A New Alignment Method of Spacecraft Assembly based on Irregular Prism

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***Abstract*—Based on physical problem in spacecraft assembly alignment, this paper presents a new alignment method of spacecraft assembly based on irregular prism, which provides a solution to the problem in the spacecraft development that the spacecraft assembly alignment cannot be measured due to the blockage of the alignment optical path when a cubic prism is used as the equipment reference prism. This method has been successfully and widely used in spacecraft development and achieves good results.**

Key words*−*alignment; irregular prism; vector; coordinate system

I. INTRODUCTION

In the final assembly and system integration of spacecraft, the installation accuracy of some critical equipment is related directly to the spacecraft's accuracy in orbit injection, attitude control and landing point reaching, and related to the success of the aerospace mission.

In order to ensure the normal flight and operation of the spacecraft, for the equipment with accuracy requirement, its final assembly accuracy must conform to the designed geometric accuracy [1]. Therefore, in final assembly the installation accuracy of the equipment on the spacecraft should be accurately measured and adjusted to the designed range. Assembly alignment is an important link to ensure the normal, long-life and highly-reliable operation of the spacecraft, and a critical and important work in the spacecraft development.

The final assembly accuracy of spacecraft is generally guaranteed by the cubic prism installed on the equipment to be measured, and the cubic prism is called equipment reference prism. The designer first calibrates the angle and position relationship between the coordinate system established by the normal lines of the three adjacent and orthogonal surfaces of the equipment reference prism and the equipment coordinate system, and then according to the requirement of the equipment's final assembly accuracy under the spacecraft coordinate system, computes the theoretical values and accuracy of the angle and positional tolerance of the equipment reference prism coordinate system under the spacecraft coordinate system. The alignment of spacecraft assembly is aimed to obtain accurately the angle between the normal lines of the three adjacent and orthogonal surfaces of the equipment reference prism and the coordinate axes of the spacecraft coordinate system, and the positional tolerance of the center point of the equipment reference prism under the spacecraft coordinate system, and to adjust the equipment to the required accuracy range based on the theoretical values.

Currently the alignment of spacecraft assembly is generally realized by a non-contact large-sized measurement system composed of several electronic theodolites [2]. In the alignment of spacecraft assembly, theodolites are used respectively for collimation of reference cubic prism of spacecraft and reference prism of equipment under measurement. All cubic prisms used are of a standard cubic structure. By measuring of the adjacent surfaces of equipment reference prism, the vectors of two orthogonal surfaces under the spacecraft's reference cubic prism coordinate system can be obtained, and then by means of multiplication cross of vectors, the vector of another surface perpendicular to both the above two surfaces under the spacecraft's reference cubic prism coordinate system can be obtained, and finally, by use of the angle relationship between the spacecraft's reference cubic prism coordinate system and the spacecraft coordinate

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system (which is obtained in the spacecraft subassembly phase through the establishment and transfer of the spacecraft reference), the angles between the normal lines of the three orthogonal surfaces of the equipment reference prism and the spacecraft coordinate system, i.e. the setting angle of the equipment under measurement on the spacecraft, can be worked out.

With the development of China's aerospace technology, the structure of the spacecraft gets more and more complicated. In the development of some spacecraft, due to the limit of overall design and layout, for some equipment using cubic prism as its reference prism, its alignment optical path may be blocked by other equipment on the spacecraft, therefore final assembly accuracy of these equipment cannot be measured. To solve the problem, this paper presents a new alignment method of spacecraft assembly based on irregular prism, i.e. according to the installation position of the equipment on the spacecraft, design and apply irregular prism to substitute for cubic prism as the equipment reference prism, so as to avoid blockage of alignment optical path. The irregular prisms currently in wide use in the model product include mainly that with a bevel of 135° (the included angle between the beveled surface and a right-angle surface is 135°) and that with an included angle of 90° (the included angle between the two side surfaces is 90°).

However, in the alignment of spacecraft assembly with irregular prism, the angles between the normal lines of the three orthogonal surfaces of the irregular prism and the spacecraft coordinate system cannot be obtained using the current measurement and computation method of cubic prism. Therefore, this paper also presents the computation method of vectors of the normal lines of the three orthogonal surfaces of the irregular prism under the spacecraft coordinate system.

The alignment method of spacecraft assembly based on irregular prism has been widely used in the alignment of spacecraft assembly, and has been confirmed by all parties that it is a successful solution to the problem in the spacecraft development that final assembly accuracy of the spacecraft cannot be measured due to the blockage of the optical path of cubic prism.

Below the methods of alignment of spacecraft assembly based on the above two irregular prisms are respectively given.

II. METHOD OF ALIGNMENT OF SPACECRAFT ASSEMBLY BASED ON IRREGULAR PRISM WITH A BEVEL OF 135°

For an irregular prism with a bevel of 135°, the included angle between the prism's beveled surface and a right-angle surface is 135°, while the other prism surfaces are parallel or perpendicular to each other. See Fig.1.

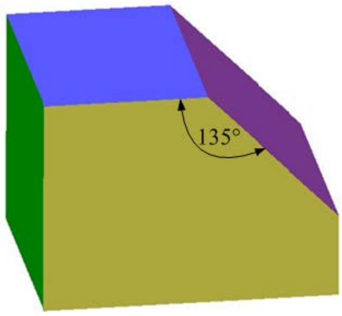

Fig.1 Schematic structure of an irregular prism with a bevel of 135°

A. Application Background of The Irregular Prism with a bevel of 135°

In the alignment of assembly of the critical equipment related to the attitude control of the spacecraft, due to the limit of the overall layout of the spacecraft and the installation position of the equipment on the spacecraft, the alignment optical path of the equipment's reference prism (a standard cubic prism) is blocked.

The left drawing in Fig.2 shows the optical path of the equipment reference prism (cubic prism). The vector Z_{GA1} and vector Y_{GA1} of the cubic prism of the critical equipment are both unobtainable due to the blockage of optical path, only its vector Y_S can be measured, and as vector Y_S and vector Y_{GA1} are complementary, the vector Y_{GA1} can be obtained indirectly. To obtain the final assembly accuracy of the equipment on the spacecraft, it is a must to measure the vector Z_{GA1}, make multiplication cross of vector Z_{GA1} and vector Y_{GA1} and then normalization, thus to obtain the vector S_{GA1} which is perpendicular to both vector Z_{GA1} and vector Y_{GA1}. And since the vector Z_{GA1} of the cubic prism of the equipment cannot be measured, the final assembly accuracy of the equipment using cubic prism as its reference prism cannot be obtained[3].