CHIP BREAKAGE CONTROL IN Ti6Al4V LONGITUDINAL TURNING WITH HPC SYSTEM

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ABSTRACT

The paper presents the results of turning tests of Ti6Al4V alloy with a sintered carbide tool. For selected sets of cutting data, two kinds of coolant supply were compared. Conventional coolant supply with the pressure of 7 bar was compared with HPC (High - Pressure Coolant) system working with the pressure of 70 bar. The tests revealed the fact that HPC system is useful for small values of feed taking into account chip form. Photographs of chips and their form analysis are presented. Taguchi method was used to select optimal set of cutting data considering chip form.

Keywords: turning, titanium alloy, HPC, chip form

1. INTRODUCTION

Problems concerning chip breakage and control have been intensively investigated by many researcher [3,6] especially when CNC machining was introduced. From many material groups difficult-to-cut materials such as HRSA alloys [4], titanium alloys or stainless steel can be distinguished. The paper is focused on titanium alloys. Their usage has increased significantly in recent years. There are widely used in aviation industry, chemical industry and medicine. Titanium is lighter than steel, corrosion resistant, has good mechanical properties in high temperature. Although cutting forces are only slightly higher than the cutting forces for steels, titanium alloys have properties that make them more difficult to machine than a steel of equivalent hardness. [1,4]. Cutting causes high temperature field in cutting zone (titanium has a low heat-transmission coefficient, e.g. for titanium Ti6Al4V this coefficient is 7 W/m K, for carbon steel is 50 W/m K). Titanium alloys are prone to chemical reaction with tool material when the temperature exceeds 500 C. That causes a chemical crater wear. The contact length between the chip and the rake face is short what causes the concentrated/high stress field. It is also possible for the heat of machining to cause some titanium alloys to ignite and burn. Titanium's low modulus of elasticity makes the part susceptible to deflection and vibration, particularly during heavy cuts.

Additionally, it is difficult to achieve correct chip form for variety of cutting data. Chip breakers located on the rake face of carbide inserts has limited range of application. Traditionally titanium is machined with coolant supply which can be delivered in traditional way with the pressure about 7 bar or when HPC (High Presure Coolant) systems were introduced with the pressure about 70 bar. In the

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paper HPC system supporting chip forming and breakage produced by Sandvik Coromant was tested and the results were compared with conventional pressure supply.

2. MACHINING EXPERIMENTS

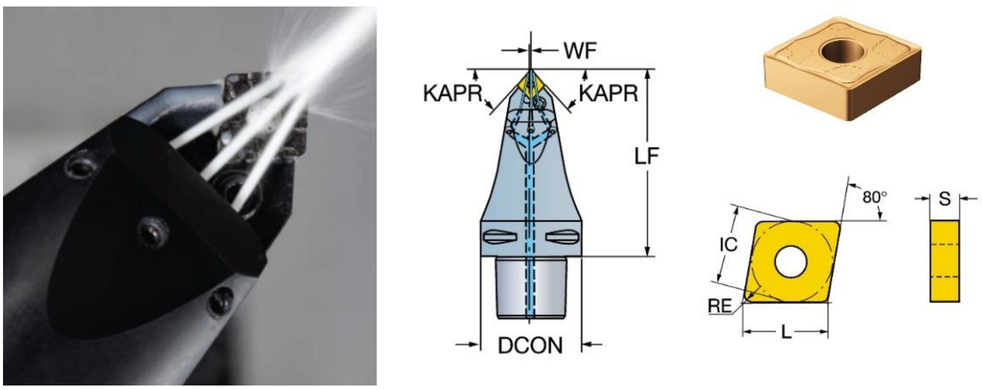
The experiments were conducted using titanium alloy Grade5 as workpiece material. Sandvik Coromant tool holder type C6-PCMNN-00115-12HP and carbide insert CNMG 12 04 08-SMC 1115 were used [5]. The chemical composition of a workpiece is shown in Table 1. The tests were carried out with Mazak Integrex 200-IV lathe equipped with a system for high pressure coolant supply. Research plan was developed by Taguchi method [2] for the three variables, assuming two levels of depth of cut (a_p), pressure (p), and four levels of feed (f). Cutting speed was constant, $v_c = 50$ m/min.

Chips evaluation and classification was carried out after each test. Table 5 presents chips achieved in particular experiment.

Depending on the form, type and length of chips a coefficient value was assigned to particular chips from the range <0;1>, where “0” described correct chip and “1” unacceptable incorrect chip. The coefficient is marked as W_{cfc}.

