

Study on Deep Hole Nesting System and Tool of TC4 Titanium Alloy

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Keywords: TC4 titanium alloy; Trepanning machining; Processing system; Trepanning drill

Abstract. For the difficult machining of large-aperture deep-hole machining and the difficult machinability of TC4 material, the type of machining system and different geometric parameters of the drill bits are optimized. Then the deep-hole nesting test was conducted. The test results showed that the inner wall of the processing hole has high precision and good chip evacuation. Provides effective tool geometric parameters and machining systems for large diameter deep hole nesting of TC4 titanium alloys.

Introduction

TC4 titanium alloy is a rare metal material, due to its excellent physical and mechanical properties, it is widely used in aerospace, petrochemical, shipbuilding, automotive, pharmaceutical and other fields, However, at the same time, TC4 titanium alloy is also a difficult-to-machine material, which has poor cutting performance and low machining efficiency. And its hard workability limits its wide application in all aspects [1]. For deep hole machining with large hole diameter ($\Phi > 50\text{mm}$), deep-hole trepanning machining method greatly reduces material waste and improves material utilization and processing efficiency.

Determination of Bit Structure and Selection of Processing System

The Structure of the Trepanning Drill. In the deep hole trepanning machining process, if the processing hole diameter is not particularly large, chip removal will be smoother with the external chip removal method, and the use of a single tooth will greatly reduce the vibration and cutting power of the system. Therefore, the single-tooth external chipping trepanning drill is used in this paper.

Selection of Processing System. In the internal chip removal system, the sectional area of the drill pipe is larger than that of the external chip removal system, so the rigidity is good. At the same time, the coolant can better suppress the vibration of the drill pipe, but the internal chip removal system requires a special oil grantor, and the structure of the processing system more complicated, the required machine power is also higher.

Compared to the internal chip removal system, the external chip removal system does not require a special oil grantor, which simplifies the processing system; for the trepanning machining of the same hole diameter, the chip removal area of the external chip removal system is larger than the internal chip removal system; For the deep hole trepanning machining of large hole diameter, the mandrel rod cut out by the external chip removal system is supported by the inner wall of the drill pipe when sagging, and will not cause blade chipping, and it will not affect chip removal [2]. Taking into account the effects of chip evacuation and mandrels, this paper uses an external chip removal system.

Deep hole machining machine modified from CW6163D lathe, Processing system shown in Fig. 1. Among them, 1 is Deep hole machine tools, 2 is Four-jaw chuck, 3 is Sample to be processed, 4 is Local rolling center frame, 5 is trepanning drill, 6 is Central rack, 7 is Drill pipe, 8 is Feed bracket, 9 is Cooling tube.

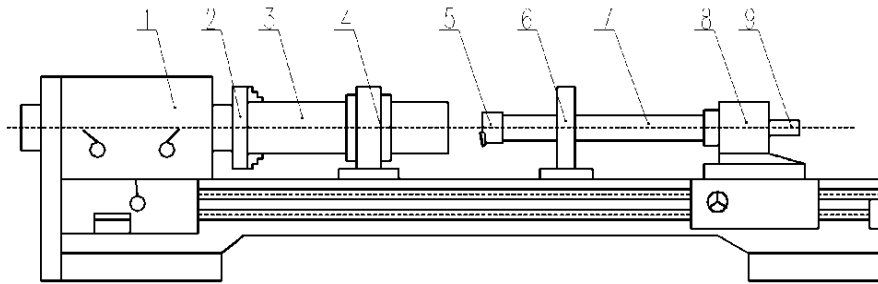


Figure 1. Finite the external chip removal system

Determination of Processing Method. Processing method: The specimen has high requirements on the straightness of the machined hole, so the workpiece rotation and the tool feed movement are adopted[3].

Determination of the Geometric Parameters of the Drill

The Width of the Cutting Edge. Under the premise of satisfying the processing aperture, the narrower cutting width should be used as far as possible in order to increase the diameter of the mandrel and save material, so the total width of the cutting edge selected in this paper is 15mm. At the same time, for good chip breaking and swarf removal, At the same time, in order to achieve good chip breaking and chip separation, the blades adopt a stepped approach in the axial direction and are divided into four steps[4]. The width of each tooth is 4mm, 4mm, 4mm and 3mm from outside to inside(As shown in Fig. 2).

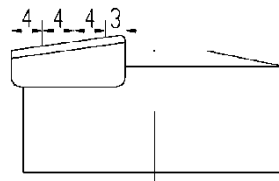


Figure 2. Finite Radial width of cutter teeth in axial step distribution

Chipbreaker Size. According to the characteristics of TC4 titanium alloy material, we use arc-shaped chipbreakers, The arc radius R_n is generally 0.5mm to 0.8mm, the width of the chipbreaker table W_n is 1.8 mm to 2.3 mm[5].

The Rake Angle γ_0 . The rake angle γ_0 is usually 0° . This is mainly because when the rake angle γ_0 is 0° , the center height of the drill bit after regrinding will not change. In fact, for deep-hole drilling, the rake angle $\gamma_0 = 0^\circ$ is not ideal angle, Due to the small plastic deformation of TC4 titanium alloy, small cutting deformation in cutting process, small contact length between rake face and chip, and relatively concentrated cutting stress, small rake angle should be selected to increase the contact area between chip and tool rake face of the tool, and to strengthen edge strength to avoid chipping and severe wear [5] , this paper selects the front angle γ_0 to 7° .

The Back Angle α_0 . The back angle of the trepanning drill, generally take α_0 60 ~ 120. When the TC4 material is be cutting, due to its small elastic modulus, the machined surface rebounds severely, which exacerbates the wear of the back face of the tool. In order to reduce the wear of the back face of the tool and make the cutting edge easy to cut into the workpiece, an appropriate large back angle should be selected, taking the back angle α_0 as 12.

