

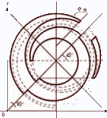
Wolfsburg Sept 2003

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## HIGH TEMPERATURE AXIAL STRAIN-CONTROLLED LCF/TMF FATIGUE TESTING OF FLAT-SHEET SPECIMENS

Dr.-Ing. Klaus F. Stärk

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HIGH TEMPERATURE AXIAL STRAIN-CONTROLLED LCF/TMF FATIGUE TESTING OF FLAT-SHEET SPECIMENS

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### Contents

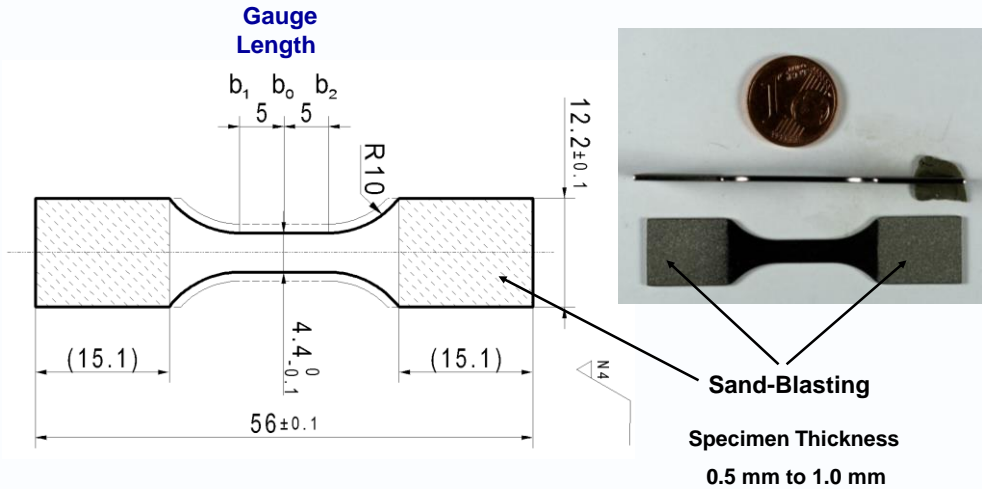
- Requirements for Flat-Sheet Specimens
- Specimen Design
- Anti-Buckling Restraint
- Susceptor and Induction Heating
- Clamping Device
- Validation LCF-Testing 12%-Cr-Steel
- Validation TMF-Testing Single Crystal

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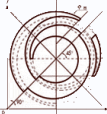


## Miniature Specimen für LCF/TMF

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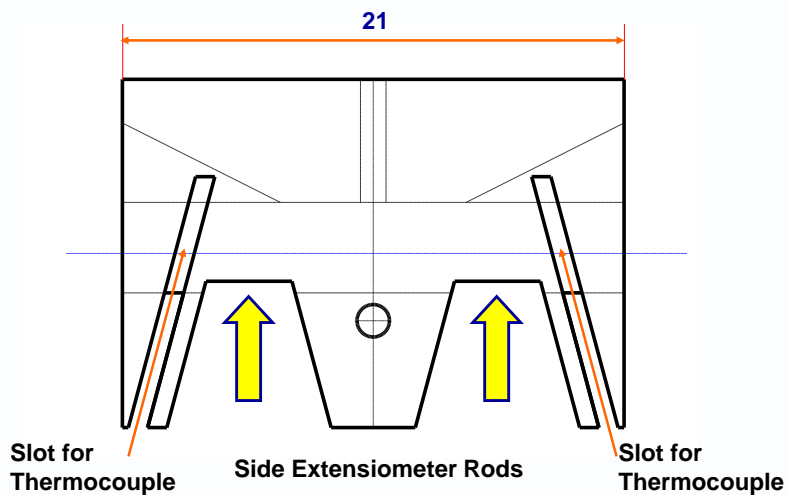


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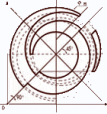


