Optimum Design and Research and Application of Protective Tools for New Generation Apogee Engine

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Abstract. The new generation apogee engine is the key equipment in the satellite propulsion system, and accompanied by the whole life cycle of AIT development and production. Therefore, there are many assembly processes around the new generation apogee engine itself and its surroundings, and the engine belongs to the star catalogue prominent product, which has the risk of bumping and scratching. In this paper, a new generation of apogee engine protection tooling is designed, and the general design and detailed design are carried out. The implementation effect is good. It can be extended to all models equipped with a new generation of apogee engine to meet the needs of scientific research and production.

1. Introduction
The new generation apogee engine (hereinafter referred to as 490NG engine) is the key equipment in the satellite propulsion system, and it appeared at the point of satellite AIT production process very early, and the subsequent AIT development and production life cycle. Therefore, there are many assembly processes around the 490NG engine itself and its surroundings, which can be decomposed into the installation of 490NG engine in the order of AIT process. There are more than 30 operations such as measuring tools, pipeline welding, winding pipeline heating belt, installation of high temperature insulation screen. Because 490NG engine belongs to star catalogue prominent product, in the process of various operations, the risk of bumping and scratching caused by operation is great, and the case of assembly problem in recent years also reflects this phenomenon. Because there are some shortcomings in the existing 490NG engine protection tooling, it is necessary to optimize the design and research application of 490NG engine protection tooling [1].

2. Current situation analysis
The commonly used 490NG engine protection tooling is shown in Figure 1. The protective tooling is supported by four oblique pillars of the satellite vehicle. The cylindrical protective body formed by the connection of the protective tooling cover forms an effective protection for the outer surface of the engine nozzle. The protective tooling has been widely used in the assembly process of the communication satellite. [2]

Current protective tooling can play an effective protective role to a certain extent, but there are still some shortcomings, which need further improvement and improvement, specifically in the following three aspects: [3]
(1) It occupies a lot of space: The glass cover of the protective tooling is cylindrical, and the protective tooling is connected with the oblique support of the whole star truck by connecting parts on the aluminium disc, which occupies a large amount of space between the truck and the whole star. Therefore, when operating near 490NG, part of the operating space is occupied.

(2) Unable to protect dynamically: The existing protective tooling is supported by the whole-star bracket truck. When carrying out some work during the assembly process, such as whole-star hoisting and precision testing, the protective tooling must be dismantled, so that the whole engine is in a non-protective state.

(3) Disassembly and assembly is inconvenient: The protective tooling is fixed by the structure of the whole star truck. In the process of installation or disassembly, it is necessary to cross the long rod into the inside of the truck, and there is no limit device in the radial direction of the guide rod for the protective tooling, so it is inconvenient to use the protective tooling in the process of use.

In view of the shortcomings of 490NG engine protective tooling in the process of protection, this paper optimizes and improves it and designs a new generation of protective tooling to improve the protection effect. [4]

![Figure 1. Installation sketch of 490NG protective tooling at present stage](image)

3. Optimal design

3.1. Installation interface

Because the existing protective tooling uses the whole-star bracket vehicle as the installation interface, in order to eliminate the dependence on the whole-star bracket vehicle, the installation interface is selected on the engine titanium alloy bracket, and the optimization design is carried out from the following two aspects: [5]

(1) Connecting with the satellite as a whole, the interface strength is high and the connection is reliable;

(2) Minimizing the maximum envelope size of engine protection tooling;

The engine titanium alloy bracket has four quadrants with 10 mitigation holes in each quadrant. After optimization, the second mitigation hole (4 holes in total) from inside to outside is selected as the installation interface, as shown in Fig. 2.

![Figure 2. Installation Interface diagram](image)
3.2. Envelope design
The overall envelope design, as shown in Figure 3, requires not only compact structure and as much operating space as possible, but also no interference with the engine. [6]

(1) The maximum outer diameter of the lower end nozzle of the engine is 303 mm, the inner diameter of the protective tooling is 382 mm, and the single side clearance is 39.5 mm.

(2) The inner diameter of both upper and lower flanges is 360 mm, and the minimum one-sided clearance with engine is 28.5 mm.

(3) The size of the flange under the protective tooling is 7mm.

