Modelisation of Thermally Induced Jitter in an Orbiting Slender Structure

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Abstract. Thermomechanical interactions aboard spacecraft interesting field of research and study. Since Bruno Boley's 1954 publication, numerous authors have contributed, if not with a multidisciplinary perspective. The Alouette 1 anomaly in 1962 signalled the start of a long succession of unexpected events due to mechanical and thermal interaction. This study uses a simple model to illustrate the basic mechanism behind thermal shock-induced elastic vibrations. This occurs when a spacecraft's flexible appendage is previously shadowed by its main body after an attitude manoeuvre [Ulysses, 1990] or during the transitions shadow-Sun and vice-versa. A thin structure was used to compare thermal and mechanical characteristic times and realise the strong coupling. The accurate thermal analysis offers a time-dependent thermal bending moment that acts as a boundary condition in the subsequent modal analysis of the structural element, triggering elastic transverse vibrations.

Introduction

Since the 1960s, thermally induced vibration has turned out to be a breakdown in spacecraft with flexible appendages. Space beams, such as spacecraft booms, solar arrays etc., could go through thermally induced vibration owing to abrupt temperature changes on night-day and day-night alterations in orbit, as shown in Figure 1. The flexible appendages of spacecraft, such as antennae and solar arrays, are exposed to a sudden solar heat flux during the orbital eclipse transition. Boley [1] predicted the thermally induced vibration of thin beams for the first time. Boley indicated that this problem involves transient heat conduction and structural dynamics. To avoid this type of failure, extensive research was conducted to design the spacecraft components properly. Authors [2-4] researched thermally induced solar panel dynamics, including an analysis of satellite attitude dynamics caused by thermally induced structural motions, an assessment of material degradation effects, and a laboratory investigation of a satellite solar panel's thermal-structural performance. Analytical and experimental results show thermal bending deformations with acceleration transients that have characteristic thermal snap disturbance histories in response to rapid changes in heating. According to the research, thermal snap disturbances in solar panels are caused by temperature differences that vary at a non-constant rate throughout the panel's thickness.

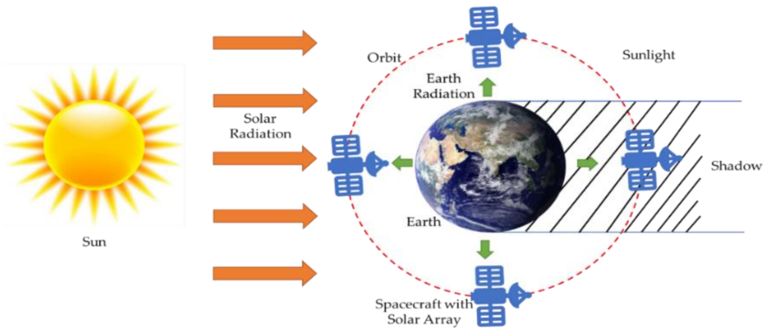

Figure 1: Satellite thermal environment in orbit.

Results and Discussion

This research work aims to analytically analyse more about the thermally induced vibration caused by solar heating. To investigate thermally induced vibrations, a novel method is proposed. The proposed analytical method allows the designer to analyse a thermally induced problem effectively with retaining the nonlinearity in the model. The research presents a new design guideline for analysing the thermal jitter of a thin spacecraft structure, which is a common occurrence in space engineering. A simplified modelisation provides a step-by-step procedure for studying and analysing the phenomenon of thermal jitter.

References

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