## Susceptor + Anti-Buckling Restraint

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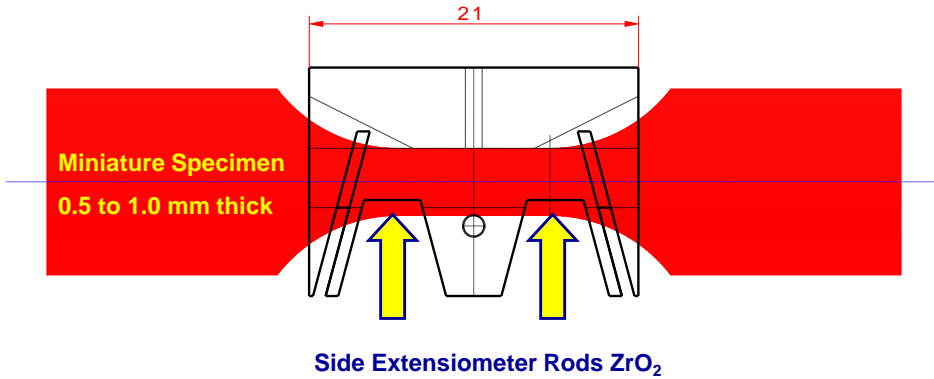
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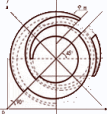
## Put together Susceptor and Specimen

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### Susceptor + Anti-Buckling Restraint Combination

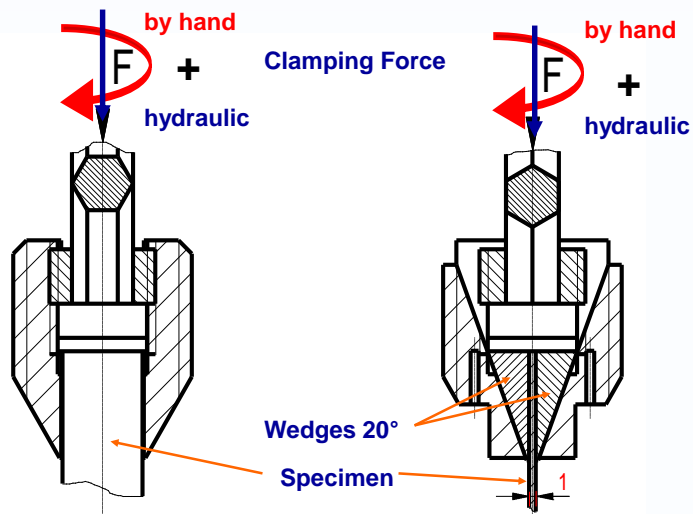


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## Fixturing Technique

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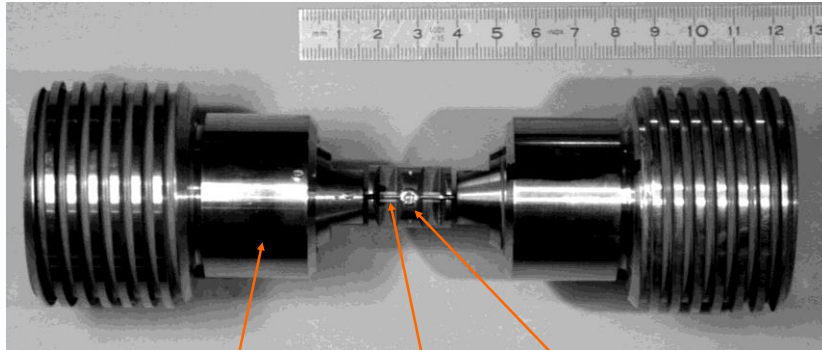


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## Fixturing Technique

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Body of Fixture

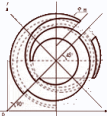
Specimen

"Free flying" Susceptor

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## Fixturing with Induction Heating Device

