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液体火箭发动机推力室内壁寿命预估

Life prediction of liquid rocket engine thrust chamber liner wall

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中文关键词: 液体火箭发动机推力室 流固耦合 循环加载 弹塑性材料 非线性分析 寿命预估

英文关键词:liquid rocket engine thrust chamber fluid-structural coupled cyclic loading elasto-plastic material nonlinear analysis life prediction

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中文摘要:

为了分析推力室内壁失效机理及准确预估推力室内壁寿命,对推力室进行流-热-固耦合计算.流-热耦合为热-固耦合提供准确的热和机械载荷,热-固耦合模型对推力室内壁在循环加载下的变形进行非线性平面应变有限元分析.通过计算,得到了推力室内壁在单循环各阶段的应力-应变分布和循环加载下的变形过程,并进行了寿命预估.结果表明:采用的流-固耦合策略能准确地实现流-热耦合模块向热-固耦合模块的载荷传递,能为结构分析提供准确的边界条件.在预冷、后冷和松弛阶段,内壁承受拉应力;在工作阶段,内壁承受压应力.随着循环次数的增加,内壁残余应力和应变不断增大,内壁向燃烧室内鼓起和不断变薄,冷却通道中心最先失效.所采用的分析模型能够模拟内壁在循环热和机械载荷下的变形过程,用于预估推力室内壁的循环寿命.

英文摘要:

To understand the failure mechanism and predict the life of thrust chamber liner wall, fluid-thermo-structural coupled numerical simulation was carried out for the thrust chamber. The thermal and mechanical loading of thermo-structural coupled analysis were provided by fluid-thermal coupled analysis; for thermo-structural coupled model, a two-dimensional plane strain finite element analysis of the nonlinear deformation of the thrust chamber liner wall was performed. Through computation, the stress-strain distribution of thrust chamber liner wall at different stages of each cycle and the deformation process under cyclic loading were obtained, and a post processing method is applied to predict the life of the thrust chamber liner wall. The results show the fluid-structural coupled method can accurately carry out the loading data exchange from fluid-thermo coupled module to thermo-structureal coupled module and provide the accurate boundary conditions for structural analysis. The liner wall is under tensile stress during the pre-cooling, post-cooling and relaxtion phases, while under compression stress during the hot run phase. The residual stress and strain are increasing with the operate cycle increasing. The cyclic thermal and mechanical loading cause the liner wall to bulge and thin, and finally lead to the failure of the cooling channel. The analysis model is able to simulate the deformation of the thrust chamber liner wall under cyclic thermo and mechanical loading and predict the cycle life.

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