Experimental Research on the Gluing and Curing Cycle Time for the Connecting Hole Sleeve of Communication Satellite Engine Bracket

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Abstract: The connecting hole sleeve of the engine bracket is an important component to ensure the reliable installation of the satellite engine. In actual production, the inner and outer connecting hole sleeves of the bracket are connected by gluing and screwing, and finally the fastening components are installed by drilling and reaming. The traditional adhesive curing cycle standard does not apply to this situation. In this paper, the influence of different curing time on the reaming operation of the connecting hole sleeve was studied through the development of the process test. The test conclusions have reached the shortest curing period of the glue that can ensure sufficient connection strength of the hole sleeve, and put forward suggestions for improvement. The test method in this article has reference significance for related research in other industries.

1. Introduction

The bearing cylindrical satellite structure is the most commonly used design configuration in the field of communication satellites in my country, and has the advantages of high reliability, long life, and strong carrying capacity. The main structure of the bearing cylinder satellite is composed of a propulsion cabin and a service cabin. The propulsion compartment is composed of a central bearing tube, a 490NG engine support, a middle plate, a back floor, a propulsion compartment north-south partition and east-west partitions\textsuperscript{[1-2]}. Among them, the 490NG engine bracket is a composite material structure, which is connected to the bearing cylinder in a three-claw type circumferential direction, as shown in Figure 1. When connecting, it is necessary to perforate the engine connection corner box according to the hole position on the bearing cylinder to ensure that each connection position is effective.
The engine bracket plays the role of fixing the 490NG engine, which has a decisive influence on the accuracy and reliability of the engine installation position. If the bracket installation accuracy and connection reliability are insufficient, it will reduce the accuracy of the engine installation strength and even adjust the satellite into orbit and space attitude Will have an impact\cite{3-4}. Therefore, effective installation between the connecting corner box of the engine bracket and the bearing tube is particularly important to ensure the quality of the entire satellite. Figure 2 shows the installation state of the engine bracket seen from the inside of the bearing cylinder.

2. Engine bracket installation status

2.1 Connection hole sleeve installation

Figure 3 shows a schematic diagram of the structure of the fastening connection between the bracket corner box and the bearing tube. The hole sleeve assembly includes an outer hole sleeve, an inner hole sleeve, an adjusting washer, and an M5 bolt assembly. The bolt assembly is composed of bolts, flat washers, and nuts. Each engine bracket has a total of 12 connecting hole sleeve structures, each of which is a group of 4, distributed in a circle along the outer wall of the bearing cylinder. Figure 4 is a physical view of the outer hole sleeve seen from the outside of the bearing cylinder.

Combined with the positional relationship of the parts in the schematic diagram of Fig.3, the installation process of the 490NG engine bracket is as follows at the current stage of installation of the bearing cylindrical satellite structure. When installing, the corner box of the engine bracket is in contact with the inner wall of the bearing tube tightly. The assembly operator tries to screw in the outer hole sleeve until it fits with the bracket corner box. At this time, there is a certain gap between the flanging inner end surface of the outer hole sleeve and the bearing cylinder. Operators make gaskets of corresponding thickness according to the amount of clearance, and apply A/B component room temperature curing structural adhesive (brand name 420) on the gasket and outer hole sleeve threads, then screw the outer hole sleeve into the inner hole sleeve. After the glue is solidified, drill through holes in the bracket corner box and the outer hole sleeve, and fasten them with M5 bolt components.
2.2 Issues that need resolving
In the professional process of aerospace products, the curing time of the structural adhesive is not less than 7 days. However, the regulations in the relevant standards are for working conditions where two metals are in face-to-face contact. The inner hole sleeve and the outer hole sleeve of the 490NG engine bracket connection hole sleeve are both threaded and bonded by structural glue. The connection state is complicated and professional craftsmanship cannot be applied.

If the curing cycle is too short, the connection strength between the inner hole sleeve and the outer hole sleeve will be insufficient. It may loosen the hole sleeve when drilling holes and cause the installation of the engine bracket to fail. If the curing time is too long, the invalid waiting time during the generation process will increase, which will reduce the production efficiency.

Looking up domestic and foreign data, there is a lack of reference data for similar experiments under the above circumstances. The method of theoretical calculation or simulation can not accurately reflect the real situation of the connection strength after curing\(^5-7\). Therefore, it is necessary to explore the shortest period of bonding and curing of the connecting hole sleeve under the condition of sufficient connection strength through process tests.

