Research and Application of Quality Control for TC4 Titanium Alloy Profile

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Abstract: Through controlling from the source, TC4 titanium alloy profile ingot heating process surface protection technology and extrusion lubrication process, extrusion die design and manufacturing, profile straightening process, finished product heat treatment process and profile hot bending forming and other key processes have been studied in depth. Technical improvements and quality assurance measures are proposed. The surface quality, shape, size and mechanical properties of the titanium alloy profile meet the requirements of the use of TC4 titanium alloy profile parts for a certain type of launch vehicle. Ensure that the TC4 titanium alloy profile acceptance inspection process is operable. The manufacturing cost of the titanium alloy outer stringer of the launch vehicle is reduced. The quality level and reliability of TC4 titanium alloy outer stringers have been improved.

1. Introduction
At this stage, due to the large volume and mass and high payload of the newly developed launch vehicle, more stringent requirements are put forward for its structure. The structural design must not only ensure the structural strength, but also reduce the weight of the body. In the development stage, the outer stringer of the launch vehicle was initially designed with aluminum alloy profiles. However, aluminum alloy has poor high temperature resistance, and the effect of surface coating is not ideal. In order to meet the requirements of hot bending forming, weight reduction, strength, ease of processing and other indicators of structural product design, the launch vehicle selected TC4 titanium alloy profiles with high temperature resistance and high specific strength.

Titanium alloy profile is actually a semi-finished product. It has the characteristics of high structural effect and can be directly used as product parts without processing or after a small amount of processing. The extrusion molding process can produce profiles with various forms and complex sections. This process has the characteristics of flexible production and high processing efficiency. And it is the only processing method for complex section, empty stomach, and variable section profiles. Compared with the plate bending profile, the extruded profile has better rigidity. Therefore, the extrusion technology for preparing titanium alloy profiles is an irreplaceable other forming process. Titanium alloy extruded profiles have been successfully produced and used in Russia and the United States for nearly 50 years. Titanium alloy profiles are mainly used as long stringers and secondary load-bearing frames in aircraft structures[1]. A certain domestic model used titanium alloy extruded profiles, but it has always relied on imports. In view of this situation, it is imminent to develop TC4 alloy extruded profiles for the product...
structure of launch vehicles, break through the key technology of titanium alloy profiles and parts production, and produce multi-specification titanium alloy profiles that meet the requirements of launch vehicles according to technical requirements.

To this end, this project comprehensively sorts out the production control conditions of titanium profiles, and controls the technical indicators of titanium alloy profiles in many aspects, so as to achieve the purpose of improving the quality requirements of titanium alloy profiles such as hot bending, weight reduction, high strength, and ease of processing. High-reliability raw materials can be applied to key structural components of launch vehicles.

2. General idea
Through combing the whole production process of titanium alloy profiles, five key processes including profile surface protection technology and extrusion lubrication process, extrusion die design and manufacturing, profile straightening process, finished heat treatment process and profile hot bending forming are conducted in-depth research and put forward Quality assurance measures ensure that the surface quality, shape and size of the titanium alloy profiles meet the requirements of the use of the structural parts of the launch vehicle. The specific process is shown in Figure 1.

3. Implementation process
Adopt the source control plan, that is, the model quality assurance department and the raw material manufacturer conduct in-depth cooperation. Jointly conduct research on the production process (including casting, forging, extrusion, orthopedics and heat treatment, etc.), sort out the key quality control points that may occur in the production process, and propose corresponding control measures to fundamentally avoid the existence of defects. At the same time, the inspection and testing requirements are refined, and the production process monitoring is strengthened to ensure the delivery of qualified products.
3.1. Titanium alloy casting process control
The titanium alloy casting process is the starting point of the production process and the most critical link in the production process. The quality of its casting directly affects whether the performance indicators of the subsequent titanium alloy profile processed products can meet the requirements of the model. Therefore, in order to ensure the quality of profile smelting and ensure that the chemical composition is qualified, it is clearly specified that the number of smelting of ingots for profile is 2 to 3 times. The last time should be smelted in a vacuum electric arc furnace and no elements are allowed to be added. It can be melted by using consumable electrode, non-consumable electrode, electron beam cooling bed furnace or plasma arc cooling bed furnace. Consumable electrodes should be welded in a vacuum welding box, and argon tungsten arc welding is not allowed.

Therefore, the ex-factory inspection and re-inspection of the chemical composition of the profile products also put forward clear requirements, that is, the chemical composition of the profile should meet the index requirements for TC4 grade titanium alloy in GB/T 3620.1-2007, and the allowable deviation of the composition should comply with GB/T 3620.2-2007.

