Research on D Subminiature Connector Plugging Method on Spacecraft

Wei Zhang*, Yugang Liu and Yue'e Wei
Beijing Institute of Spacecraft Environment Engineering, Beijing Engineering Research Center of the Intelligent Assembly Technology and Equipment for Aerospace Product, Beijing, China

*Corresponding author e-mail: zhangwei308308@163.com

Abstract. This paper reviews the applications of D Subminiature connectors in assembly and integration process of spacecraft. The locking force control is a key factor through analysis of D-Sub connectors plugging method. To meet the general locking force control of male screw of D-Sub connectors in assembly and integration process of spacecraft, the vibration environment test of cable bracket with D-Sub connectors is designed to set the torque value of male screws of D-Sub connectors, and two kinds of torque wrenches are designed.

1. Introduction
There are a large number of electrical connector plug operations in assembly and integration process of spacecraft. The importing electrical connector using screw fastening, which includes D-Sub connectors and Airborn connectors, are complicated during operation. Some of the quality problems about electrical connection are owing to manufacturing defect of connector; some are due to improper electrical connector method. The main reason is the lack of adequate understanding of the applications and the characteristic structure of D-Sub connectors. Aimed at the Reliability of D-Sub connectors in assembly and integration process of spacecraft, the key factors determining the reliability of D-Sub connectors assembly are studied.

2. The Applications of D-Sub Connectors in AIT of Spacecraft
D-Sub connectors are the imported rectangular electrical connectors commonly used on spacecraft; The contact arrangement and the shell size is indicated by the codes E,A,B,C,D. In AIT of spacecraft, the D-Sub connectors include solder contact and crimp contact categories divided by the contact type, include straight clamp, round clamp, angled clamp categories divided by the backshells, include standard density and high density categories divided by density of contacts [1-5].

D-Sub connectors have 2 kinds of locking screw, male screw and female screw. D-Sub connector socket which is fixed on device or cable bracket is installed by female screw. D-Sub connector pin which is plugged on socket is installed by male screw. The screws lock assemblies of D-Sub connectors which contains front panel mount and rear panel mount are showed in Figure 1. Two plant washers are used in front panel mounting when D-Sub connector socket are fixed on cable bracket in AIT of spacecraft. The male screw is made of brass or stainless steel, but brass male screw is widely
used, compared with AIRBORN connectors whose screw head is hexagon hole, the screw head of D-Sub connector is slotted.

3. The Analysis of D Subminiature Connectors Plugging Method on Spacecraft

The reliability of the product of D-Sub connectors depends on the structural design, process manufacturing, environment and other factors, and the reliability of D-Sub connectors coupling depends on the operator plug and unplug technology of the operators, the reliability of D-Sub connectors coupling is more important than the reliability of the product itself in AIT of spacecraft.

The main flow process of plug D-Sub connectors including four steps which are plug preparation, initial plug connection, screwing and tighten the locking screws. Plug preparation is mainly the visual inspection about the D-Sub connector pin or socket and the screw lock assemblies. For example, if there is only one plant washer in front panel mounting, the spacing between the mated connectors can’t be satisfied and this screw lock assembly is not allowed. Initial plug connection is paralleled pushing the D-Sub connector pin to prevent damage of the male or female connectors.

There are a lot of quality accidents about Screwing the locking screws in AIT of spacecraft, for example, the male screws can’t screws the female screws, or the screw thread is damaged after the forcibly screwing, the main reason is the misaligned central axis of the male and the female screws. The distance between the mounting holes has stringent tolerances, which is ±0.13mm, so the distance between the mounting holes on the panel needs strictly controlled in design and processing stage. Even so, the male screws can’t screws the female screws if the assembly errors beyond the design range. So if there is significant resistance while screwing, forcibly screwing is not allowed, re-assembly may be necessary. So the alignment control is one of the key factors determining the reliability of D-Sub connectors coupling.

The locking force control of male screws is another key factor determining the reliability of D-Sub connectors coupling. Actually in AIT of spacecraft, there is no torque value for male screws, and the male screws are tightened with operator experience, so security risk is exit in tighten the locking screws. If the tightening force is too small, the locking screw may lose when experiencing harsh launch environment. If the tightening force is too large, the screw thread may be damaged. Compared with hexagon hole head screw, the slotted head screw is more easily to be damaged. The connectors usually experience multiple plugs and unplug in actually, the female screw maybe loose when unplugging the connectors if the tightening force of the male screw is too large, and the device have to open the panel to fasten the female screw. Compared with stainless steel screw, brass screw is also more easily to be damaged. ESCC Detail Specification No. 3401/022[2] gives the maximum torque value of brass male screw which is 0.33Nm, so it is urgent to set the torque value of male screws of D-Sub connectors in the AIT process of spacecraft, this value should not too large, the locking force control should as little as possible and only used when the spacecraft is about to suffer vibration environment or launch.
4. Experimental Verification for Torque Value of Male Screws

Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper.

The vibration environment test of cable bracket with D-Sub connectors is designed to set the torque value of male screws of D-Sub connectors in the AIT process of spacecraft, the cable bracket with own worst mechanical conditions has double row plugs, it is 225mm high, 186mm wide and 2mm thickness. It is made of LY12M, and a size C and a size D D-Sub connector are mounted on the bracket at the height of 180mm. 12 aluminum connection pieces which are simulated the other connectors are mounted on other openings of the cable bracket.

