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# Damage operator based lifetime calculation under thermo-mechanical fatigue for application on Ni-resist D-5S turbine housing of turbocharger

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ABSTRACT

The turbine housing of a turbocharger is exposed to extensive cyclic thermo-mechanical loading. This leads to a major challenge to design the turbine housing in order to ensure its guaranteed lifetime in relation to the high temperature behaviour of the material. The first step is to develop and validate a damage operator based lifetime calculation approach together with a constitutive material model for application on the casting material Ni-resist D-5S. A satisfactory prediction of the number of cycles until crack initiation by considering fatigue and creep damage is demonstrated on specimens subject to characteristic loading conditions and further on the critical positions of turbine housings, respectively.



## 1. Introduction

One key component of a turbocharger is the turbine housing (T/H) that provides the kinetic energy required for charging in making use of the remaining enthalpy in the exhaust gas. Inhomogeneous temperature distributions and the interaction with the neighbouring components constrain the thermal expansion and contraction of the T/H, thus causing local stresses and inelastic strains during operation in particular. The combination of thermal transients with mechanical loading cycles leads to thermo-mechanical fatigue (TMF) and, ultimately, after a certain number of loading cycles, to component failure. Numerous test stand tests are generally inevitable in order to find the appropriate combination of the complex design and the material. On the one hand, functionality without leakage during the guaranteed service life has to be ensured and, on the other hand, application specific customer requirements need to be met. Hence, there is a demand for reliable calculation methods allowing the lifetime calculation early in the design process.

A commonly applied procedure for qualitative lifetime assessment relies on thermo-mechanical finite element analysis (FEA) together with the use of material dependent limit values as results of long time experience. Since such an assessment on the basis of individual experience involves various risks, improvements in this respect can be expected in terms of coupling the numerical calculation with validated lifetime calculation approaches based on a description of physical damage effects. With a better understanding of the mechanical long term behaviour under static and cyclic loading at elevated temperatures, more reliable quantitative lifetime calculations enable, for instance, to employ full potential of materials or to reduce the effort for component structural analysis and testing.

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