2.3 Research content of this article
The specific project objectives are: 1) Verify the shortest curing time required for the glued and screwed forms through the simulated torque test under the condition of reliable bonding quality; 2) After different curing times, the punching operation will affect the curing quality of the glue. 3) Through experimental analysis, the conclusion of the curing cycle is drawn, and suggestions for improvement of the existing assembly technology process are put forward to provide a reference for improving the production efficiency and quality of this link.

3. Test plan

3.1 Test piece design
The size, material, connection form of the product parts, and the design simulation test piece are shown in the figure. The moving end joint and fixed end joint are added to the test piece to connect with the torque tester. The inner hole sleeve test piece increases the height of the hole sleeve and increases the upper flange surface to simulate the mounting surface of the bearing cylinder. Other aspects of the test piece, such as thread structure, surface treatment, and working environment, are the same as the real product.

3.2 Test plan
Make simulation test pieces of inner and outer hole sleeves, and use the same batch of 420 structural glue for bonding. The minimum torque value of the inner and outer hole sleeves loosened after curing for different time periods (4h-24h) was recorded by the torque tester under the two working conditions.
of punching and non-punching respectively. After data analysis, the minimum time for reliable solidification under screwing and bonding conditions is obtained. Eliminate the hidden danger of loosening of the connecting hole sleeve due to the punching. The specific test workflow is shown in Figure 6.

Figure 6 The overall process of the test

The test program includes two types of torque test and displacement test. In the torque test, apply 420 glue to the threads on the outer hole sleeve and the adjusting washer and screw them into the inner hole sleeve. After the adjustment gasket and the outer hole sleeve are attached, they are cured according to the five time periods of 4, 8, 10, 12, and 24 hours respectively. Three sets of test pieces are prepared for each time period, and the working condition names are defined as N1, N2, N3. N1 means that after a certain period of time after cementing and curing, the torque test is carried out without expanding the hole. N2 means that the hole is expanded after cementing and curing for a certain period of time, and the torque test is performed after the curing time reaches 24 hours. N3 means that the hole is reamed after cementing and curing for a certain period of time, and the torque test is performed immediately after the hole is reamed.

The method of displacement test is as follows: Engrave the line before reaming to mark the relative positional relationship between the outer hole sleeve and the inner hole sleeve. Carry out the reaming operation after different curing time. If the outer hole sleeve rotates under the action of reaming cutting force, the offset can be found through the position of the scribe line. The working condition of the displacement test is represented by W1, and the actual test piece is shown in Figure 7.

Figure 7 The actual object of the W1 test piece

4. Experimental procedure

4.1 Test preparation
According to the test piece and tooling model in the design plan, the prototype was machined and produced. Figure 8 shows the inner hole sleeve, gasket, and outer hole after the surface treatment is completed. The actual photo of the test piece of the set, Figure 9 is the actual photo of the moving end joint and fixed end joint tooling.
According to the actual product bonding situation, we mixed the Redux420 structural glue in a ratio of 5:2, and then applied the glue to the gasket and the outer hole sleeve, as shown in Figure 10. According to the above test plan, after different curing time of the glue, the process test work of 4 working conditions was carried out. The bonding work is carried out in the assembly integration center, and the temperature environment during curing is 21-23°C.

Before the test, install the test piece with the fixed end joint and the movable end joint to form a test assembly, as shown in Figure 11. The torsion test was carried out in the test center of the Beijing Satellite Manufacturing Plant. As shown in Figure 12, the right side of the torsion testing machine is the fixed end, and the left side is the rotating part of the testing machine. The movable end joint drives the outer hole sleeve to rotate in the direction of screwing. Use the computer to record the load torque changes.

4.2 Test results

4.2.1 4 hours curing test result
When the sealant is cured for 4 hours, the strength of the glue is very weak, and the outer sleeve can be loosened by a torque of less than 1 N/m. The peak value of the torque curve at this time is between 0.42 N/m and 0.81 N/m. The torque curves of the N1 and N3 test pieces are shown in Figure 13. The torsion test was carried out after curing for 24 hours, and the moving end joints and the test piece were obviously damaged, and the final curing strength will not be affected by the hole-making operation performed during the 4-hour curing.
In the displacement test, the reaming operation will cause obvious rotation of the outer hole sleeve. There is a very obvious deviation between the marking lines of the outer hole sleeve and the inner hole sleeve. This phenomenon shows that in the 4 hours of curing time, the degree of curing of the glue is still very poor, and it is completely unable to resist the cutting force during the reaming process.

