial depth of cut, RDC and small axial depth of cut, ADC and Case (II) with small RDC and large ADC. In experiments 91 HRB Mild steel plates were used as test pieces and two 16 mm diameter solid carbide flat end mill cut them for two cases. Surface roughness analysis was carried out by making test cut with eight side milling operations, four for Case (I) and the others for Case (II). To show the greater performance, the cutting speeds of Case (II) are set to two times of Case (I) and higher machining parameters were used for every operations of each case. By analyzing roughness data of each operation, it has been observed that large radial depth of cut and small axial depth of cut caused higher surface roughness Ra than that of small RDC and large ADC.

***Keywords**:* Axial depth of cut, radial depth of cut, side milling, surface roughness

1. Introduction

Milling is a fundamental machining process and the most encounter metal removal operation in manufacturing industry. The quality of a milled surface is a key role for improving fatigue strength, corrosion resistance, and creep life [2]. The process of generating a milled surface is affected by several factors, some of them, namely the cutting conditions and tool geometry, are of primary importance in determining the quality of a milled surface [1]. The main purpose of this paper is to study surface roughness affected by machining parameters such as radial and axial depth of cut. R. Jalili Saffar et al. [4] stated that the main parameters in machining affecting tool deflection and surface finish are axial and radial depth of cut and feed rate. Nagi et al. [3] described that surface roughness is more sensitive to the feed rate and the depth of cut. In experiments of this paper, two rates of cutting speed (V_c) were used for each case and other machining parameters were changed for each operation.

2. MACHINES AND EQUIPMENTS

DMG vertical precision milling machine, DMC 105 V linear machine with Heindenhain iTNC 530 control was used to make test cut.

Table. 1 shows detailed information of machining and testing equipments of experiments.

Table. 1 Machining and testing equipments

Milling Machine	DMC 105V Linear
CAM	Hypermill V 9.7
Touch Trigger	Renishaw OMP60 Touch Probe
Roughness Measuring Machine	Surfcom 1800D
Hardness Testing	Mitutoyo Hardness Testing Machine, HV

2.1 Holder and Tool

Titex Plus TiCN coated solid carbide end mills code: D3473 TCN for dry-cutting of steels and cast materials performed all cutting operations. Detail geometry and information are shown in Fig. 1 and Table. 2.

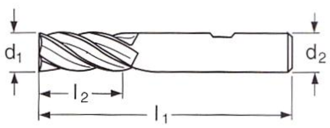


Fig. 1 Tool geometry

Table. 2 Tool dimensions

d_1 mm h10	No. of teeth	l_1 mm	l_2 mm	d_2 mm h6
16.0	4	92	32	16

Sandvik hydraulic chuck: HSK 63-A/C, G2.5 at 25000 rpm was used to give run-out precision 2 to 3μm, fine balanced and excellent transmittable torque see in Fig. 2.

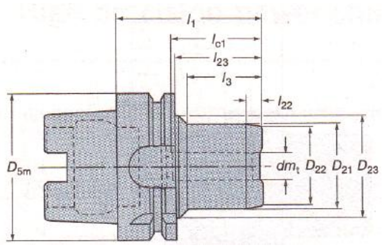


Fig. 2 Hydraulic chuck holder

2.2 Experiment Procedure

DMC 105 V Linear milling machine, shown in Fig. 3 cut 91 HRB mild steel plates (150 x 150 x 25 mm) in two cases: Case (I) and Case (II). Before cutting operations, Renishaw touch probe was used to measure differences between the highest and lowest value of the part in Z-direction and set to 2 to 5 μm, Fig. 4.

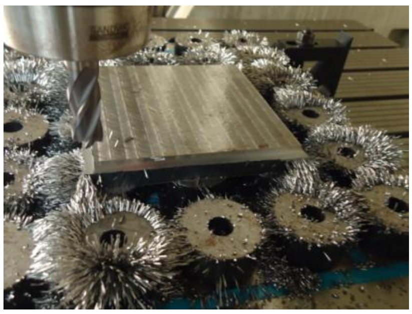


Fig. 3 Test cut by DMC 150V Linear

Fig. 4 Measuring by Renishaw touch probe

Eight cutting operations were made for two cases: four for Case (I) and the others for Case (II). Details of cutting data of each operation are shown in Table 3.

Table. 3 Cutting data for side milling operations

No.	Case (I)					Case (II)				
	Radial depth of cut (RDC) mm	Axial depth of cut (ADC) mm	Cutting Speed (V_c) m/min	Feed (F) mm/min	mm/ tooth (f_z)	Radial depth of cut (RDC) mm	Axial depth of cut (ADC) mm	Cutting Speed (V_c) m/min	Feed (F) mm/min	mm/ tooth (f_z)
1.	3	1	151	480	0.04	1	3	302	960	0.04
2.	4	1	151	600	0.05	1	4	302	1680	0.07
3.	5	1	151	720	0.06	1	5	302	2400	0.10
4.	6	1	151	960	0.08	1	6	302	3840	0.16

As shown in Table. 3, RDC and ADC values were changed for two cases and cutting speeds of Case (II) are set to double and machining parameters such as F and f_z are higher and higher in operation by operation. The finished parts are measured on Surfcom 1800D in two ways; in cutting tool direction, viz., X direction and transverse direction, Y, Fig. 5. Air is used as coolant for all operations.

