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THERMAL FATIGUE ANALYSIS OF FGM BASE PLATE OF SATELLITE STRUCTURES

Abstract

Satellite structures are designed to sustain thermal fatigue damage due to cyclic temperature variations in orbit. Several materials have been used to satisfy the structural constraints on the main components of satellite structures, namely base plate, satellite case, and mounting plate. The thermal loads typically require an additional separate heat shield, which adds more weight to the satellite structure. Functionally graded materials FGM have shown excellent potential to be used in satellite panels, given the flexibility to change their constituents' distribution across thickness to provide superior heat shielding capability, thus eliminating the need of a separate heat shield. Friction Stir Additive Manufacturing Method FSAM have been developed to produce more manageable FGMs, and much larger parts, compared to those produced by powder bed fusion. Accordingly, FGM structures manufactures by FSAM approach have been gradually introduced into the aerospace applications, including whole satellite structures. In this work, the cyclic temperature variation on the base plate of a small satellite is first determined from the orbit and satellite attitude information. A sun-synchronous orbit of 600-800 km is used, with inclination 97.78o. The initial orbital elements are the Keplerian orbital elements and assumed to be constants except the true or anomaly. The perturbation in the orbital elements due to air drag or gravitational forces of a third body will be neglected in the current study. Temperature environment is determined from the angle between the solar vector and the normal direction of the orbital plane. Then, the temperature distribution across the FGM plate is calculated by solving the heat balance equation. Maximum and minimum temperatures for the satellite are calculated for the orbit's sunlight and eclipses zones, and cyclic load damage is investigated using Finite Element Method (ANSYS). The thermal damage is calculated as the ratio between the number of cycles corresponding to the operation life time (n) and the time life cycles (N). Finally, the effect of the FGM across thickness material property distribution function on the accumulating damage is studied. The procedure described above is applied to three types of FGM base plates, E-, S-, and P-FGM. Each of these has a different transverse constituents distribution profile, with dimensions 500x500x3 mm. Material properties and across-thickness distributions are found in the literature. Results of the fatigue analysis of the highly stressed corner are compared for these three types of FGM materials. Relationships between the amount of thermal damage and profile parameters are presented.