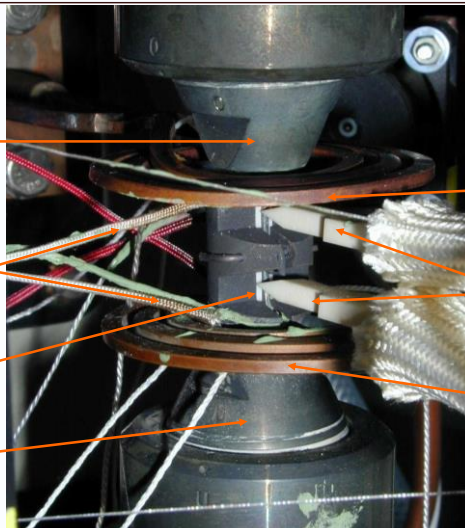
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Body of Fixture

Thermocouples  
PtRh/Pt Type S

ZrO<sub>2</sub> -Anti-  
Friction Tiles

Body of Fixture



Induction Coil 1

Side Contact  
Extensiometer  
with ZrO<sub>2</sub> Rods

Induction Coil 2

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## Set-Up for Complex TMF-Testing

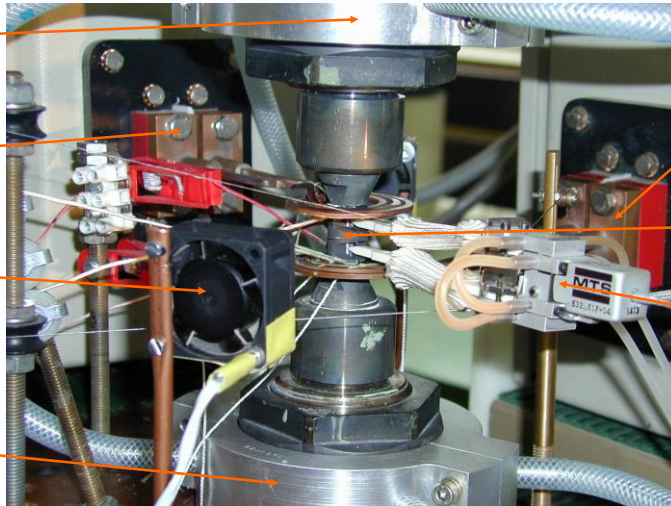
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Water Cooling

Induction Oscillator 1

Mini-Fan Cooling

Water Cooling



Induction Oscillator 2

Susceptor

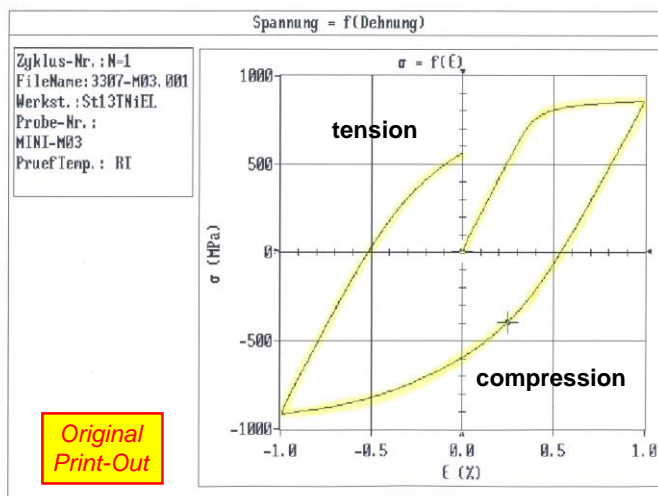
Side Extensometer with ZrO<sub>2</sub> Rods

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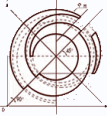
## Hysteresis Loop 1<sup>st</sup> Cycle 12%-Cr-Steel

