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小卫星姿态控制飞轮系统热设计

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Thermal design of attitude control flywheel system for small satellites

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摘要 为了满足小卫星姿态控制飞轮系统热设计的要求,对飞轮系统的热特性进行了分析和试验验证。根据飞轮运行工况,分别对飞轮系统机械损耗和电控损耗进行了理论计算,确定了系统主要热源点的分布情况。然后,依据系统拓扑结构,建立了整机的等效热网络模型;采用有限元法,分别对飞轮相关组件和整机在卫星连续侧摆工况下的热特性进行了分析。最后,研制了实验样机,并对样机进行了热真空试验。在经过8 h卫星连续侧摆机动工况下的实验结果表明:当环境温度为45.0 ℃时,监测点最后平衡温度约为57.8 ℃,相对于有限元分析结果的53.2 ℃,误差为8.6%,表明热分析结果与试验结果吻合度较好,可为姿态控制飞轮系统的热设计提供重要参考。

关键词 : 小卫星, 姿态控制飞轮, 热设计, 等效热网络, 有限元法

Abstract : To meet the thermal design requirements of an attitude control flywheel system for small satellites, the thermal performance of the flywheel system was analyzed and an experimental verification was carried out. According to the flywheel operating conditions, the electronically controlled loss and the mechanical loss of the flywheel system were calculated in theory to determine the distribution of the main heat source of the system. Then, an equivalent thermal network model was established based on the whole mechanical topology structure. The Finite Element Method (FEM) was applied to analysis of the thermal performance of the main components and the whole system under the swinging condition, respectively. Finally, a prototype was developed and the thermal vacuum test was carried out to validate the analysis results. The results show that the final equilibrium temperature of the monitoring point is about 57.8 ℃ under the swinging operating condition for 8 hours with the ambient temperature 45.0 ℃. The error is 8.6% relative to the FEM result of 53.2 ℃, which indicates that the temperature values obtained in the analysis and the experiment are coincident with well and the thermal design meets the thermal requirements of the satellite systems. This analysis provides an important reference for the thermal design of attitude control flywheel systems.

Key words : small satellite attitude control flywheel thermal design equivalent thermal network Finite Element Method (FEM)

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