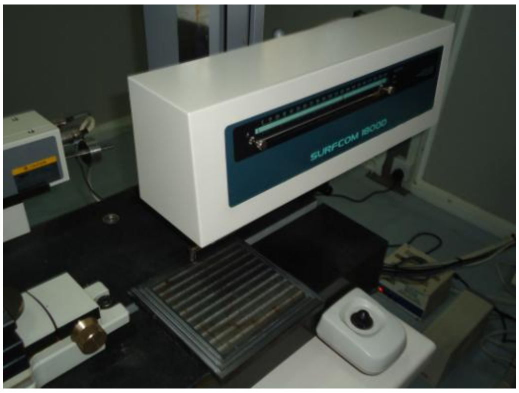


Fig. 5 Surface roughness measurement

3. Results and discussions

From the results obtained by roughness measurement, it has been clearly seen that maximum Ra value of 1.4507 μm occurred at Case (I) of RDC=6 mm because of unstable condition of cutting tool during operation whereas minimum value, Ra=0.1394 is at Case (II) of ADC=3 mm. Some surface profiles measured are shown in Figure 6 and 7 and roughness values of each operation are shown in Table. 4.

Table. 4 Experimental roughness values

Operation No.	Case I		Case II	
	Ra µm (X)	Ra µm (Y)	Ra µm (X)	Ra µm (Y)
1.	0.6685	0.4382	0.1394	0.1881
2.	0.6872	0.4625	0.2047	0.2433
3.	1.1508	0.5197	0.2347	0.2874
4.	1.4507	0.8222	0.3165	0.3277

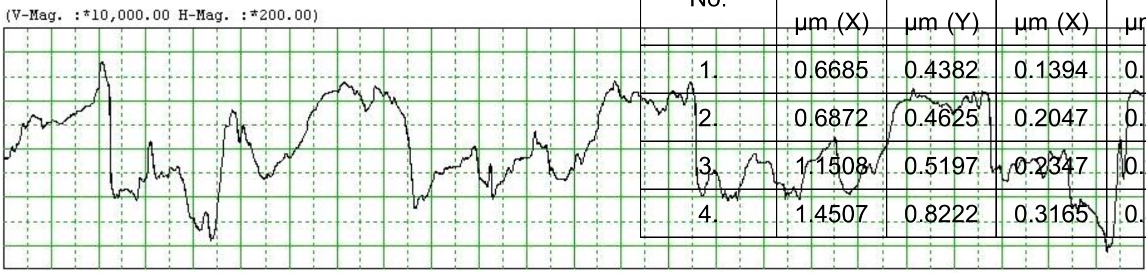


Fig. 6 Surface profile at RDC is 6mm, Ra = 1.4507 µm

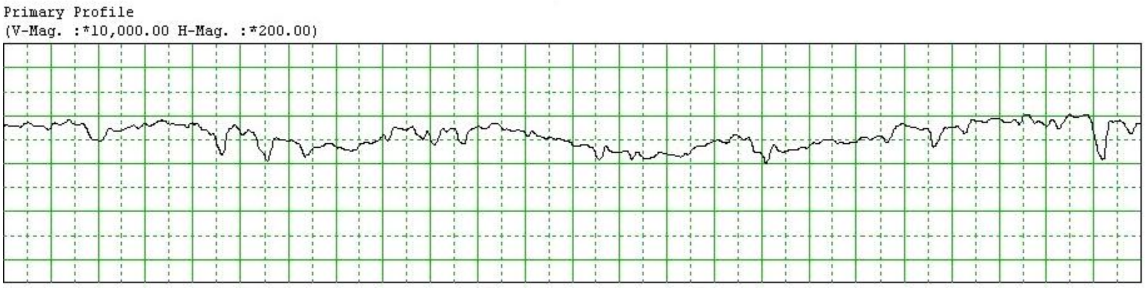
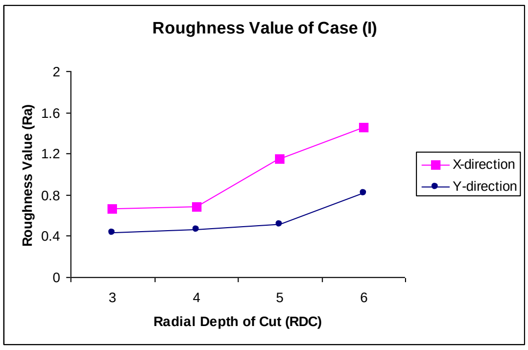
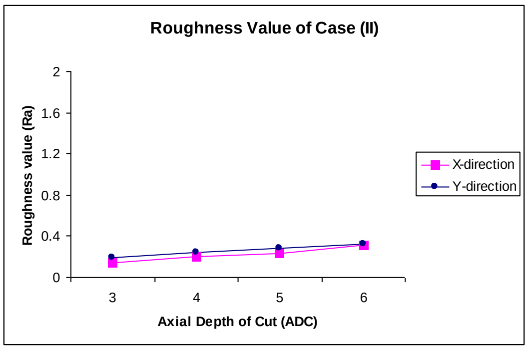