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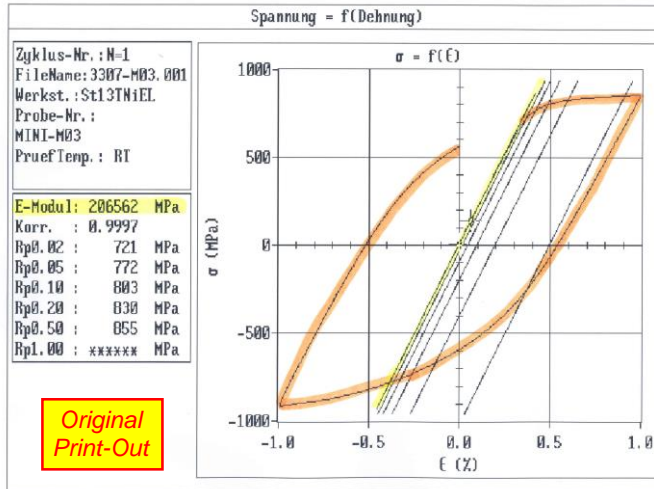


no buckling at high strain amplitudes and low friction

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# Hysteresis Loop 1<sup>st</sup> Cycle 12%-Cr-Steel ALSTOM

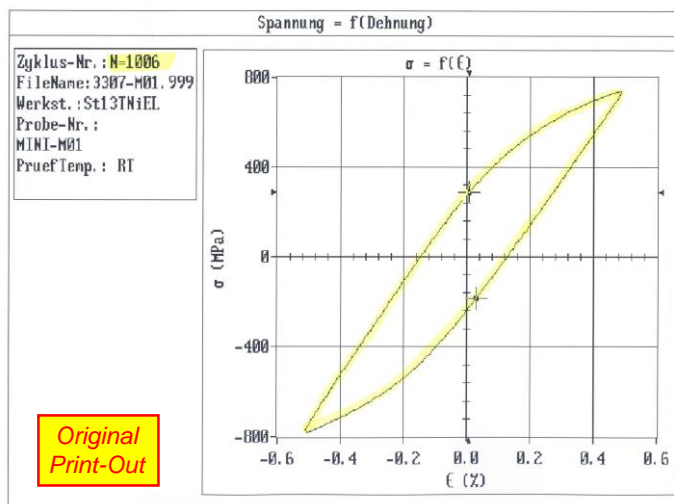


elastic modulus check

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# Hysteresis Loop Cycle 1006 12%-Cr-Steel ALSTOM

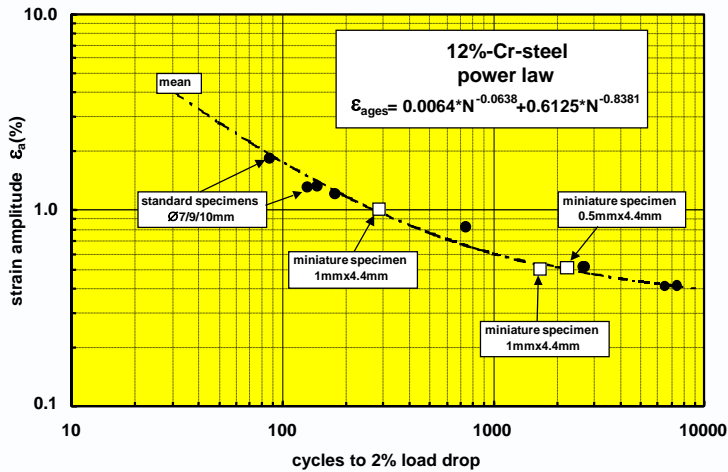


long term testing  
no friction indication

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# Verification of Miniature Specimens Fatigue Strain-Life Curve

