Research on Numerical Control Machining Process of Nailing Thin Wall Tube

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Abstract— Based on the study of the characteristics of the material, the fixture of the clamping fixture for the milling and milling process was designed and the rough and fine cutting tools and cutting parameters were selected reasonably. Developed its NC milling complex machining program, and in the turning center HTC2050Z lathe milling machine to complete the complex processing, thin-walled titanium alloy parts processing technology to provide support.

1. INTRODUCTION
Titanium alloy material Ti-6Al-4V (TC4) high strength, good thermal stability, corrosion resistance, high strength at high temperature, at 300 ~ 500 ℃ temperature, the strength of aluminum alloy 10 times higher, it is widely used in aerospace, petrochemical, shipbuilding, automotive, medical equipment and other industries [1][2]. Because of its low thermal conductivity, high cutting temperature, the tool is very easy to wear, making it a typical difficult to machine difficult to cut material. The thin-walled titanium alloy parts processing is even more difficult in the modern machinery manufacturing industry, due to poor rigidity of thin-walled parts, the strength is weak, and in the process of processing and vulnerable to stress, heat and vibration deformation, affecting the dimensional accuracy of the workpiece, shape, position accuracy and surface roughness, not easy to ensure the quality of parts processing, so the titanium alloy thin-walled parts processing technology research, of great significance.

2. TITANIUM ALLOY MATERIAL Ti-6Al-4V (TC4) FEATURES AND THIN-WALLED PARTS MAP
A. Titanium alloy material Ti-6Al-4V (TC4) Features Titanium alloy TC4 material composition of Ti-6Al-4V, has good mechanical properties. The specific strength of TC4 is sb = 1.012MPa, density g = 4.5g / cm3, specific strength sb / g = 23.5, and the specific strength of alloy steel sb / g is less than 18. The thermal conductivity of titanium alloy is 1/5 of iron and 1/10 that of aluminum, and its thermal conductivity is lower. The thermal conductivity of TC4 is l = 7.955W / m • K. Linear expansion coefficient of 7.89 * 10⁻⁶ °C, the specific heat of 0.612 cal / g • °C. The lower the elastic modulus of titanium alloy, TC4 elastic modulus E = 110GPa, about steel 1/2, titanium alloy has three kinds of matrix organization, titanium alloy also divided into the following three categories: α alloy, (α + β) Alloys and β alloys [3][4]. China, respectively, TA, TC, TB said, and TC4 belongs to (α + b) titanium alloy, titanium alloy is very easy to process deformation. The chemical composition of the table shown in Table 1.
Table 1. Titanium alloy Ti-6Al-4V chemical composition

| Chemical composition | Ti    | Al    | V     | Fe    | C     | N     | H     | O     | other |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                      | 5.5-6.75 | 3.5-4.5 | 0.30  | 0.08  | 0.05  | 0.015 | 0.20  | 0.10  |

B. Titanium thin-walled parts  
Titanium alloy nailing thin-walled tube parts machinability is poor one of the difficult processing of materials, the cutting performance characteristics as follows:

① modulus of elasticity of its elastic modulus of about 45 just 1/2, deformation and vibration processing;

② low thermal conductivity during the cutting process so that the sharp heat of the tool wear and tear, while the workpiece surface will produce work hardening, affecting the uniformity of titanium parts on the surface, reducing the fatigue resistance of light, precision parts geometry;

③ large cutting force per unit area As a result of the contact length of cutting and rake surface is extremely short, the cutting force per unit contact area greatly increased;

④ severe chilling Titanium chemical activity, cutting is easy to absorb oxygen and nitrogen in the air to form a hard and brittle skin.

Titanium alloy nailing thin-walled tube parts shown in Figure 1, the total length of 60.55mm, the outer contour of a plurality of stepped cylindrical surface, the maximum diameter of Φ 26.15 ± 0.02mm, the smallest diameter of Φ6.3 mm, the diameter of the smallest hole in the right end hole of the part is Φ6.096 mm, and the outer diameter Φ6.3mm is 0.102mm thick, the length of the thin wall hole is 40.15mm; the maximum diameter of the inner hole of the left end of the part is Φ 10.17 ± 0.01mm, a φ 1.5H7 counterbore on the outer circle Φ 26.15 ± 0.02mm, a 1.5mm slot on the left side and a uniform through hole of 8-2Φ 2.5mm, on the outer circle of Φ 14.463 ± 0.01mm There is a Φ 1.4 mm through hole.