3.2. Surface quality and size requirements of titanium alloy profiles
Titanium alloy profile is a semi-finished product, and the surface quality is one of the important indicators to measure the quality of profile products. Compared with the preparation of aluminum alloy profiles, it is difficult to obtain good surface quality and flatness in the preparation of titanium alloy profiles. The production process needs to be optimized from the following aspects:

3.2.1. High temperature deformation process.
Titanium alloy has high strength and large deformation resistance, and titanium is a hexagonal crystal metal, which is difficult to deform. In order to reduce the deformation resistance and improve the uniformity of extrusion deformation, the extrusion of titanium alloy needs to use a higher temperature. For TC4 titanium alloy profile extrusion, it needs to be performed above its phase transition temperature, which is greater than 1000°C. The temperature drops quickly during the extrusion process, and appropriate heat insulation measures must be taken and the temperature must be strictly controlled.

3.2.2. Titanium Oxidation.
At high temperatures, titanium metal has high chemical activity and is easy to form hard and brittle oxide scale. The oxide scale breaks when flowing through the die hole and causing surface defects. This places stricter requirements on the extrusion die, so it is necessary to further optimize the extrusion die Design and mold manufacturing process, improve mold surface protection technology.

3.2.3. Extrusion lubrication.
Titanium metal can form a molten eutectic with iron at high temperatures, causing the titanium metal fluid to bond with the mold, which seriously deteriorates the surface quality of the product; when TC4 alloy is extruded, only the gap between the ingot and the extrusion cylinder, between the ingot and the mold There is better lubrication in the room to obtain a good surface quality. However, under the conditions of extrusion temperature, conventional molybdenum disulfide and copper sheathing cannot be used, and glass can only be used as a lubricant. At the same time, the glass lubrication process and the extrusion process need to be deeply optimized during the extrusion process.

3.2.4. Straightening process.
Titanium alloy profiles have high strength at room temperature, large springback, and difficulty in straightening. Optimizing the profile straightening method and adopting the local precision forming process can effectively guarantee the dimensional accuracy and straightness of the titanium profile product.
3.2.5. Other processes.
In addition to the control of the production process, the addition of ex-factory inspection and arrival re-inspection can ensure that the surface quality of the material meets the requirements of the model. The specific inspection requirements are as follows:

a. Make detailed requirements for the size and allowable deviation of the cross-section of the profile, the unevenness of the bottom plane, the curvature of the straight section, the twisting degree and the angle of the section, and they will be carried out item by item during the factory inspection and re-inspection on arrival.

b. The manufacturer is required to supply the profile after alkali pickling the surface;

c. The surface of the profile should be clean, free of oxidized color or other foreign substances, and there should be no visible defects such as cracks, folds, peeling, pinholes, etc.

d. It is allowed to remove local defects by grinding, and the cleaning place should be smooth transition. The ratio of cleaning width to depth should be greater than 6. After cleaning, the minimum allowable size of the profile must be guaranteed;

e. Under the premise of ensuring that the profile meets the lower limit of size, the surface is allowed to have minor scratches, extrusion marks, pitting and other defects with a depth of not more than 0.1mm.

4. Implementation effect
By formulating technical conditions for titanium alloy profiles, and implementing the technical conditions during the production, factory inspection, arrival re-inspection, and processing and assembly processes of the manufacturer and user units, the effectiveness and advancement of the control measures are verified. During the implementation of the technical conditions, the production process of titanium alloy profiles proceeded smoothly, and the product quality level and performance stability could be well controlled. The product acceptance process indicators are clear, the inspection methods are reasonable and effective, and have good operability. The factory inspection and the arrival re-inspection can fully exclude the unqualified products and ensure that the model products use raw materials with zero defects. The processing process is smooth, and the increased hot bending forming of titanium alloy profile products not only improves the subsequent processing efficiency, but also reduces the processing cost of model parts[2-4].

5. Innovation
a. Realized the localization of TC4 titanium alloy profiles, and successfully manufactured titanium alloy profiles that meet the requirements of the launch vehicle;

b. TC4 titanium alloy profile is formed by one-time extrusion, which has better rigidity than aluminum bending;

c. TC4 titanium alloy profile extrusion process uses glass as a lubricant to improve the surface quality of the extruded profile;

d. In addition to the conventional mechanical performance requirements for TC4 titanium alloy profiles, 400°C high temperature mechanical performance requirements have been added to meet the working requirements of the model in extreme environments;

e. TC4 titanium alloy profile products increase the hot bending forming of parts, which not only guarantees the stability of the performance during the deformation process of the profile, but also reduces the subsequent processing flow of the material and improves the efficiency of product processing and delivery.

6. Conclusion
The research results have significantly improved the reliability of titanium alloy profiles, ensured that the quality and reliability of TC4 titanium alloy profiles meet the model design requirements, and ensured the smooth progress of model development and production tasks. The project has significant economic, military and social benefits.
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