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CYCLIC STRESS ANALYSIS OF SEMICRYO ENGINE THRUST CHAMBER USING CHABOCHE UNIFIED VISCOPLASTIC MODEL

Abstract

The engine investigated is a Semicryo rocket engine, envisaged for propelling new generation Indian launch vehicles. One of the significant subsystems of this rocket engine is its thrust chamber, which is of double walled construction made of high ductile low strength stainless steel (SS321). Both the inner and outer walls are of SS321 and are joined by high temperature brazing done in a furnace. Due to the combined action of high thermal and pressure loads experienced by the thrust chamber during its operation, the material exhibits significant strain rate dependency due to viscous effects apart from cyclic plasticity. To capture this behaviour, the well-known Chaboche unified viscoplastic model is chosen and is implemented in ANSYS combining multiple material models like third order Chaboche non-linear kinematic hardening model and Exponential visco hardening model. In order to completely describe constitutive model in ANSYS, a total of 15 material parameters are to be evaluated, including 2 for linear isotropic model, 7 parameters for non-linear kinematic hardening model and 6 for exponential visco hardening model. A step by step procedure for the identification of these parameters as applied to SS321 is given in detail. Low cycle fatigue tests were conducted in an INSTRON Fatigue Testing Machine at different temperatures with a hold period corresponding to steady state operating duration of the engine, in tension and compression, for evaluating the cyclic stress-strain characteristics of the material. The model parameters are determined by comparing test results with numerical simulations of uniaxial test in ANSYS, using a single element finite element model subjected to cyclic deformations. The parameters are calibrated by trial and error method till the cyclic stress-strain pattern from simulation and LCF test match well. Finite element modelling of the thrust chamber is carried out using ANSYS accounting for all non-linearities. Using these model parameters, cyclic stress analysis of the chamber is performed for 15 cycles to study cyclic hardening and stress relaxation characteristics of the chamber.

This methodology proves to be useful in the life-estimation of similar structures that are subjected to high cyclic thermal and pressure loads.