4.2.2 8 hours curing test result
When the sealant is cured for 8 hours, the glue can be cured to reach a certain strength, and the outer hole sleeve can be rotated and loosened by applying a certain torque on the torsion machine. The peak value of the torque curve at this time is between 41.1 N/m and 41.2 N/m. The torque curves of the N1 and N3 test pieces are shown in Figure 14. The torque test shows that the outer hole sleeve can be loosened under the drive of the torque machine, and this process will not damage the outer hole sleeve and the moving end joint products. The glue liquid can make the product bear about 41N./M torque during this curing time without failure. The torsion test was carried out after curing for 24 hours, and the moving end joint and the test piece were obviously damaged.

In the displacement test, the reaming operation will not cause the outer hole sleeve to rotate. This phenomenon shows that the glue can be cured to a certain extent in the curing time of 8 hours. This curing strength can resist the influence of cutting force during the hole reaming process.

4.2.3 Curing 12 hours and 24 hours test results
Tests have shown that when the curing time is not less than 12 hours, the glue can be cured to reach a very high strength. During the torsion test, the mating orifice of the moving end joint and the outer sleeve is obviously damaged, and it is still not possible at this time. Rotate the outer sleeve to loosen it. The peak value of the torque curve at this time is above 81.9N/m. For the 12-hour and 24-hour test pieces, the torque curves are shown in Figures 15 and 16, respectively.
The torsion test showed that the outer hole sleeve could not be loosened under the drive of the torsion machine, and this process caused obvious damage to the outer hole sleeve and the movable end joint. The four matching cylinders of the movable end joint were obviously bent, and the outer hole sleeve The mating orifice of the device is obviously damaged, as shown in Figure 17. The glue liquid can make the product reach a high strength within this curing time without failure. The torsion test was carried out after curing for 24 hours, and the moving end joint and the test piece were obviously damaged, which was the same as the effect after curing for 8 hours.

In the displacement test, the reaming operation will not cause the rotation of the outer hole sleeve. The phenomenon shows that the glue has been reliably solidified to a certain strength, which can resist the influence of cutting force in the process of reaming.

4.3 Results and discussion
The following results can be obtained by applying Redux420 structural adhesive to multiple test pieces and curing for 4-24 hours:

(1) The glue cannot provide sufficient bonding strength after curing for 4 hours. During this curing time, no operations including hole expansion can be performed on the product.

(2) The glue has been solidified for 8 hours. The glue has been solidified to a certain degree. A larger rotating torque is required to loosen the outer sleeve. This torque is greater than the cutting force torque generated during reaming. Therefore, the reaming operation of the outer hole sleeve can be carried out under this curing time.


(3) After curing for more than 12 hours, the glue can reach a higher strength. The torque test performed at this time is a destructive test, and the outer hole sleeve cannot be rotated and loosened. Therefore, according to the test data, the shortest curing time required for the glued and screwed forms is 12 hours.

(4) Whenever the hole-making operation is carried out, it will not affect the curing performance of the final glue.

5. Conclusions

5.1 Test summary

The 490NG engine bracket connecting hole sleeve is threaded after applying 420 structural glue. This structure has a reliable connection strength. Torque and displacement tests on more than 20 sets of test pieces show that after the glue is cured for more than 12 hours, the reaming operation on the connecting hole sleeve will not affect the connection strength of the hole sleeve. After this test verification, the expected test target was achieved, and the hidden quality hazard caused by shortening the curing cycle of the glue liquid due to the accelerated progress in the actual work was eliminated.

5.2 Guiding advice

Suggest revisions to the traditional 490NG engine bracket assembly process. The revised content includes: (1) The glue application process needs to be checked to confirm that the thread of the hole sleeve is uniformly glued, and the adjustment gasket should be glued on both sides; (2) Consider the test process to be carried out in an environment of 21-23°C, and the actual production of the product is 18-28°C. Temperature fluctuations may have an impact on the quality of the bonding. From the perspective of safety, it is recommended that the punching work be carried out at least 24 hours after the bonding is cured.

The results of this process verification work can be applied and promoted in the fields of communication satellites and remote sensing satellites. In addition to the aerospace field, other industries can also learn from this test method to carry out process verification and study the bonding strength and curing cycle of other products.

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