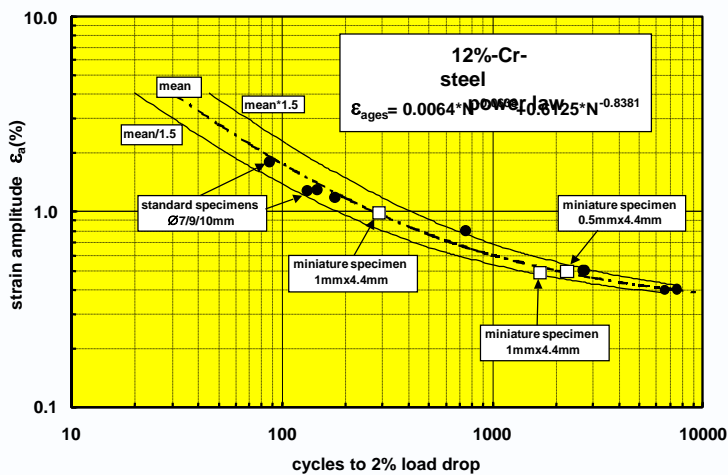


Comparison  
Miniature and  
Standard  
Round  
Specimens

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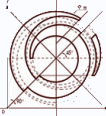


# Verification of Miniature Specimens Fatigue Strain-Life Curve



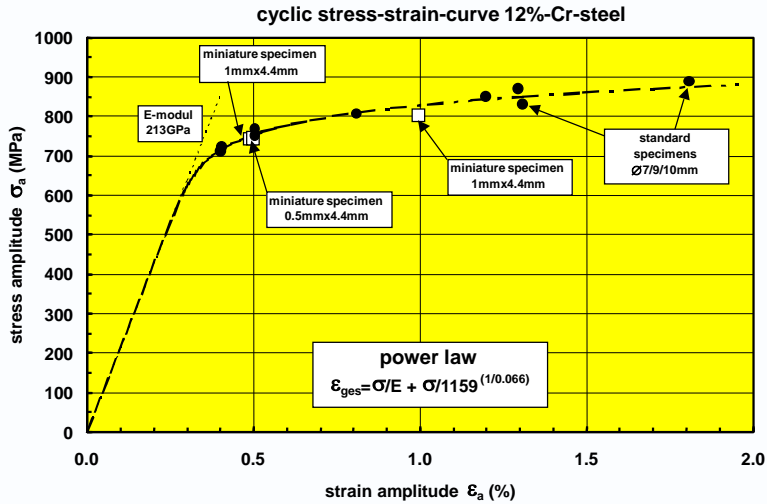
Standard  
Scatter Band  
Factor 1.5  
in Number of  
Cycles

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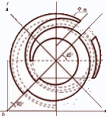
## Verification of Miniature Specimens

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Comparison  
Miniature and  
Standard  
Round  
Specimens

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## Miniature Specimens Cut-Out

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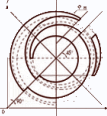


Pressure Side Wall  
of a Cooled Engine  
Blade out of  
Operation

Electrical  
Discharge  
Spark Erosion  
Cut-Out  
of 4 coated  
Miniature  
LCF/TMF  
Specimens

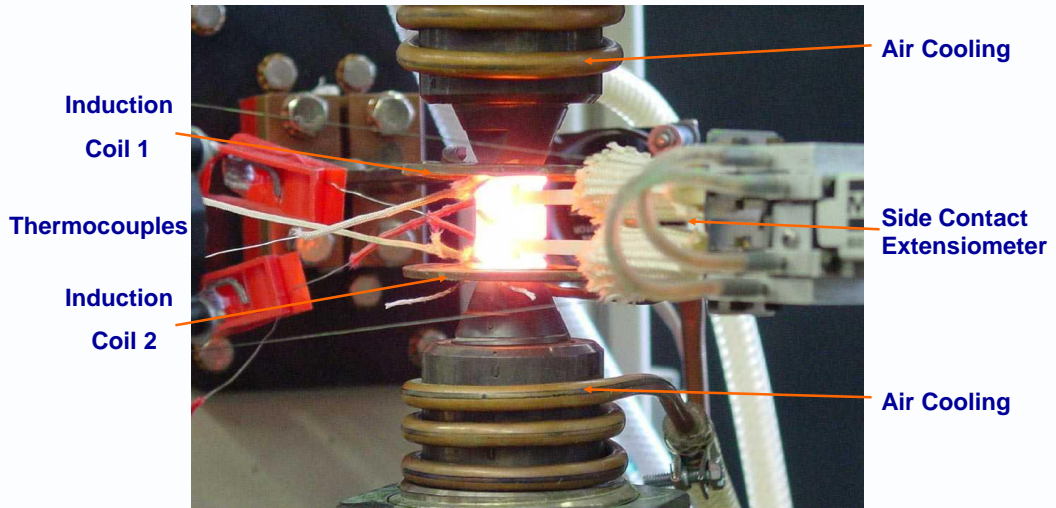
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## TMF-Test 100/1000°C

