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Orthogonal Experimental Study on Tool Lifein Milling TB6 Titanium Alloy

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Abstract. The tool wear was studied using orthogonal experiment method while milling titanium alloy TB6 in different milling parameters. The flank face wear was measured by the photomicrograph after a certain period of millingDuring the milling process. It can be seen from the differenceresults of the experiment that the most significant factor affecting the durability of titanium alloy TB6 cutter is the cutting speed, which difference is 130.67. Followed by the feed, the difference is 106.33; Next is the milling depth and its difference is 61.33; The least significant factor is the milling width.

1 Introduction

With the development of national defense industry, aerospace and other new technologies, the use and demand of titanium alloy materials are more and more extensive. Titanium alloy has excellent properties such as high specific strength, high specific modulus, lowexpansion coefficient, impact resistance, wear resistance, heat resistance and so on[1], therefore, titanium alloy has a good prospect. But its unique physical and chemical properties make titanium alloy a recognized refractory material[2], In the actual cutting process, the tool durability is low, the tool wear is serious, and the processing cost is high, which greatly hindered the application and promotion of this kind of materials[3]. The titanium alloy TB6 is a kind of titanium alloy near β type,which has high toughness, high strength and excellent machinability.The titanium alloy TB6 has higher specific strength and can greatly reduce the structural weight compared with the same strength structural steel or some other titanium alloys[4].

In the process of metal cutting, tool wear is a common concern[5]. Because it involves many aspects, it has a great influence on tool life, processing economy, machining accuracy, surface quality and reliability of machined workpiece. Many scholars at home and abroad have carried out a great deal of research on tool wear during cutting.Attanasio and other tools were used to predict the tool wear during the cutting of AISI1045 with carbide tools[6]. Filice and other tools were used to predict tool wear during the cutting of medium carbon steel[7]. ZhengMinliand other people, used uncoated carbide tool for titanium alloy cylindrical cutting experiment, founding the tool wear with adhesion wear, diffusion wear, and tool wear intensifiedwith the increase of cutting speed and feed rate[8]. ChenYan and other people used software on the tool in high speed cutting titanium alloy TC4 wear through finite element analysis and they found speeding up the tool wear with the increasing ofcutting speed, and when the cutting speed is 300m/min, tool life is only 1/3 of 130m/min[9].

In this paper, the titanium alloy TB6is subjected todry orthogonal cuttingunder different cutting parameters to process experimental research, comparative analysis of tool wear under different cutting parameters, andis subjected to regression analysiswith the experimental results to get regression

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formula of tool wear, and it provides some reference for the optimization of cutting parameters, improving tool life and reducing processing costs.

2 Experiment scheme

In this experiment, nine sets of milling parameters are selected according to the production experience, literature data and tool manufacturer's recommended value. Orthogonal cutting experiments are carried out, and the milling method is progressive milling. Experiment with nine identical tools. According to the recommended durability test standard, the flank wear amount VB=0.25-0.3mm is chosen as the tool wear standard. The wear of the tool is detected by a micro camera, machining the workpiece according to the experimental milling parameters, stoppingprocessing at regular intervals, the tool flank wear image is taken during the experiment, and processing wear images in software. Finally Current tool wear can be obtained.

The orthogonal experiment was adopted to design the experiment. Four factors and three levels of orthogonal experiments were designed. The four factors were milling speed, feed per tooth, cutting depth and cutting width. The level of each factor is shown in the following table 1.

Table.1 The cutting factor and level table

	level1	level2	level3
Cutting speed V_c m/min	15	25	35
Feed per tooth f_z mm/z	0.04	0.08	0.12
Depth of cut a_p /mm	1	1.5	2
Width of cut a_c /mm	0.12	0.17	0.22

3. Experimental condition

3.1 Experimental machine and Experimental tool







Fig.1 Experimental machine **Fig.2** Experimental tool **Fig.3** Experimental microscope

Fig.1 is machine tool used in experiments . Fig.2 is cemented carbide cutting tool used in experiments, 55° integral alloy end milling cutter, φ6R0.5*15*φ6*50L*55°*4T, Fig.3 was the experimental microscope camera.

3.2 Experimental material

TB6 cuboid material was used in the experiment. TB6 alloy, is also calledTi-1023. Ti-1023 is a typical titanium alloynearβtypewith a nominal component of Ti-10V-2Fe-3Al. The chemical composition and mechanical properties are shown in table 2 and table 3 below.

Table.2 Chemical composition of TB6 titanium alloy

Element	H	O	N	Fe	Al	V	Ti
Content（%）	0.01	0.03	0.03	1.93	2.95	10.16	other

Table.3 Mechanical properties of TB6 titanium alloy

Tensile strengthσ_b/MPa	Yield strength$\sigma_{0.2}$/MPa	Elongation rateδ/%	Shrinkage rateψ/%	Impact toughnessα_k/(J•cm^{-2})
1005	1035	6	64	60

3.3 Experimental instrument

Measure the wear of the tool by using a micro camera as shown as the Fig.3.The camera is connected with the computer, and the tool wear can be enlarged by using relevant software so as to be easily observed on the computer. Fix the camera on the machine tool and move the fitted tool to the right place to record the current coordinates. After a certain period of time, the cutting is stopped and the tool is moved to thebeforehandrecorded coordinates. The camera is used to observe and record the wear. If the desired amount of wear is not reached, the cutting can be continued for a certain period of time, then the cutting is stopped and the tool is moved to the beforehand recorded coordinate position. The wear condition is observed until the tool reaches a predetermined amount of wear.