Figure 1. Titanium nailing thin-walled tube parts map

3. ANALYSIS AND CLAMPING SCHEME OF CLAMPING DEFORMATION OF THIN TI ALLOY PARTS

3.1 Deformation Analysis of Processing and Clamping of Titanium Alloy Thin Parts

The thickness of the thin-walled tube of titanium nail gun is less than 2mm, the rigidity of the parts is very poor. It is easy to produce "heart-shaped" shape when clamping the three-jaw chuck \(^5\)\(^6\)\(^7\) Knife cutting force and the role of cutting heat, deformation and vibration. The deformation of the main (1) clamping deformation \(^8\), due to the workpiece wall thin, under the action of clamping force will produce deformation. When the use of three-jaw chuck clamping thin-walled cylinder parts, under the action of the clamping force, the parts into a triangle, resulting in uneven machining of the circumferential margin, the hole is completed, the release of the jaw and take After the parts, Due to elastic recovery and internal stress deformation, the part is restored
3.2 Titanium thin-walled parts processing positioning fixture program

Titanium alloy nail thin-walled tube parts easily deformed due to temperature increases\cite{9-11}, so that processed holes appear over size and shape tolerances. In order to prevent the titanium alloy thin-walled parts due to clamping and turning machining deformation, clamping and processing must ensure that the coaxiality of the outer axis, the end face of the hole axis of the vertical and parallelism of the two planes. Thin-walled parts of titanium alloy clamping mutual reference and benchmarking principle of unity, to ensure processing accuracy. The first installation, the design of the fixture shown in Figure 3 (a), set the left block positioning, the right end of the nut lock, the parts from radial clamping to axial clamping, axial clamping force Normal stress is about 1/6 of the radial clamping force, to minimize the deformation of thin-walled parts. The second installation, as shown in Figure 3 (b) shows, with the opening sleeve to change the self-centering chuck three-point clamping for the entire round of clamping\cite{12-16}, or fan-shaped clamping chuck, modified self-centering chuck Of the three claws, welded on three universal claws fan soft claws, increasing the clamping area of the site, reducing the thin-walled parts of the clamping and turning deformation.

Figure 2. Titanium alloy nail thin-walled tube parts deformation diagram to a cylindrical shape, and the already machined circular hole becomes an arc-shaped triangle, and the stress is restored and deformed as shown in FIG. 2. (2) cutting thermal deformation: Due to the thin parts, cutting heat will cause the workpiece to produce thermal deformation. (3) cutting vibration deformation: due to the thin parts, cutting force under the action of the thin wall parts prone to vibration and deformation.
a) Open bushing b) Fan-shaped soft jaws (1 is a fan-shaped soft jaw, 2 is the workpiece)
Figure 3. (b) Second fixture diagram

4. TITANIUM THIN-WALLED PARTS MACHINING MACHINE SELECTION
If this part is processed by ordinary CNC lathe or CNC milling machine, it needs to be repeatedly installed to be completed several times, occupying more CNC lathes and/or CNC machining centers, resulting in a longer NC dimensioning process chain and mismatch of positioning datum. Difficult to guarantee, low processing efficiency. Therefore, the use of turning and milling machining centers to complete the thin-walled titanium alloy machining parts[17-18], select Shenyang Machine Tool Group Corporation HTC2050Z Turning Center, the internal structure and tool magazine shown in Figure 4. The CNC system of the turning center is FANUC 0i-TC. The total tool storage capacity is 12 tools and the tool post is the rear type rotary turret. It can finish the turning, milling, drilling, hinge, tapping and other turning and milling processing contents.

