

Research on tool wearing on milling of TC21 titanium alloy

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Abstract. Titanium alloys are used in aircraft widely, but the efficiency is a problem for machining titanium alloy. In this paper, the cutting experiment of TC21 titanium alloy was studied. Cutting parameters and test methods for TC21 titanium alloy were designed. The wear behavior of TC21 titanium alloy was studied based on analysis of orthogonal test results. It provides a group of cutting parameters for TC21 titanium alloy processing.

1 Introduction

Titanium and titanium alloys has high specific strength, high temperature resistance, good corrosion resistance and a series of outstanding advantages. It can be welded in various ways, for example, parts forming and machining. However, It is a kind of hard processing material, and its milling characteristics are shown as follow^[1-2].

(1) The deformation coefficient is small, which is a remarkable characteristic of titanium alloy milling. The deformation coefficient is less than or close to 1 of titanium alloy^[3]. The distance of sliding friction of the chip on the rake face is greatly increased, and the tool wear is accelerated in milling.

(2) Milling temperature is high. That because the thermal conductivity of titanium alloy is very small (equivalent to only $1/5 \sim 1/7$ of 45# steel^[4-6]). Chip that contact with the rake face in length is extremely short. Heat generated during milling, and it is not easy to transmit. Concentrated deformation in milling area is near the smaller range of the milling edge. In these areas, the milling temperature is very high^[7].

(3) The milling force per unit area is large. That's because the contact length of chip and rake face is very short. The milling force on the unit contact area is greatly increased, and it lead to chipping easily.

(4) The chilling phenomenon is serious. That due to the large chemical activity of titanium alloy at high a milling temperature. In this process, oxygen and nitrogen absorbed easily in the air, and forming a hard and brittle skin^[8-9]. In addition, the plastic deformation in the milling process can also cause a surface hardening.

(5) Machining tools are easy to wear in stamping, forging, hot rolling and other miling processing. In this process, a hard and brittle uneven skin can formed easily, and it cause chipping phenomenon. That is to say, the removal of crust to formed in miling rocess of most titanium alloy. In addition, due to the strong chemical affinity of titanium alloy to cutting tool materials. Tools are easy to produce adhesive wear under the condition of high milling temperature and milling force per unit area.

In the actual titanium alloy processing, the titanium alloy milling processing mainly has following several problems.



(1) Processing efficiency is ever low. aircraft titanium alloy parts have a large part of the thin-walled frame parts. In addition to parts of the can be forged outside. A substantial amount of material must be removed from the bulk stock during actual processing. However, titanium alloy is a difficult processing materials. So the material removal efficiency is very low. Generally speaking, processing of titanium alloy should using high-speed steel cutting tools. When the milling speed is exceed 30m/min, carbide cutting tools milling speed exceed 60m/min^[10], it will make the processing become difficult. When the milling speed of 100 m/min or more, it immediately enters the high-speed milling range. At present, advanced level of milling in foreign is during 100 m/min-200 m/min. It is a higher degree of application of high-speed milling. Only a small number of domestic enterprises are to carry out some local research. There reserch can be close to high-speed milling range. The overall level of titanium alloy milling processing is still relatively low in domestic. The milling speed is no more than 60 m/min compared with foreign countries, and there is still a big gap^[11] in this reserch area.

(2) The lack of an effective support of titanium alloy technology database. Only a parameterthe range is given in milling manual. In the specific process arrangement and milling selection, process parameters to be determined with experienceand of oprationtor. The commercialization process database is required to provide this workt. Kozlov. V.^[12] and other scholars have done a lot of optimization milling parameters of the research work.

(3) At present, China's high-speed milling machine, tool and milling fluid are low relatively. These restricts the improvement of titanium alloy in milling processing.

In the final analysis, the main reasons of backward technology are the the basic theory of high-speed milling for current titanium alloy and processing specification are not perfect. This technology are not enough to guide the production practice. Therefore,

Breakthrough of low efficiency of titanium alloy machining problems are necessary to study the mechanism of high-speed milling, and explore the method to improve the processing level of titanium alloy. This paper combines the manufacturing experience of titanium alloy processing, collecting a large number of titanium alloy processing information. Aiming at how to improve the processing efficiency of titanium alloy for performing milling parameter assignment, tool path design and other aspects of research. Thereby improving the processing efficiency of titanium alloy parts.

2 Test material and method

2.1 Test material

Workpiece material for milling is TC21 titanium alloy. It belongs to the type of ($\alpha+\beta$) titanium alloy. The chemical composition and mechanical properties at room temperature of TC21 titanium alloy are given in Tab.1 and Tab.2.

