Improved Method of Pasting and Fixing Metal Conduit Heating Tape

Yun He¹,²,*, Ruizhao Du¹,² and Qiang Zhang¹,²

¹Beijing Institute of Satellite Environmental Engineering, Beijing 100094
²Beijing Aerospace Product Intelligent Assembly Technology and Equipment Engineering Technology Research Center, Beijing 100094

*Corresponding author: he_yun@spacechina.com

Abstract. In the development process of my country's spacecraft, the heating of the working medium in the metal conduit primarily adopts the method of winding a heating tape on the outer wall of the metal conduit. Silicone rubber is usually used as the filling medium to achieve good heat transfer between the heating tape and the metal conduit. The heating tape winding and fixing method of the cotton thread used at this stage has disadvantages such as time-consuming, labor-intensive, and low work efficiency. Based on the experience of the spacecraft's final assembly, a method of winding and fixing the heating tape with a fixing clip is proposed in this paper. This method is simple and convenient, improving the efficiency of pasting and winding the heating tape of the metal conduit.

Keywords: Metal conduit, heating tape, pasting and fixing.

1. Introduction

In China’s aerospace field, metal conduits are widely used in the transportation of propellants (divided into oxidants and combustion agents) on satellites and spacecraft [1]. Common metal conduits are mainly made of titanium alloy, stainless steel, and aluminum. Since the spacecraft needs to work in the cold black background of space, it is necessary to prevent the low temperature in space from cooling the propellant in the duct. Thus, a heating tape is pasted on the outside of the metal pipe to heat the metal pipe and the propellant inside it using electrification in the final assembly stage of the spacecraft [2].

The outer diameters of common metal conduits mainly have three specifications: Φ10, Φ8, and Φ4. The heating tape is mainly in the form of a metal strip, with a metal wire sandwiched in a double-layer polyimide film. The pipeline heating tape is a smooth strip without backing glue. When pasting on the pipeline, it needs to be glued with GD414 silicone rubber. Moreover, the starting and ending positions of the heating tape are fixed with cotton ropes to ensure the bonding and fixing effect of the heating tape and the metal conduit.
2. Existing measures
The selection of cotton rope is mainly considered from the following three aspects:
1. When the cotton rope is fixed on the heating tape in multiple loops, the silicone rubber can be squeezed into the gap between adjacent cotton ropes, so as to ensure the full coverage of the silicone rubber between the heating tape and the pipeline and achieve good heat transfer between the heating tape and the metal pipe;
2. The cotton rope is made of flexible non-metallic material, which will not cause damage to the heating tape of the pipeline during the pressurization process;
3. The cotton rope and the silicone rubber overflowing on the heating tape are in a line contact form, which is convenient for the disassembly of the cotton rope after the silicone rubber is cured.

However, the cotton rope also has the disadvantage of low work efficiency. Besides, when the cotton rope is wound and fixed, two people need to cooperate, which is time-consuming and labor-intensive. With the accelerating rhythm of the spacecraft assembly, it is necessary to improve the method of pasting and fixing the heating tape on the metal conduit to increase the operating efficiency.

3. Improving method of heating tape fixing
After preliminary investigation and inspired by the long-tail ticket holder, it was preliminarily selected to pressurize and fix the pipeline heating tape through torsion spring clamping. The fixed clamp is mainly composed of four parts: the upper half clamp, the lower half clamp, pin shaft, and torsion spring [3].

Figure 2 Schematic diagram of pipeline fixing clamp configuration
According to the pasting experience of pasting and winding heating tape, the general clamping force is about 15N.

The torsion spring is selected. According to the relevant information on the cylindrical spiral torsion spring in the mechanical design manual, the spring stiffness calculation formula is [4]

\[ T = \frac{Ed^4}{3667Dn} \]

- \( T \) — Spring stiffness N·mm/°;
- \( E \) — Elastic Modulus MPa;
- \( D \) — Torsion spring pitch diameter mm;
- \( n \) — Effective number of springs.

For the spring wire, the diameter, the pitch diameter of the thread, and the effective number of springs are initially selected to be 1.2mm, 5mm, and 3 turns, respectively. The stiffness of the spring is calculated as [5]

\[ T = \frac{Ed^4}{3667Dn} = \frac{206 \times 10^3 \times 1.2^4}{3667 \times 5 \times 3} = 7.78 \text{N} \cdot \text{mm/°} \]

The initial angle of the selected spring is 90 degrees. In the working state, the spring is compressed by 40 degrees (the working angle is 50 degrees); the torque of the spring is 310N·mm, and the force arm at the end of the clip is 21mm. Then, the clamping force at the end of the clip is 14.76N, which meets the requirements for use.

A force analysis on the upper part of the fixing clip is performed. A fixed constraint is applied at the pin, a clamping force of 5N is applied to the end, and the fixing clip is made of aluminum, grade 6061. After calculation, the stress and deformation of the fixing clip meet the requirements of material selection.
According to the above configuration, the fixed clip is put into actual production. At the same time, a circle of the granular film is pasted on the inner circular surface of the fixing clip to prevent the metal fixing clip from damaging the pipeline heating tape. If an ordinary flat film is used, the silicone rubber between the heating tape and the pipeline will be squeezed out under the action of the clamping force. As a result, there is no silicone rubber between the heating tape and the pipeline. However, the grainy film can effectively solve this problem. The silicone rubber at the protrusion will be squeezed to the non-grained area to ensure the continuous and even existence of the silicone rubber between the heating tape and the pipeline.

The actual product of the heating tape press clamp is exhibited in Figure 6 and tested. The trial site map is presented in Figure 7. The trial effect is good.
4. Conclusions
Through practice, the heating tape pressure clamp is convenient to use and can be used to fix the heating tape of the pipeline by a single person. Meanwhile, the clamping force is constant and controllable, avoiding the inconsistency of the clamping force of different operators. At present, it has been successfully applied in the implementation of thermal control of cargo spacecraft pipelines, presenting good application and promotion value.

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