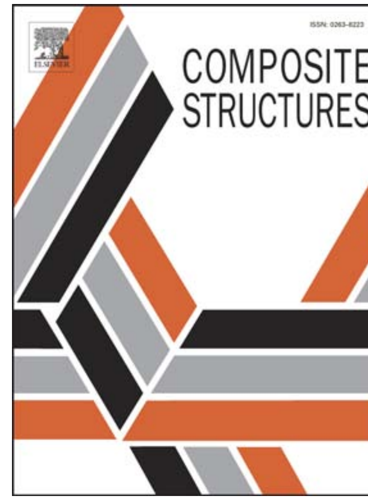

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Design and application of composite platform with extreme low thermal deformation for satellite

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Abstract: Thermal Dimensional stability is an important issue for many space structures. an extremely low thermal deformation composite platform is designed with the prototype application in the satellite payload-mounting platform. The platform was achieved through using composite material to provide near-zero Coefficient of Thermal Expansion (CTE) and isolating the residual thermal expansion by flexible structure connection to obtain the entire stability rather than the traditional thermal control technology, which is energy-consuming. Firstly, the design of systematical scheme with near-zero CTE is investigated, by which the extremely low CTE components of satellite structure were developed. Then, a flexible connecting method is proposed to further minimize the thermally induced deformation through “deformation isolation”. The effectiveness of this method is demonstrated by Finite Element analyses and further verified by physical Composite Fiber Reinforced Plastics (CFRP) prototype. The experiment results of the prototype recorded a 90% reduction measured by theodolites and projection moiré methods. The thermally induced pointing accuracy is dramatically decreased from 72.6" down to 3.6" in the flexible connection compared with the rigid connection, while the panel wrapping displacement reduced from 1.013mm to 0.104mm. The result proves that this method is effective to the thermal deformation isolation so that it has an extraordinary potential to engineering practical application.

KEY WORDS: Composite structure, satellite platform, payload, thermal deformation, isolation, CFRP

1. Introduction

In recent years, space technology is becoming strategically important in High-tech fields, such as the military and civilian fields. More and more large structures are needed in a wide range of situations, including future astrophysical and next-generation optical imaging satellites. For instance, the size of the supporting structure of the James Webb Space Telescope [1], which is well known as a typical large-scale precise structure, is approximately 2×2×1.5 m.

However, the variation of environments (including weight loss, temperature and vacuum, etc.) will influence the accuracy of the large structure and the satellite platform. Those earth-orbiting satellites regularly pass from sunlight to shade and back [2]; these transitions are typically accompanied by significant temperature changes. When adjoining parts of a satellite that are made of different materials [3] are subjected to large temperature changes, thermal mismatch stresses arise as a function of the temperature change and the difference in coefficients of thermal expansion (CTEs) between the two materials [4]. These thermal stresses are linked to the undesirable deformation [5-7], which will deteriorate the working environment of on-board instruments, for example, downgrading the precision of sensitive optical telescopes or the positional accuracy of space cameras. Moreover, it may also cause fatigue and failure of the structure through long-term cycling. Therefore among all the factors, the periodically-changed thermal deformation of the structure platform is one of the most serious problems. Traditionally, an additional apparatus or device was used to control the on-board environment temperature. However, the temperature control device has proved to be a heavy burden to the satellite because it not only occupies a lot of effective payload weight, but also consumes large on-board energy.

Thermal dimensional stability is an important performance parameter for many space structures [2,8]. One of the technology needs for large-precision structures, for future astrophysical and optical imaging satellites, is a kind of material, which can provide dimensional stable lightweight characteristics in mechanical properties. Composite materials are being considered as next-generation materials for space-borne application due to excellent mechanical properties such as high stiffness and strength to weight and low coefficient of thermal expansion [9-11].

Composite materials and structure providing predetermined value of CTE (positive, negative, or zero) were widely investigated in recent decades in Lakes [11-12], Gibiansky and Torquato [13], Sigmund and Torquato [14,15], Steeves et al. [9], Jefferson et al. [16], Berger et al. [9], Gdoutos et al. [17], and Lehman and Lakes [11]. The present work, based on the ideas described in Steeves et al. [9] and Toropova and Steeves [18], mostly describes the design of anisotropic lattices that have different CTEs on their top and bottom edges [19-22]. However, little was reported to discuss the composite material and structure