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Author: Mr. Pascal H. Kringe
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany, pascal.kringe@dlr.de

RESULTS OF A TMF PANEL FATIGUE LIFE EXPERIMENT REPRESENTING LIQUID ROCKET ENGINE COMBUSTION CHAMBER GEOMETRY

Abstract

This paper presents the results of the latest thermomechanical fatigue (TMF) life experiments at DLR Institute of Space Propulsion in Lampoldshausen. Thermomechanical fatigue is a major issue for the life time of regeneratively cooled rocket engines, particularly regarding reusability and multiple reignitions. Due to high temperature, temperature gradients and pressure loads significant plastic strain is induced in the inner liner of a liquid rocket engine, ultimately leading to a crack of the respective cooling channel after accumulating a sufficient amount of deformation, known as the so-called "doghouse effect". Such a crack changes the mixture ratio in the combustion chamber reducing the efficiency of the engine, locally increases the heat flux and eventually can cause the disintegration of the engine. The material investigated here is suitable for lowly loaded regeneratively cooled rocket engines like reigniteable cryogenic upper stages. Within the TMF panel experiment only a small section of five cooling channels of the rocket combustion chamber wall is cyclically heated with a high power diode laser while being cooled with supercritical nitrogen until the central channel intentionally cracks. Nitrogen is used for safety reasons. The experimental results are then used for the validation of a finite element (FE) fatigue life analysis in order to reduce costs during the development of new rocket engines. The test conditions in the present experiment consisted of a TMF panel surface temperature of $T_s = 800$ K, a heat flux into the panel of $\dot{q} = 25$ MW/m^2, laser-on (heating) time of $t_{on} = 200$ s and a nitrogen mass flow of $\dot{m} = 47$ g/s per cooling channel.