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LIFE EVALUATION OF REUSABLE RAMJET ENGINE SUBJECTED TO CREEP-FATIGUE INTERACTION

Abstract

The ramjet is expected to be the main reusable propulsion system for the next generation cruise vehicles, thereby the life evaluation become the critical design factors. It is, therefore, important to develop a life prediction method so that the realistic life evaluation of ramjet could be made. Based on the metallographic analysis and micro hardness testing on the crack of the thermal protection structure(TPS), which occurs after several hot tests, the thermal fatigue and creep fatigue are considered to be the main damage modes in the ramjet combustion chamber. The results of metallographic analysis and micro hardness testing indicate that the crack grows along the crystal grain boundary, the average grain grade is lower, and the surroundings of the crack suffer from extremely high temperature over 1300K, which can't be directly measured in the hot tests of the engine. A analytical procedure called multi-physics coupled simulation is conducted and it is focused on simulating thermo-fluid-structure behavior in the combustion chamber simultaneously. Thermal shock and steady state operation are both considered. Thermal shock means the high-level peak thermal stress generated as a result of significant temperature gradients which occur during start-up, shut-down and thermal transient conditions of ramjet. And the steady operation means the low-level steady thermal stress caused by high temperature but not high temperature gradients, which occurs during the cruise phase of ramjet. The peak thermal stress causes the high temperature low cycle fatigue(LCF) of TPS, and the steady thermal stress leads to the creep fatigue of TPS. Therefore, determination of the TPS temperature field distribution and the accuracy of thermal structure analysis corresponding to structure stress and strain are the key to life estimation. On the basis of the multi-physics coupled simulation, both the peak thermal stress and the steady one in the TPS of combustion chamber are calculated, and the mechanism of the structure deformation and crack observed in the firing test are discussed. The high temperature LCF tests and creep fatigue tests are carried out to obtain the p-S-N curve equation of the TPS material. In addition, the life of TPS under the testing condition has been predicted based on a cumulative fatigue damage rule. Some simulation results are compared with the data measured during engine hot tests, and the agreement is excellent, which verify the numerical method.