Online available since 2012/Oct/08 at www.scientific.net
© (2012) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.576.32

Influence of Magnetic Field on Reduction Chatter and of Surface Roughness in End Milling of Titanium Alloy - Ti-6Al-4V

Syidatul Akma Sulaiman[1,a], A.K.M. Nurul Amin[1,b] and M. D. Arif[1,c]

[1]Department of Manufacturing and Materials Engineering

Kulliyyah of Engineering, International Islamic University Malaysia

[a]sas_1309@yahoo.com, [b]akamin@iium.edu.my

Keywords: Chatter, Permanent Magnet, Surface Roughness, Uncoated Tungsten Carbide.

Abstract. One of the most challenging issues in machining process is understanding the chatter phenomenon. Chatter mechanics is still not fully understood. It is inconsistent in character, making it difficult to analyze and predict. This research work investigates the influence of permanent magnets on chatter suppression in end milling of Titanium alloy (Ti-6Al-4V) using uncoated WC-Co insert. The experiments were designed based on the Response Surface Methodology (RSM) approach using DESIGN EXPERT (DOE) software. The experiments were performed under two different conditions: under normal condition and under the application of magnetic fields from two permanent magnets located in opposite direction. Ti-6Al-4V was used as the work material. The resultant average surface roughness was found to be reduced by a maximum of 50% due to magnet application. Scanning Electron Microscope (SEM) was used to analyze the chip morphology. The microphotographs showed the evidence of more stable chip formation under the influence of magnetic fields.

Introduction

In machining, chatter arises due to resonance when the frequency of chip serration (primary or secondary) and the natural vibration modes (natural frquencies) of the system components coincide. Campa et al. [1] described chatter as a dynamic problem at high material removal rate condition. In addition, Quintana et al. [2] specified that chatter can be predicted from the loud noise and the poor surface finish due to the chatter marks. Several hypotheses were developed, over the years, to address chatter formation phenomenon and its suppression methods. Piezoelectric actuators [3], magnetostrictive actuators [4], and multiple time-varying parameter (MTVP) [5] have been employed to reduce chatter in turning. Stone [6] extended the non-uniform pitch concept by proposing end mills with a different helix on adjacent flutes. Alternating the helix increased the pitch variations along the axial depth of cut hence, both the chatter free performance and the speed range were improve. Moreover, a fuzzy logic approach for chatter suppression in end milling process was discussed by Liang et al. [7]. Using this approach, chatter is detected using the peak sound spectrum amplitudes at chatter frequency ranges. Experimental results show that chatter can be effectively suppressed. However, chatter cannot be suppressed by feed adjustment alone because it needs simultaneous adjustment of feed and spindle speed.The use of permanent magnets for chatter suppression is a new research. Therefore, the information regarding the effects of magnetic fields on chatter suppression is very limited. In this study, the influence of permanent magnets in suppressing the chatter phenomenon in end milling operations on Ti-6Al-4V using uncoated WC-Co insert, specifically the improvement in surface roughness and chip formation stability, were investigated.

Experimental Details

Experimental tests were conducted on a Vertical Machining Center (VMC ZPS, Model: 1060, maximum speed 8000 rpm). Machining was done under normal conditions and under the influence of magnetic fields from permanent magnets. Two ferrite magnet bars with dimensions 1 inch x 6 inches x 3 inches were mounted near the cutting tool, using a fixture specially designed by the authors. The strength of the magnets was between 2500 and 2700 Gauss. Machining was performed with a 20 mm diameter end mill tool holder fitted with one uncoated WC-Co insert. Mitutoyo SURFTEST SV-500 profilometer was used to measure the surface roughness. Scanning Electron Microscope (SEM) was employed in order to investigate the chip segmentations. Fig.1 displays the schematic diagram and photograph of the experimental setup.