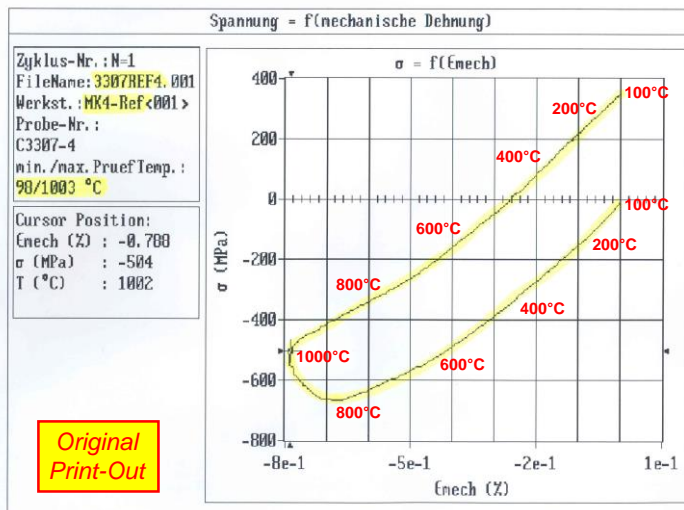
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## Hysteresis Loop 1<sup>st</sup> TMF Cycle SX <001> ALSTOM

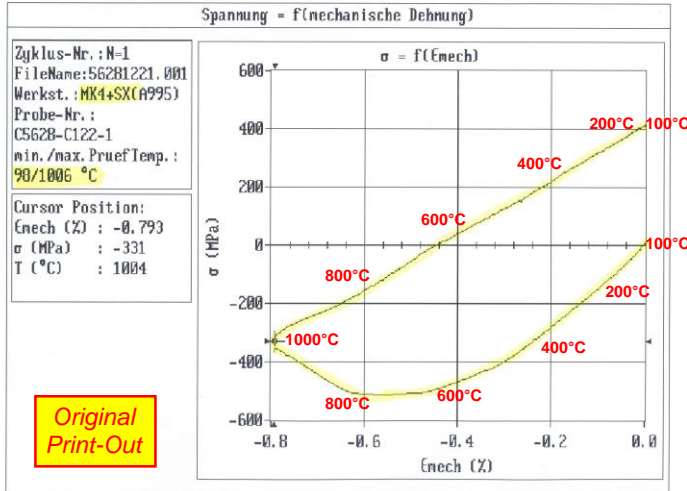


TMF-cycle  
100°C to  
1000°C  
Out of Phase

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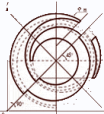