![HTC2050Z turning center and the rear cutter](image)

5. DESIGN OF PROCESSING TECHNOLOGY FOR THIN Ti ALLOY PARTS
Titanium thin-walled tube, the biggest difficulty is processing in the hole and wall thickness control accuracy, it is necessary to ensure that the hole size Φ6.096, the surface roughness of 0.2μm but also to ensure that the wall thickness of 0.1mm, and in the process of processing. But also to solve the clamping force, cutting force, cutting heat and deformation of the tool vibration, the workpiece clamping, geometry parameters, the preparation of the program and so have higher requirements for this titanium thin-walled tube Parts processing, the design uses two sets of process options:

Process plan one: the two sides of the rough fine car (ensure the total length) → crude car bore Φ6.3, Φ10.17 → roughing the outer Φ10.17, Φ10.19, Φ14.463, Φ17.4, Φ26.15 → heat treatment → semi-fine car Inner hole Φ6.3, Φ10.17 → Excavator Cylindrical Φ10.17, Φ10.19, Φ14.463, Φ17.4, Φ26.15 → 1.5mm roughed → Drilled to Φ1 (Φ1.5) → Drilled to Φ2 (Φ2.5) → Drilling to Φ1 (Φ1.4) → Aging → Inner hole of precision car Φ6.3, Φ10.17 → Finish car Φ10.17, Φ10.19, Φ14.463, Φ17.4, Φ26.15 → Semi-fine milling, fine milling groove 1.5mm drilling to Φ1.5 → drilling to Φ2.5 → drilling to Φ1.4 → deburring, cleaning.
Process plan two: the two ends of the crude car (ensure the total length) → rough car, semi-fine car bore Φ6.3, Φ 10.17 → rough car, semi-fine car outside Φ10.17, Φ10.19, Φ14.463, Φ17.4, Φ 26.15 → Heat Treatment Roughing, Semi-finishing Slot 1.5mm → Drilling to Φ1 (Φ1.5) → Drilling to Φ2 (Φ2.5) → Drilling to Φ1 (Φ1.4) → Aging → Fine Car Inner hole Φ6.3, Φ 10.17 → Finish hole Φ10.17, Φ10.19, Φ14.463, Φ17.4, Φ26.15 → 1.5mm finishing groove → Drilling to Φ1.5 → Drilling to Φ2.5 → Drilling Hole to Φ1.4 → deburring, cleaning.

In the first program of the program, the roughing, semi-finishing, finishing separately, and throughout the heat treatment and aging process; in the process of program two, only the rough, finishing the program, the precision Small parts, machining allowance small, more difficult to ensure accuracy[19-20]. Based on the above, choose a program for this part of the processing program. Direct drilling, boring, boring, milling and grooving in the CNC turning center is carried out according to the spindle speed S: 300-400r / min, feed rate F: 0.1mm / min, cutting depth: 0.05-0.1mm. After processing the hole in full compliance with the drawings.

6. DESIGN OF THIN - WALLED TITANIUM PARTS WALKING PATH
The parts need two clamping, the design of the retractable point in A, the coordinate value of A (15,0), because the turning center of the turret for the rear rotary turret, so go the route above, right outside Circle contour path design shown in Figure 5. Design point B, the coordinate value is B (15,-61), because the turning center of the turret for the rear rotary turret, so the path of the top in the guide, the left end of the outline of the outer contour path design shown in Figure 6. After finishing the process design, the parts are adjusted according to the average of the tolerances. After the clamps are calibrated, they are tested and cut. The machining inspection can meet the requirements of parts shape, size and position tolerance, and the surface roughness is qualified. Processed parts shown in Figure 7.

ACKNOWLEDGMENT
After studying the material and the corresponding processing characteristics of the thin-walled tube of the titanium nail puller, we select the milling and milling process for such thin-walled tube parts, design the corresponding fixture, and develop a variety of processing programs to ensure that the thin-walled tube parts The dimensional accuracy of Φ6.3, Φ6.096 shape and position tolerance of parallelism 0.01mm, concentricity of 0.02 mm, and the inner surface roughness of 0.2μm requirements for the processing of thin-walled titanium alloy tube parts to provide technical support.

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