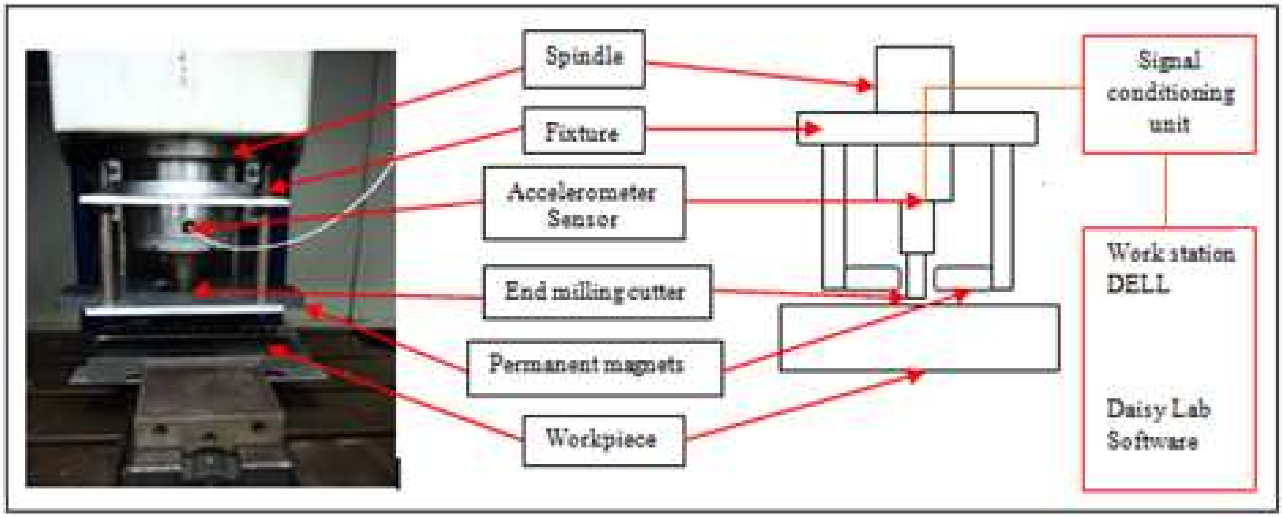


Fig. 1: Experimental set up for end milling operations

Central Composite Design (CCD) of Response Surface Methodology (RSM) was used for the design of experiments. The values of cutting parameters (cutting speed, feed and axial depth of cut) used in the experiments are shown in Table 1.

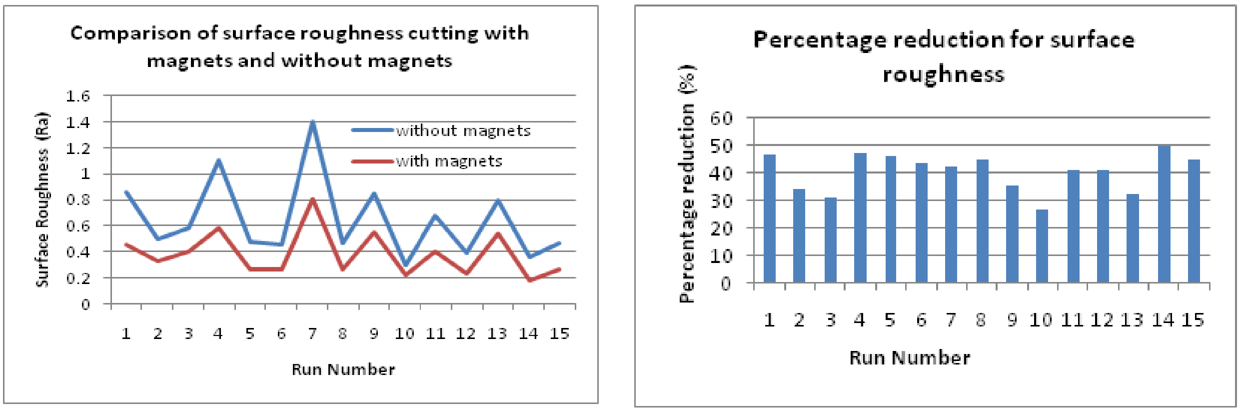
Results and Discussions

Surface Roughness. Table 1, below, compares the resultant surface roughness for the two cases.