# 1<sup>st</sup> TMF Loop SX(700 $\mu$ m) + Coating (300 $\mu$ m) ALSTOM

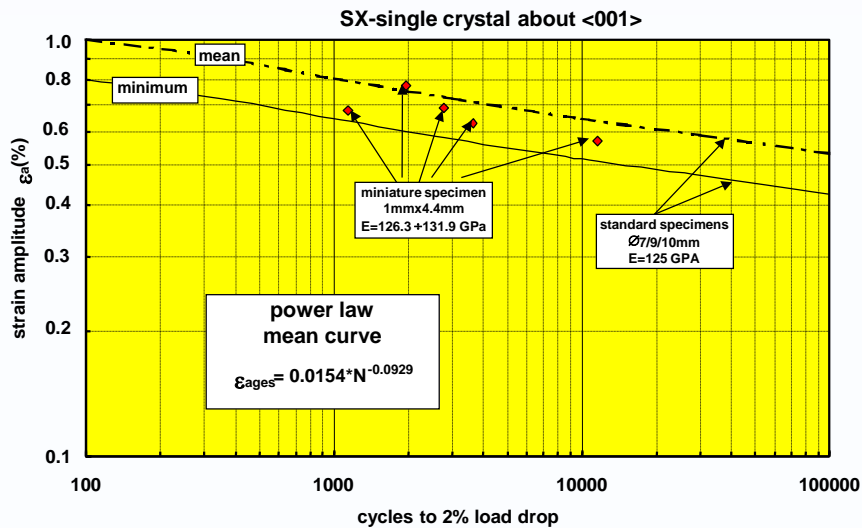


TMF-Cycle  
 100°C to  
 1000°C  
 Out of Phase

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# Verification of Miniature Specimens Fatigue Strain-Life Curve



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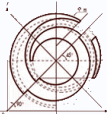


## Summary

- Design Task for LCF, TMF, CSR, CREEP



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## Summary

- Design Task for LCF, TMF, CSR, CREEP
- Experimental Work
  - Safe Fixture with Wedges
  - Anti-Buckling Restraint for HT
  - Susceptor for Induction Heating
  - Cooling for Thermal Mechanical Fatigue

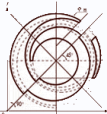
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## Summary

- Design Task for LCF, TMF, CSR, CREEP
- Experimental Work
- Working Free-Flying Anti-Buckling Restraint
  - Single Crystal Material (SX)
  - “Free-Flying” Restraint
  - Oxidation Resistant Material
  - Low Friction Forces with  $ZrO_2$ -Tiles
  - Adaptable for 0.5 to 1.0 mm Specimens

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## Summary

- Design Task for LCF, TMF, CSR, CREEP
- Experimental Work
- Working Free-Flying Anti-Buckling Restraint
- Working Susceptor and Induction Heating
  - Single Crystal with Ceramic Tiles
  - DUPLEX-Induction Heating with 2 Coils
  - 2 Independent Temperature Controller
  - 2 PtRh-Pt (S) Thermocouples  $\varnothing$  0.35mm

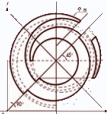
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## Summary

- Design Task for LCF, TMF, CSR, CREEP
- Experimental Work
- Working Free-Flying Anti-Buckling Restraint
- Working Susceptor and Induction Heating
- Working for LCF, TMF, CSR, Tension/Creep
  - Validation Tests with 12%-Cr-Steel
  - Validation with Single Crystal
  - TMF-Tests with coated/uncoated Material

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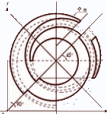
## Summary

- Design Task for LCF, TMF, CSR, CREEP
- Experimental Work
- Working Free-Flying Anti-Buckling Restraint
- Working Susceptor and Induction Heating
- Working for LCF, TMF, CSR, Tension/Creep
- Application for Materials
  - as cast, rolled
  - out of operation, degraded
  - coated in Original Condition

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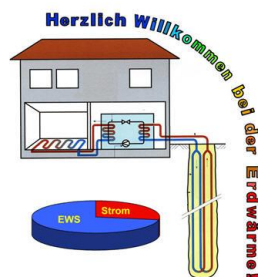


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**Beratung, Messungen, Präsentationen, eigene Anlage**

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