4. Experimental results

According to the specified experimental scheme, the cutting time of each group is calculated as the wear criterion of the tool under the cutting parameters of each group, and the cutting time VB = 0.26mm is used to calculate the cutting time required for each group. As shown in the following table 4:

Table.4 Experimental results of tool durability

Serialnumber	Horizontal combination	Millingdepth $a_p$mm	Millingwidth $a_e$mm	Feed rate $f_z$mm/z	Cutting speed V_c m/min	Durability T min
1	A1B1C1D1	1	0.12	0.04	15	218
2	A1B2C2D2	1.5	0.17	0.08	15	190
3	A1B3C3D3	2	0.22	0.12	15	65
4	A2B1C2D3	1.5	0.22	0.04	25	144
5	A2B2C2D1	2	0.12	0.08	25	38
6	A2B3C1D2	1	0.17	0.12	25	25
7	A3B1C3D2	2	0.17	0.04	35	55
8	A3B2C1D3	1	0.22	0.08	35	18
9	3B3C2D1	1.5	0.12	0.12	35	8

The test specimen is a rectangular cubic titanium alloy, cutting in one direction after repeated cutting, record the number of times each group of repeated cutting and time, when the tool flank wear 0.26mm to stop cutting, at this time cutting Time is tool durability.

Figure 4 for a certain photomicrograph by the computer on the cutting tool when the wear and tear measurement, the figure at the tip of the white band with a tool wear, measured by the computer width.The difference is that the larger the difference is, the greater the influence of the parameter on the measured effect. The results of the above orthogonal experiments were used to calculate the average effect. The results of the analysis are shown in the table below.

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Fig.4 Flank wear of the tool

Table 5. The impact results VS cutting parameters

	t			
	a_p	a_e	f_z	V_c
K_1	87	88	139	157.67
K_2	114	90	82	69
K_3	52.67	77.67	32.67	27
R	61.33	12.33	106.33	130.67

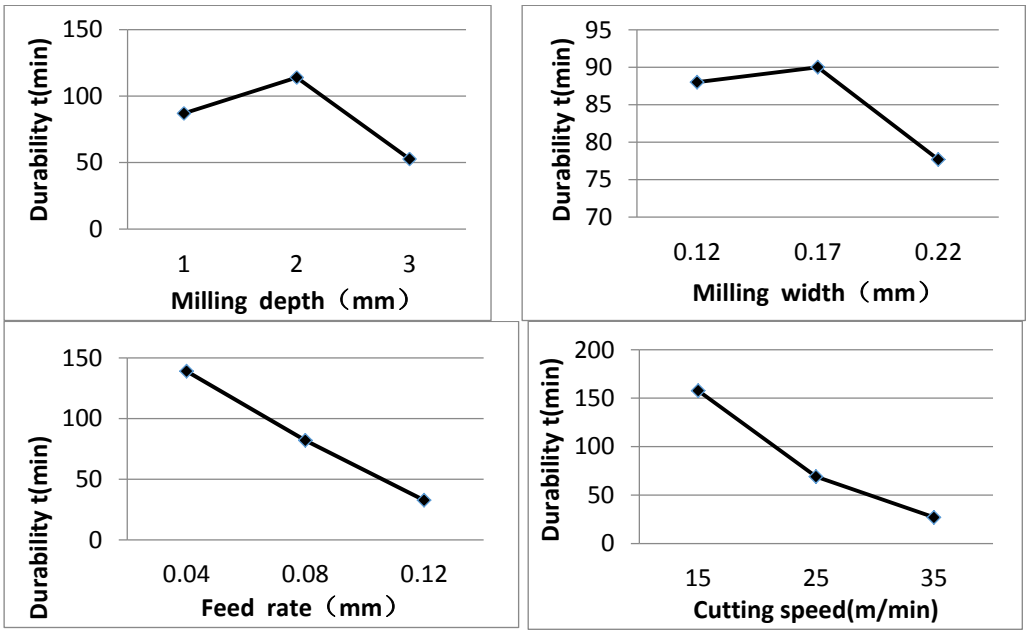


Fig5 Durability vs. change of cutting parameters

From the experimental results can be seen in the titanium alloy TB6 knife milling, the most significant impact on the durability of the cutting speed, the difference is 130.67; followed by the feed, the difference is 106.33; followed by Milling depth, the difference is 61.33; the most significant factor for the milling width, the difference is 12.33. The impact of factors on the durability of the impact of the effect of Fig5 shown.

It can be seen from the Fig 5 that the durability decreases with the increase of feed rate and cutting speed. The reason is that the higher the milling speed is, the higher the friction, the higher the milling temperature, the faster wear and the durability. The increase in feed volume to make the chip wide, conducive to heat conduction, speed up the temperature increase, thereby reducing the durability.

Durability increases first and then decreases with increasing milling depth. The durability increases first and then decreases as the milling width increases.

5 Conclusion

(1) By the above experimental results and analysis can be concluded that, when using TB6 titanium alloy cutting tools, milling dosage effect on durability according to a significant degree of milling speed, feed, milling depth, milling width; The durability decreases with the increase of feed quantity and cutting speed, and the durability decreases with the increase of the depth of milling. Durability decreases as the width of milling increases first.

(2) Milling depth and milling width have less impact on durability than milling and feed. So with titanium alloy TB6 tool, the use of small feed, small milling depth, low milling speed can be very high durability, improve tool life, take a good cutting effect.

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