Table 1: Comparison of surface roughness for the two cases: with and without magnets

Run	Cutting speed (m/min)	Feed (mm/tooth)	Depth of Cut (mm)	Surface roughness (Ra) (µm)		Percentage of reduction (%)
				Without magnet	With magnet	
1	70	0.1	1.51	0.86	0.46	46.51
2	70	0.1	0.24	0.50	0.33	34
3	100	0.05	1.25	0.58	0.40	31.03
4	100	0.15	0.5	1.10	0.58	47.27
5	70	0.10	0.88	0.48	0.26	45.83
6	70	0.10	0.88	0.46	0.26	43.47
7	70	0.18	0.88	1.40	0.81	42.14
8	70	0.10	0.88	0.47	0.26	44.68
9	40	0.15	1.25	0.85	0.55	35.3
10	70	0.02	0.88	0.30	0.22	26.67
11	120.45	0.1	0.88	0.68	0.40	41.14
12	40	0.05	0.5	0.39	0.23	41.03
13	19.55	0.1	0.88	0.80	0.54	32.5
14	70	0.10	0.88	0.36	0.18	50
15	70	0.1	0.88	0.47	0.26	44.68

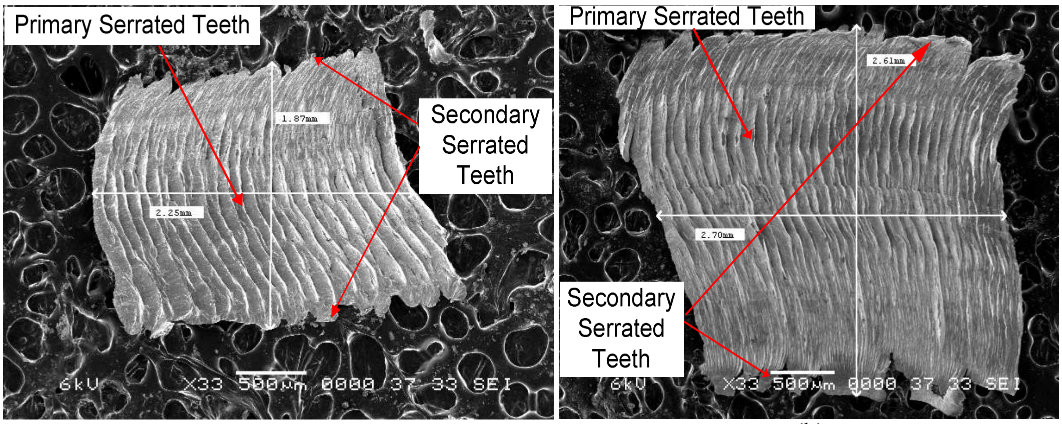
From Table 1 it can be inferred that with the increase of cutting speed, feed, and depth of cut, surface finish became better. Also, the influence of magnetic fields significantly reduced surface roughness. The highest percentage reduction for roughness was observed when cutting the work material at 70 mm/min speed, 0.10 mm/tooth feed, and 1.0 mm depth of cut. As shown in Fig. 2 (b), the highest percentage reduction was observed in run number 14. In this case, surface roughness was reduced from 0.36 µm to 0.18 µm when magnets were added to the system. The corresponding surface roughness reduction percentage was about 50%. This reduction was caused by the damping effect of the magnets on the oscillatory motion of the tool. This results due to the retarding forces of attaction from the magnets, located in diagonally opposite direction, on the vibrationg tool. Under the effect of the magnetic forces the tool requires higher energy to vibrate around its neutral position, and hence, its vibration is damped.



(a) (b)

Fig. 2: Influence of magnets on surface roughness: (a)Comparison of Surface Roughnesses, and (b)Percentage reduction of surface roughness

Chip Morphology. Chips were studied under SEM to observe the pattern of segmentation. Since the highest percentage of surface roughness reduction was obtained for run number 14, these chips were observed. Fig. 3 shows the SEM photographs for the two cases (with/without magnets).



(a) (b)

Fig. 3: SEM microphotograph of chips (cutting speed 70 m/min, feed 0.10 mm/tooth, and depth of cut 1.0 mm) (a) Without magnets, and (b) With magnets.