The vibration environment test of cable bracket with D-Sub connectors is showed in Figure 2. The cable of the two connector pin are fixed on bracket with tape, the female screws and other part are fixed and gummed, the male screws which are not gummed are fastened with default torque value, and the maker on male screw is showed in Figure 3. The condition of vibration environment test which is the worst conditions for spacecraft components is showed in Table 1. The sweep rate of sinusoidal vibration is 20ct/min, and the time of Random vibration is 2min/direction.

![Figure 2. The vibration environment test of cable bracket with D-Sub connectors.](image1)

![Figure 3. The maker on male screw.](image2)

| Vertical to mounting surface | Parallel to mounting surface |
|-----------------------------|-----------------------------|
| Frequency (Hz) | Magnitude (o-p) | Frequency (Hz) | Magnitude (o-p) |
| Sinusoidal     |                 |                 |                 |
| 5–17          | 10.3mm          | 5–17            | 8.58mm          |
| 17–100        | 12 g            | 17–100          | 10 g            |
| 10–200        | +6dB/oct        | 10–200          | +6dB/oct        |
| 200–1500      | 0.25 g²/Hz      | 200–1500        | 0.16 g²/Hz      |
| 1500–2000     | -12dB/oct       | 1500–2000       | -12dB/oct       |
| RMS           | 20.3g           | RMS             | 16.1g           |
| Random        |                 |                 |                 |

Table 1. The condition of vibration environment test.
In three conditions of the vibration environment test, 0.20Nm, 0.22Nm and 0.24Nm are set respectively as the torque value for male screws of D-Sub connectors. Each condition consists of 3 direction vibration tests, every direction vibration test including five steps which are feature scans before sinusoidal vibration, Sinusoidal vibration, feature scans after sinusoidal vibration, Random vibration and feature scans after Random vibration. The makers on male screws are inspected after each direction vibration test, and no relative displacement is happened. The qualification vibration test shows that the lowest natural frequency of the cable bracket is 51Hz on the direction of mounting surface of connectors. A vibration sensor is set on the surface near the connectors, and the acceleration response on the direction of mounting surface of connectors in Sinusoidal vibration environment test in condition of 0.22Nm torque value is showed in Figure.4. The value is 113.3g at the frequency of 51.59Hz.

Figure 4. Acceleration response in Sinusoidal vibration environment test.

The torque value of brass male screw of J6W connectors which is similar to D-sub connectors is 0.20 Nm ~0.25Nm given by factory and it is required in AIT of navigation satellites in recent years, 0.22 Nm is the default value in practice, and the satellites for male screws of D-Sub connectors in the AIT process of spacecraft.

5. Design of Torque Wrenches Used on Male Screw
Two kinds of torque wrenches are designed to meet the general locking force control of male screw of D-Sub connectors in AIT of spacecraft. Conventional torque wrench which is made of slotted head screwdriver adapter and torque screwdriver is showed in Figure.5, the RTD30CN made by Tohnichi is selected due to the small size, and the range is 0.04 Nm ~0.3Nm can also satisfy the engineering requirements. Many male screws cannot be tightened with conventional torque wrench in AIT of spacecraft because of restricted spaces, so a new-style breaking torque wrench is designed to solve the problem, the TBN 2 torque wrenches made by Torqueleader is showed in Figure.6, on reaching the pre-set torque value, it ‘break’ at a pivot point at an angle of 20°, the slotted head screwdriver adapter is designed by condition of use, The application of breaking torque wrench is showed in Figure.7. This new-style breaking torque wrench can be calibration and verification by ET-cal 1 which is a compact torque calibration analyzer.
6. Conclusion
The alignment control and the locking force control are analyzed as the key factors determining the reliability of D-Sub connectors coupling by reviewing the applications and the characteristic structure of D-Sub connectors in AIT of spacecraft. If there is significant resistance while screwing, forcibly screwing is not allowed, re-assembly may be necessary. The qualification vibration test of a bracket with D-Sub connectors shows that 0.22Nm can be set as the torque value for male screws of D-Sub connectors in the AIT of spacecraft. Two kinds of torque wrenches are designed to meet the general locking force control of male screw of D-Sub connectors in AIT process of spacecraft.

References
[1] ESA-SCC-3401, Connectors, electrical, non-filtered circular and rectangular esa/sec general specification;
[2] ESCC Detail Specification No. 3401/022; accessories for rectangular connectors 3401/001, 3401/002 and connector savers 3401/020, 3401/080
[3] Handbook of rectangular connectors, C&K
[4] Handbook of D subminiature Connectors, ITT Cannon
[5] Handbook of Non-magnetic D-sub Connectors, SOURIAU
[6] JIN Xun-shu, (1996) Environmental engineering and Simulation test of satellite, China Astronautic Publishing house.
[7] Q/W 1226-2009, Requirements for mechanical environment test for spacecraft products, The standard of China Academy of Space Technology
[8] DU Yong-ying, (2015) Reliability analysis on terminal contact parts for electrical connector based on ANSYS, Chinese Journal of Construction Machinery, 13 (6)
[9] Pan Jun, Structural Analysis of Electrical Connector contacts and Insertion-Extraction Test, China Mechanical Engineering, 2013, 24 (12)
[10] Chen Wenhua, (2003) Reliability Test and Statistical Analysis of Electrical Connector under Vibration Stress, Acta Aeronautica Et Astronautica Sinica, 24 (4).