Cutting data are shown in Table 2 and the results of tests are presented in Table 3. According to the Taguchi quality design concept a L8 orthogonal array has been used to determine the S/N ratio (dB), ANOVA and ‘F’ test values for indicating the most significant parameters affecting the machining performance criteria, i.e. chip form. To obtain optimal testing set of cutting data, the-lower-the-better quality (1) characteristic was accepted.

$$\frac{S}{N} = -10 \cdot \log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \tag{1}$$



KAPR = 95 deg
DCON = 63 mm
LF = 115 mm
IC = 12.7 mm
S = 4.7625 mm
L = 12.8959 mm
RE = 0.8 mm

Fig. 1
C6-PCMNN-00115-12HP tool holder and CNMG 12 04 08-SMC 1115 carbide insert

Table 1
Composition of Grade5 (Ti-6Al-4V) titanium alloy

Material	Al	Fe	O	Ti	V
Ti-6Al-4V	6	0.25	0.20	90	4

Table 2
Cutting data

Symbol	Cutting data	Level			
A	Feed f [mm/rev]	0.15	0,20	0,25	0.30
B	Depth of cut a_p [mm]	1.0		3.0	
C	Cutting pressure p [bar]	7		70	

Table 3 shows actual value of implemented cutting data for experiment plan and assigned average values of chip form classification coefficient W_{cfc}.

The analysis shows that the optimal cutting data for achieving correct chip form are data from the test number 7, (f = 0.3 mm/rev, a_p = 1 mm, p = 70 bar) for which S/N factor has the highest value.

For all tests with HPC system high values of S/N factor were obtained as well as correct chip forms.

Table 3
Experimental results and S/N ratio of chip form

No.	Coded level			Actual setting values			Chip form classification (weight) W_{cfc}	S/N ratio	Calculated value W_{cfc_calc}
	A	B	C	f	a_p	p		[dB]	
1.	1	1	1	0.15	1.0	7	1.00	0.00	1.005
2.	1	2	2	0.15	3.0	70	0.20	13.97	0.195
3.	2	1	1	0.20	1.0	7	1.00	0.00	0.995
4.	2	2	2	0.20	3.0	70	0.18	14.89	0.185
5.	3	1	2	0.25	1.0	70	0.10	19.97	0.105
6.	3	2	1	0.25	3.0	7	0.396	7.99	0.391
7.	4	1	2	0.30	1.0	70	0.075	22.49	0.069
8.	4	2	1	0.30	3.0	7	0.35	9.11	0.355

Table 4
Analysis of variance for chip form in machining Grade5 titanium alloy

Source	DoF	Seq SS	Adj SS	Adj MS	F	P
A	3	0.267	0.267	0.089	819.6	0.001
B	1	0.137	0.137	0.137	1264.0	0.001
C	1	0.600	0.600	0.600	5524.6	0.000
Residual Error	2	0.0002	0.0002	0.0001		
Total	7	1.005				

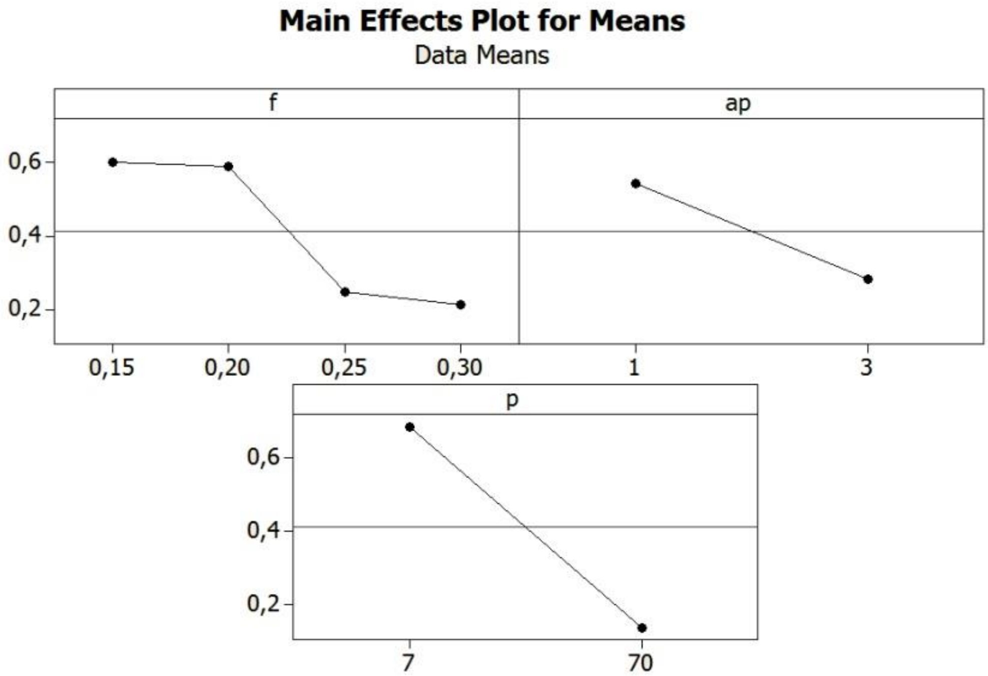


Fig. 2
Cutting data influence on the coefficient describing chip form

Fig. 3 shows the method used for chip classification and determination the chip form classification coefficient. Table 5 presents photographs of chips forms achieved in performed tests together with the classification of their forms. The following assigns were accepted:

"+" - chips correct
"-" - chips incorrect
"=" - chips acceptable.

