Thermal fatigue analysis of turbine discs on the base of deformation criterion

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Abstract

The lifetime of turbine discs under complex non-proportional thermo-mechanical cyclic loading is analyzed by means of the direct finite-element simulation of deformation and fracture processes using thermo-elasto-visco-plastic material model and deformation failure criterion. A good agreement is observed in comparison of the obtained number of cycles to macrocrack initiation with experimental results for five turbine discs made from different materials and subjected to various loading conditions.

Keywords: *thermal fatigue, turbine discs, plasticity, creep, damage.*

1. Introduction

Gas turbine discs are usually the most critical engine components attracting the main research attention in the engine life management [1-6]. Turbine discs are subjected to high level complex thermo-mechanical non-proportional loading. Discs may fail by various root causes among them the thermal fatigue is the main one. A very high kinetic energy of fragments arising from a broken disc leads to catastrophic consequences [6,7]. Therefore the design of the disc has to ensure that disc fracture does not occur.

In 1970s the unique experiments for measurement of thermocyclic strength of real gas turbine discs up to the failure were made in TsNIITMASH [8,9]. The experimental results obtained in [8,9] for different materials are the base in current research for the accuracy evaluation of the considered below the thermal fatigue criteria.

There is a wide range of approaches to the thermal low cycle fatigue analysis of turbine discs [5,6,8-21]. Nowadays the Manson's formula is widely used for the fatigue analysis of discs [22,5,6]:

$$\Delta\varepsilon = \frac{3.5\left(\sigma_b - \sigma_m\right)}{E} N^{-0.12} + \varepsilon_r^p N^{-0.6}, \qquad (1)$$

where main parameters for the computation of the number of cycles to a macrocrack initiation N in (1) are: the total strain range $\Delta\varepsilon$, the ultimate tensile strength σ_b and ultimate plastic strain ε_r^p.