![Figure 3. Envelope design sketch](image)

4. Design scheme
As shown in Fig. 4, the protective tooling is divided into two parts: the hanging module and the protective tooling module. The lifting device and the protective tooling module are fixed by bolts. [7]

The support sleeve and the support sleeve nut clamp the 2.5mm rib plate of 490NG engine bracket tightly, as shown in Fig. 5, realizing the purpose of fixing the protective tooling to 490NG engine bracket.

![Figure 4. Overall Installation Drawing](image)

4.1. Hanging module
The suspension module consists of the following components: support ear, support sleeve and support nut, upper flange and support shaft, as shown in Figure 6. [8]
4.2. Protective tooling module

The protective tooling module consists of the following components: PV plate protective cover, lower flange, upper flange, gasket, inner lining and outer lining, as shown in Fig. 7.
Figure 7. Schematic diagram of protective tooling module

(1) PV board protective cover
The protective cover of PV plate is rolled up with 1 mm thick PV plate. The structure is of high steel and toughness. The holes on the circumference are made of inner lining and outer lining. The holes are integrally embedded in the grooves of upper and lower flanges. The inner lining and outer lining are clamped with upper and lower flanges and fixed with screws.

(2) Lower flange
The lower flange is made of 4mm thick aluminium alloy plate with surface anodization. It is connected and fixed with the outer liner and the bottom plate by screw, which facilitates the disassembly and assembly of the bottom plate. The upper surface is grooved, and the PV plate protective cover is embedded in the groove.

(3) Upper flange
The upper flange is made of 6mm thick aluminium alloy plate with surface anodization. The lower surface is grooved, and the PV plate protective cover is embedded in the groove.

(4) Cushion block
Aluminium alloy is used for surface anodization. Eight M4 countersunk head bolts were used to fix four cushions 90 degrees equally on the upper flange. The upper surface of the pad is padded with a 3 mm thick silicone rubber plate to prevent its surface from linear contact with the engine bracket to protect the engine bracket.

(5) Inner lining and outer lining
The inner lining is made of 304 stainless steel plate with thickness of 1 mm, which is sheared and bent. It is connected and fixed with the protective cover of PV plate, which enhances the steel degree and makes the structure compact.

4.3. Mechanics Analysis
The vertical mechanical analysis of 490NG engine protective tooling is shown in figs. 8 and 9. The maximum displacement and stress are 4.84 x 10^-9mm and 1.09MPa respectively.
5. Application effect
The new generation 490NG engine protection tooling is suitable for various working conditions and covers the whole assembly process. It effectively improves the protection capability and guarantees the quality and progress of spacecraft assembly development. It is embodied in the following six aspects:

(1) Life cycle protection: It can realize the life cycle protection of 490NG assembly in Beijing area and launch site area. It is not suitable for the first fine test adjustment of 490NG engine (requiring removal of engine fasteners) and installation of 490NG high temperature heat shield (requiring full coverage of engine and docking frame area).

(2) Suitable for whole-star brackets and leak detection low-rise trucks: It is suitable for the working conditions of satellite parking on the Whole-Satellite bracket vehicle and leak detection dwarf vehicle.

(3) Applicable to two-axis turntable: It is suitable for satellite parking on Two-axis turntable, and can realize the protection of 490NG engine under horizontal attitude of satellite under two-axis turntable condition.

(4) Surrounding operation space is large: The maximum diameter of the outer envelope is 410 mm, and the surrounding operation space is large.
(5) Precision measurement can be accomplished: Because the inner diameter of the protective tooling is 382 mm, which is larger than the size of the 490NG engine precise gauge 17 *17 *367 mm, the precise measurement of 490NG engine on the whole-star bracket vehicle can be completed.

(6) Easy disassembly and assembly: When it is necessary to disassemble and assemble protective tooling, only the protective tooling module needs to be dismantled, while the hanging module is not dismantled (except for the test conditions of quality characteristics).

6. Concluding remarks
Through the optimization design and research and application of the new generation apogee engine protection tooling, the improved protective tooling can protect 490NG engine no matter the star is parked on the whole-star bracket vehicle, two-axle turntable, leak detection dwarf truck, and the protective tooling does not block the precise light path of 490NG engine. The practical application in the model shows that the engine protection tooling meets the requirements of the model application in the aspects of assembly and disassembly safety, product life cycle protection and so on. It can be applied in all models with 490NG engine, reducing or avoiding damage to key products, greatly reducing the probability of quality and safety problems in assembly production, and ensuring the quality of spacecraft assembly development. Quantity and progress, with high promotion value.

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