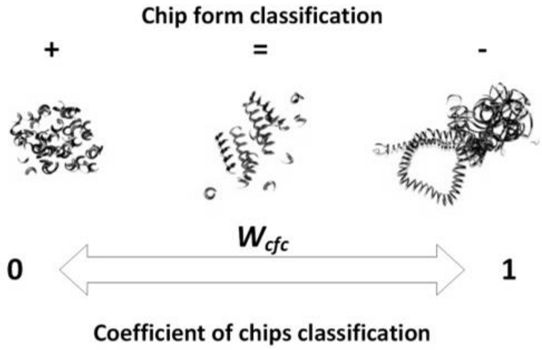
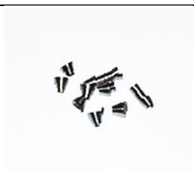
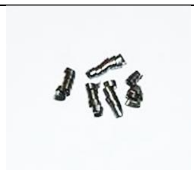


Fig. 3
Coefficient of chip form classification

Table 5
Chip classification in particular tests

	Numbers of test and setting values			
Nr of test	1	2	3	4
f [mm/rev]	0.15	0.15	0.20	0.20
a_p [mm]	1.0	3.0	1.0	3.0
p [bar]	7	70	7	70
Chip classification	-	+	-	+
W_{cfc} coefficient	1.0	0.2	1.0	0.18
				
Nr of test	5	6	7	8
f [mm/rev]	0.25	0.25	0.30	0.30
a_p [mm]	1.0	3.0	1.0	3.0
p [bar]	70	7	70	7
Chip classification	+	0	+	0
W_{cfc} coefficient	0.1	0.39	0.075	0.35
				

It should be noticed that in tests with the conventional coolant supply, chip form changes when the feed value increases. Fig. 2 shows that for the feed value greater than f = 0.2 mm/rev chip form changes from incorrect to acceptable. The conclusion is that the decisive factor in the selection of the way of coolant supply (conventional or HPC) could be the quality of machined surface. Fig. 4 presents the results of surface quality measurement (Ra) for conventional and HPC coolant supply.

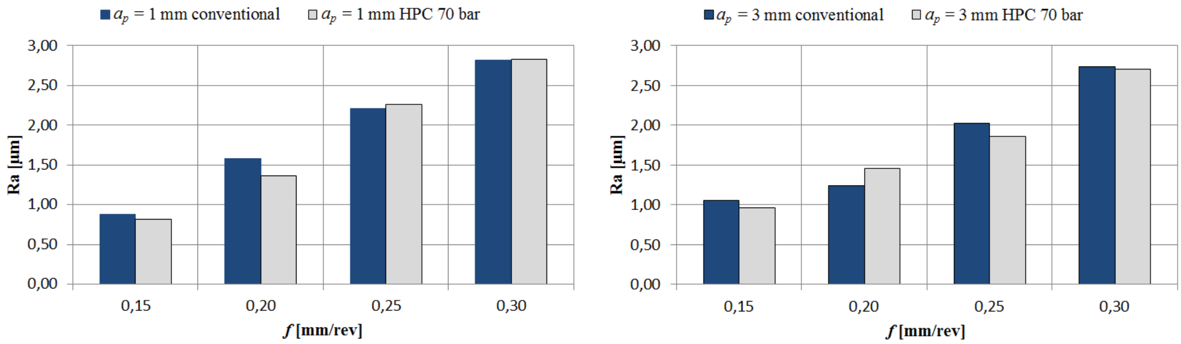


Fig. 4
Surface roughness

Test results show that HPC system does not significantly influence the surface roughness. Similar conclusion was drawn by the authors in [7]. Thus, the optimal implementation of HPC system in longitudinal turning of titanium alloy is a finishing turning with low values of feed (below f = 0.2 mm/rev). For greater values of feed and depth of cut (rough turning) HPC implementation for achieving correct chip form can be a too expensive solution.

3. CONCLUSIONS

The paper presents research results of Ti-6Al-4V turning with the implementation of HPC system. The applied method of assigning weights of the chip form coefficient value (W_{cfc}) together with Taguchi method give the good results in optimal cutting data selection, taking the chip form into account. The analysis of results showed that HPC system could be effectively used for finishing turning. In the case of roughing turning the effectiveness of HPC system, supporting the chip breakage decreases and production costs are higher.

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