

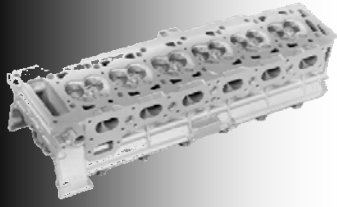


# Superimposed TMF/HCF-Loading

Experimental Techniques and some Characteristic Results for Nickel Base Superalloys and Cast Aluminum Alloys



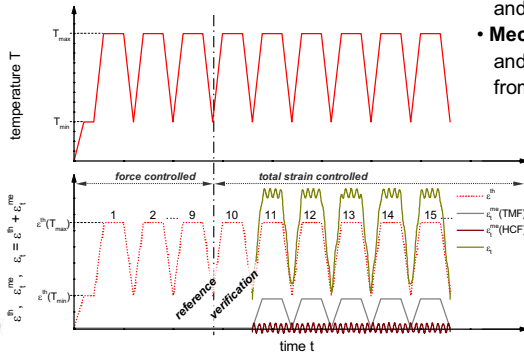
Gas turbine blades  
Inconel 617



Combustion engine  
AlSi10Mg



Servohydraulic testing device for superimposed TMF/HCF-loading up to 1000 Hz



Experimental parameters

## Motivation:

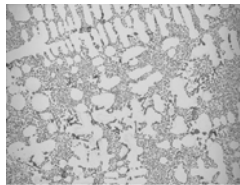
Many technical components, e. g. gas turbines and combustion engines, are exposed to complex loadings:

- **High temperatures**
- **Thermal induced mechanical loading** due to transient and inhomogeneous temperature distributions (constraint of thermal expansion) } **Low frequency range** resulting from start-stop-cycles
- **Mechanical loading** due to internal and/or extrinsic centrifugal forces
- **Mechanical loading** due to vibrations and/or pressure fluctuations resulting from unsteady combustion } **High frequency range** resulting from operating conditions

## Objective Target:

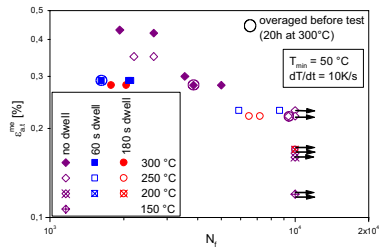
- Investigation of damage progress
  - Crack initiation
  - Propagation of short cracks
  - Transition to propagation of long cracks
- Development of a concept for lifetime estimation

## Cast Aluminum Alloy A360 (AlSi10Mg)

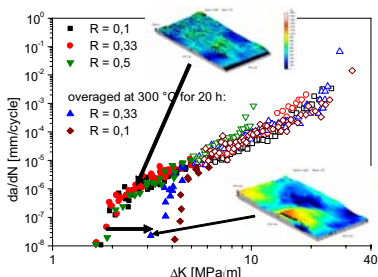
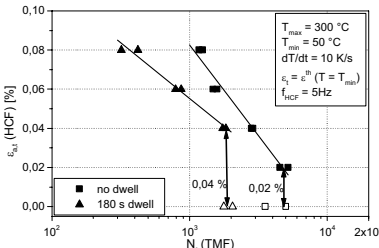


Element	Al	Si	Mg	Cu	Zn	Sn	Mn
Concentration [%-ma.]	bal.	10,918	0,332	0,012	0,023	0,002	0,231
Element	Fe	Ni	Ti	Pb	Cr	Sr	
Concentration [%-ma.]	0,276	0,008	0,045	< 0,001	0,002	0,018	

- Dwell times of 60 sec lead to a significant reduction of lifetime, whilst an increase of dwell times up to 180 sec does not result in further reduction of lifetime.
- Overaged specimens show the same lifetime like peak hardened specimens.

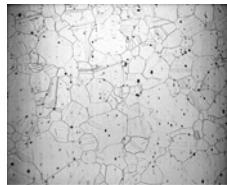


- A reduction of lifetime by the HCF loadings only occurs if the HCF amplitude exceeds a threshold which depends on  $T_{max}$  and  $t_d$ .
- There seems to be a strong correlation between the threshold for isothermal fatigue crack propagation and the impact of HCF amplitudes on TMF life and their respective dependencies on overaging.



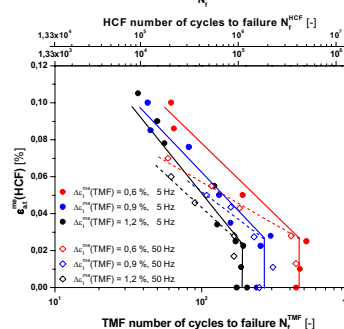
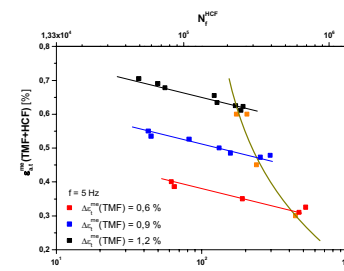
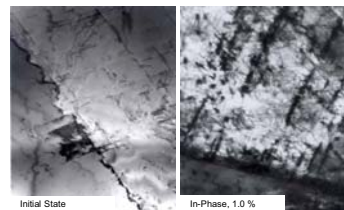
- Neither temperature nor load ratio shows a significant influence on the threshold of fatigue crack propagation. The threshold for overaged specimens is much higher than for peak hardened specimens.
- Nanofocus investigations for  $R = 0.33$  show a flat crack surface for T6-hardened specimens and a cliffy crack surface for overaged specimens.

## Nickel Base Superalloy Inconel 617 (IN617)



Element	Ni	Cr	Co	Mo	Al	Fe	Ti	Si
Concentration [%-ma.]	bal.	22,25	11,45	8,88	1,28	0,56	0,4	0,11

Microstructural changes occur for pure TMF-loadings as well as for superimposed TMF/HCF-loadings.



- Superimposed strain amplitudes  $\leq 0.02\%$  do not affect the lifetime.
- Higher superimposed strain amplitudes result in a significant reduction of lifetime compared to pure TMF-tests.
- Increasing the superimposed loading frequency from 5 to 50 Hz results in a further reduction of lifetime, though estimating the lifetime by means of lifetime fraction rules fails.

- The number of lines of rest on the crack surface correlates with the number of TMF-cycles.
- Fractographic investigations show, that only one incipient crack grows. This becomes the major crack propagating and resulting in fracture. All minor cracks stop after the initiation phase.