Table.1 Chemical composition of TC21 titanium alloy

Element	Al	Cr	Sn	Mo	Zr	V
Content (wt%)	6.29	1.74	2.38	2.59	2.24	0.029
Element	N	H	O	C	Ti	
Content (wt%)	0.008	0.002	0.077	0.026	allowance	

Table.2 Mechanical properties of TC21 titanium alloy at room temperature

Material	σ_b /MPa	$\sigma_{0.2}$ /MPa	δ / %	ψ / %
TC21	1110	1060	15.67	20.67

The material shape of the workpiece in the milling test are cubic block, which dimension is 140mm×140mm×140mm. The milling experiment is carried out on the three coordinate NC machining center(TK5680). The milling tool in used is coated carbide tools with a diameter of 20mm, the number of teeth is 4, which are imports from United States. The milling process and tool of TC21 are shown in Fig.1.

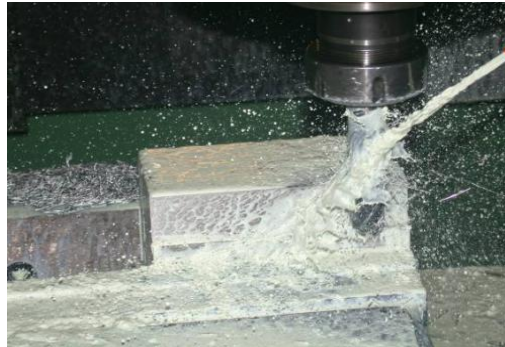


Figure. 1 Milling process of TC21



Figure. 2 Milling tool of TC21

2.2 Milling parameter design and analysis method

In order to study the tool wear behavior for milling TC21 titanium alloy, a single factor test was designed. The parameters of the experiment are shown in Tab.3, Tab.4 and Tab.5.

Table.3 Milling parameters under different speed

Milling parameters	Milling level		
Speed(r/min) v	160	250	500
Feed rate(mm/r) f	0.1	0.1	0.1
Milling depth(mm) a_p	1	1	1

Table.4 Milling parameters under different feed rate

Milling parameters	Milling level		
Spindle speed (r/min) v	160	160	160
Feed rate(mm/r) f	0.1	0.2	0.3
Milling depth(mm) a_p	1	1	1

Table.5 Milling parameters under different Milling depth

Milling parameters	Milling level		
Speed(r/min) v	160	160	160
Feed rate (mm/r) f	0.2	0.2	0.2
Milling depth (mm) a_p	1	2	3

The durability of milling tool test is expensive and time-consuming, In order to obtain the correct test results with less test times, In this paper, orthogonal test design method is used to arrange the test and data processing. The Orthogonal test of milling parameters si shown in Tab.6.

Table.6 Orthogonal experimental design of milling parameters

Test ID	Speed v r/min	Feed rate f mm/r	Line speed v /min	Feed rate f_z /mm
TC21-C-1	160	0.1	20	0.05
TC21-C-2	250	0.1	60	0.05
TC21-C-3	500	0.3	100	0.15

The results of the milling test are analyzed by using the visual analysis method, the variance analysis method and the significance test.

3 TC21milling tool wear analysis

3.1 TC21 study on tool wear behavior of single factor milling test

The variation curves of tool wear with processing time are shown by Fig.3 and Fig.4. In the situation, All the curves did not reach the tool wear state. In this paper, the wear capacity of flank face is to be 0.3mm as the tool wear state.