Fig. 7 Surface profile at ADC is 6mm, Ra = 0.1394 µm

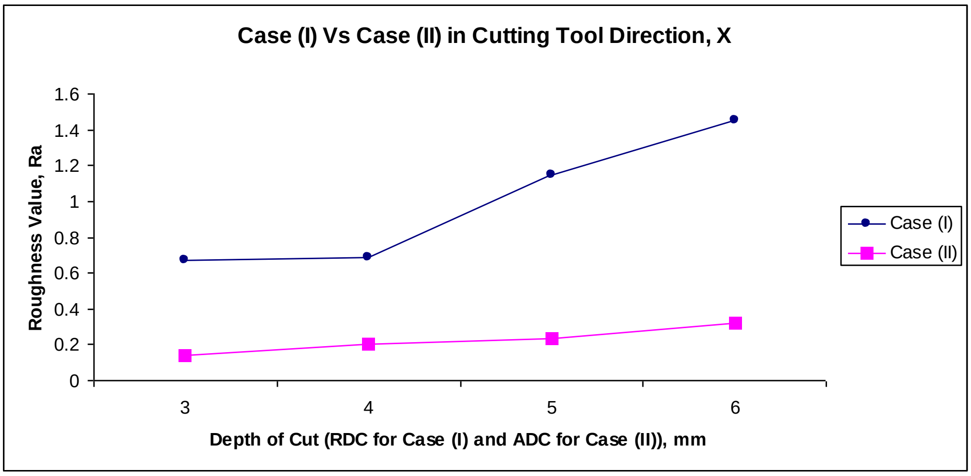
The recorded roughness data for all cutting operations are plotted in Fig. 8 and 9. These figures show the behavior of unstable cutting tool condition that affect on the surface roughness. In case (I) Ra values in X-direction are much higher than that of Y-direction. Although Ra values occurred at RDC 3 and 4 are nearly the same, values are significantly high to more than 1 µm at 5 and 6. On the other hand, Ra values are not much different in any direction, X and Y, of Case (II). It is apparently that on the one hand Ra values of Case (I) in X-direction are higher than that of Y-direction, but on the other hand Case (II) shows the converse results.



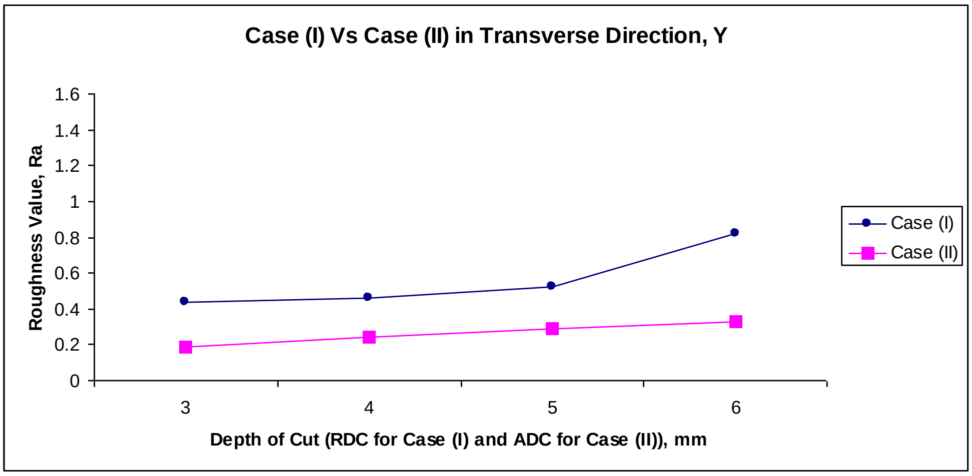


(a) Graph of Case (I) (b) Graph of Case (II)

Fig. 8 Roughness values of Case (I) and (II) in two directions



(a) Surface roughness comparison of Case (I) and (II) in cutting tool directions



(b) Surface roughness comparison of Case (I) and (II) in transverse of cutting tool directions

Fig. 9 Surface roughness of Case (I) Vs (II) in two directions

By analyzing roughness data of Fig. 9, Case (II) method give better surface finish than that of Case (I) in any direction. It was found that the surface roughness value is evidently increased with the increase of RDC of Case (I) method. Nevertheless, surface roughness was rather stable in Case (II), even if ADC values were increased. On the whole, Case (II) machining method can reduce unstable cutting tool condition and ensure the better surface quality of product if it compares to Case (I).

4. Conclusion

Radial depth of cut and axial depth of cut are mainly dominant on surface quality of finished part. Instead of using larger value of radial depth of cut, it is better to increase axial depth of cut if higher values of machining parameters such as feed rate and cutting speed are needed to increase production rate, as which can give better surface quality and reduce hand work.

5. References

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