The Blade Angle λ_s . The blade inclination controls the chip flow direction and the chip breaking mode. For the deep-hole drilling, the general inclination angle λ_s is 0° .

The Main Angle K_r . Small main angle will lead to increase of radial component F_y , decrease of axial component F_x , and less rigidity of the system, which will cause vibration, vibration will reduce the tool durability and increase the roughness of the machined surface[6]. In order to ensure the machining accuracy and satisfy the rigidity of the processing system, it is appropriate to take a

large lead angle. This paper chooses the main angle K_r to be 80° .

Selection of Materials for Blades and Guide Blocks. TC4 titanium alloy has poor cutting performance, large cutting force during cutting process, and large impact vibration of the tool; at the same time, it has poor thermal conductivity, high cutting temperature and severe tool wear. Therefore, we chose YG8 cemented carbide that with high bending strength and toughness, good wear resistance and good thermal conductivity as the blade material.

The guide block material also selects YG8 hard alloy material with low affinity and high wear resistance to the workpiece material.

Selection of Cutting Fluid. The purpose of the cutting fluid is mainly to smooth chip removal and reduce the temperature of the cutting zone. When processing deep holes with nesting, it is advisable to use active mineral oil instead of emulsion or kerosene[7]. 20# mechanical oil was selected as the cutting fluid for deep hole drilling of TC4 titanium alloy.

Deep Hole Drilling Test

Connect a drill pipe (connecting drill) with a diameter of $\Phi=150\text{mm}$ to the tailstock of the machine tool, Install the TC4 bar to be machined on the modified deep hole machine. using the cutting speed $v=80\text{r/min}$, $v=110\text{r/min}$, using the feed rate $f=0.16\text{mm/r}$, $f=0.18\text{mm/r}$, $f=0.20\text{mm/r}$, cutting fluid pressure 2.5Mpa , measuring axial cutting force and calibrating torque with resistance strain gauge during processing.

Workpiece Structure. The test piece is made of TC4 titanium alloy bar. The diameter of the test piece is $\Phi=230\text{mm}$, the processing aperture is 150mm , and the processing length is 1140mm .

Processing Test. The deep hole drilling of TC4 specimen stock was performed under different drilling parameters. The test results are shown in Table 1.

Table 1 Test processing results

Test number	Rotating speed [r/min]	Feed Rate [mm/r]	Axial cutting force [N]	Torque [N.m]	Cutting fluid flow [L/min]	Cutting condition	Tool wear condition
1	80	0.16	970.12	119.41	125	No chip jams	Without passivation
2	110	0.16	915.75	117.18	125	No chip jams	Without passivation
3	80	0.18	1028.33	126.56	250	No chip jams	Slightly passivated
4	110	0.18	970.69	125.86	250	Slight chip clogging	Seriously passivated
5	80	0.20	1084.11	134.92	250	Chip jam	Blade tipping
6	110	0.20	1023.35	133.67	250	Severe chip clogging	Seriously worn

When the speed is $n=80\text{r/min}$, the feed rate is $f=0.18\text{mm/r}$, and the cutting fluid flow rate is 250L/min , the chip removal is good, the processing hole inner wall size accuracy up to IT8, the surface roughness can reach $3.2\mu\text{m}$ (as shown in Fig. 3), and the machining efficiency is also high. The chip shape is shown in Fig. 4.



Figure 3. Finite Processed specimens and bars



Figure 4. Finite Good form of swarf

Analysis of Test Results and Tool Wear. In tests 1 and 2, the minimum feed $f=0.16\text{mm/r}$, the force and deformation of the cutting edge of the drill were minimal, so the tool was not passivated (as shown in Fig. 5), and there was no scumming phenomenon, but due to feed rate is small, so processing efficiency is low.

During the test 3, the smaller feed rate $f = 0.18\text{mm/r}$, the force and deformation of the cutting edge of the drill are small, and the cutting temperature of the cutting edge of the drill bit is decreased when the large cutting fluid flow rate is $Q=250\text{L/min}$. The chip removal is smooth and the cutting edge deformation is also reduced. Therefore, the tool is only slightly passivated, and the chip is well-distributed without chipping.

In test 4, compared to test 3, the increase in tool speed increases the cutting temperature, and there is a slight chipping phenomenon, which exacerbates the tool wear, and the passivation of the tool is severe (as shown in Fig. 6).

In tests 5 and 6, the maximum feed rate $f=0.20\text{mm/r}$ was adopted. After the feed rate was increased, the cutting force was correspondingly increased, and the force and deformation of the edge of the drill bit were concentrated. At the same time, the torque in the machining system is also increased after the feed amount is increased, causing severe vibrations in the machining system. As a result, the tool has collapsed and the tool has been chipped (as shown in Fig. 7), and chip evacuation has not been smooth.



Figure 5. Finite Blade without passivation



Figure 6. Finite Blade passivation severe



Figure 7. Finite Severe blade wear

Conclusion

Taking into account the effects of chip evacuation and mandrels, this paper uses an external chip removal system. When the drill bit adopts rake angle $\gamma_0 = 7^\circ$, The back angle $\alpha_0 = 12^\circ$, The main angle $Kr = 80^\circ$, The blade angle $\lambda_s = 0^\circ$, and rotation speed $n = 80 \text{ r/min}$, feed rate $f = 0.18 \text{ mm/r}$,

cutting fluid flow rate Q At 250L/min, the chips are well-distributed ,The sample has high processing efficiency.

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