It was observed from Fig. 3 that primary (saw) serrated teeth were formed in the main body of the chip for both cases. Secondary serrated teeth were also formed in both cases but are more prominent when cutting without magnets. However, cutting under the presence of magnets made the chips more stable with comparatively higher frequency (Fig. 3 b) and with lower height of primary serration teeth. The formation of primary serration of chips is difficult to avoid during machining of titanium and its alloys. Nevertheless, chatter appears in the system when these serrated teeth get amplified and their frequencies are lowered and coincide with the natural frequencies of the system components, leading to resonance [3]. The application of magnets made the system more stable and as a result the chips were formed at the nominal frequencies of the work material without getting biased by the system. Thus, chatter was reduced and surface finish improved by this novel technique.

Conclusions

The following conclusions were drawn from the research results:

1. The combination of high cutting speed, low feed, and small depth of cut, reduced the surface roughness to a maximum of 50%. This significant improvement in surface finish would likely eliminate the cost operations for grinding and polishing in machining of Ti-6Al-4V.
2. Both primary and secondary serrated teeth were formed in end milling of Titanium alloy using uncoated WC-Co. It was found that, chip formation was more stable while cutting under the presence of magnetic fields, which improved the surface finish.

References

[1] F.J. Campa, L.N.L. Lacalle, A. Lamikiz, J.A. Sanchez, Selection of cutting conditions for a stable milling of flexible parts with bull nose end mills, J. Materials Processing Technol. 191 (2007) 279-282.

[2] G. Quintana, J. Ciurana, I. Ferrer, C.A. Rodriguez, Sound mapping for the identification of stability lobe diagrams in milling processes, Int. J. of Machine Tool & Manufac. (2007).

[3] S.G. Tewani, K.E. Rouch, B.L. Walcott, A study of cutting process stability of a boring bar with active dynamic absorber, Int. J. of Machine Tools Manufac. 35 (1995) 91–108.

[4] J.R. Pratt, A.H. Nayfeh, Chatter control and stability analysis of a cantilever boring bar under regenerative cutting conditions, Philosophical Transactions: Mathematical, Physical and Engineering Science, Nonlinear Dynamics in Metal Cutting. 359 (2001) 759–792.

[5] F. Yang, Bi. Zhang, J. Yu, Chatter suppression with multiple time-varying parameters in turning, J. of Materials Processing Technol. 141(3) (2003) 431-438.

[6] B.J. Stone, Advances in machine tool design and research, Proceeding of the 11th International MTDR Conference, Vol. A (1970) 169-180.

[7] M. Liang, T. Yeap, A. Hermansyah, A fuzzy system for chatter suppression in end milling, Mech. Engrs. Vol. 218, Part B: J. Engineering Manufac. (2003).

Advances in Manufacturing and Materials Engineering
10.4028/www.scientific.net/AMR.576

Influence of Magnetic Field on Reduction Chatter and of Surface Roughness in End Milling of Titanium Alloy - Ti-6Al-4V

10.4028/www.scientific.net/AMR.576.32

DOI References

[1] F.J. Campa, L.N.L. Lacalle, A. Lamikiz, J.A. Sanchez, Selection of cutting conditions for a stable milling of flexible parts with bull nose end mills, J. Materials Processing Technol. 191 (2007) 279-282.
doi:10.1016/j.jmatprotec.2007.03.023
[3] S.G. Tewani, K.E. Rouch, B.L. Walcott, A study of cutting process stability of a boring bar with active dynamic absorber, Int. J. of Machine Tools Manufac. 35 (1995) 91–108.
doi:10.1016/0890-6955(95)80009-3
[4] J.R. Pratt, A.H. Nayfeh, Chatter control and stability analysis of a cantilever boring bar under regenerative cutting conditions, Philosophical Transactions: Mathematical, Physical and Engineering Science, Nonlinear Dynamics in Metal Cutting. 359 (2001).
doi:10.1098/rsta.2000.0754
[5] F. Yang, Bi. Zhang, J. Yu, Chatter suppression with multiple time-varying parameters in turning, J. of Materials Processing Technol. 141(3) (2003) 431-438.
doi:10.1016/S0924-0136(03)00427-8