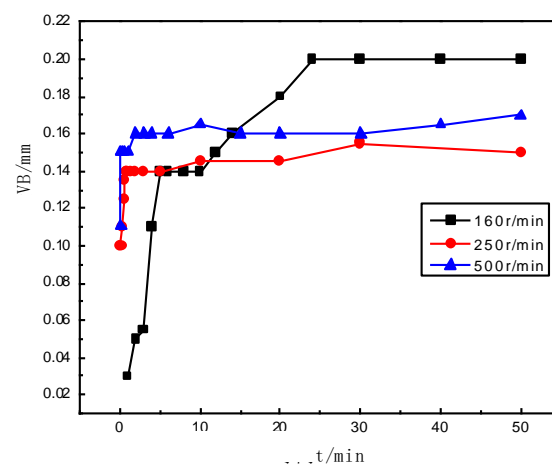


Figure.3 Variation of tool wear with time under different speed

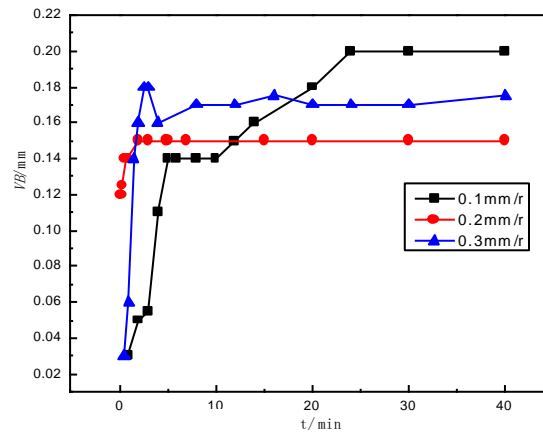


Fig.4 Variation of tool wear with time under different feed rate

A law can be obtained from above as follow. At the same feed rate (0.1mm/r), the same cutting depth (1mm), and the same spindle speed (250r/min), the minimum amount of wear is 0.15mm. flank face wear value is 0.17mm in high speed (500r/min). It is small than lower speed (160r/min), which wear value is 0.2mm. Under the three test conditions, the average wear rate was not up to standard (0.3mm). In this situation, all the tools can continue to milling. It was found from Fig.4 that the wear amount of flank face was the smallest when the feed was 0.2mm/r. Too fast or too slow of walking knife will lead to increased wear.

In order to study the influence of different processing parameters on tool wear, the orthogonal test of TC21 titanium alloy was carried out. This experiment provides data for parameter optimization.

3.2 Study on TC21 orthogonal experiment

In the orthogonal test of milling TC21, spindle speed has the greatest influence on tool wear during milling test. Tool wear is not serious when the spindle speed is not more than 250r/min. tool wear increases sharply when the spindle speed is during 250r/min to 500r/min, and flank wear is very serious. With the increase of feed rate, the tool wear is not monotonically increasing, but there is a minimum value.

Fig.5, Fig.6 and Fig 7 are the tool wear morphology of flank face for milling TC21 orthogonal test design in 3 different milling parameters.

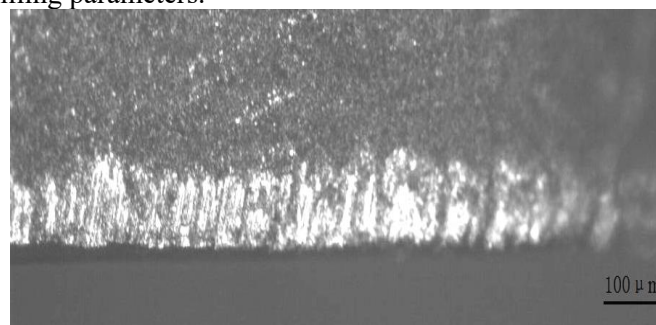


Fig.5 TC21-C-1 wear of flank face

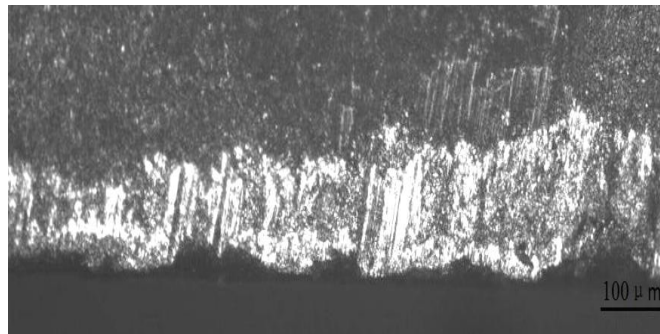


Fig.6 TC21-C-2 wear of flank face

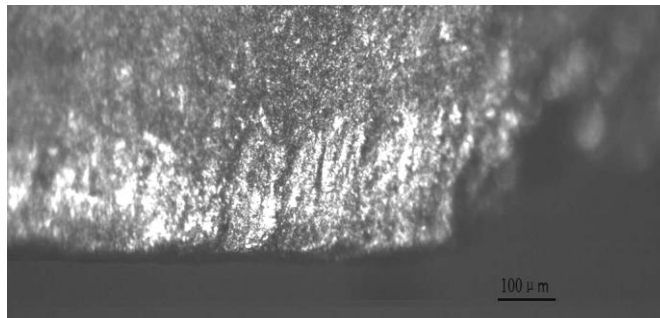


Fig.7 TC21-C-3 wear of flank face

The wear morphology of the tool flank face is slightly different under different milling speed. The distribution of tool flank face wear along the depth of cutting direction is uniform when the milling speed is during 160r/min(TC21-C-1) to 250r/min(TC21-C-2).

4 Conclusion

In this paper, the tool wear behavior of TC21 titanium alloy high speed milling is studied by milling experiment. The influence of different process parameters on tool wear in TC21 milling process is analyzed. The research results provide a feasible technical parameters for TC21 milling, and the process level of TC21 milling is improved.

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