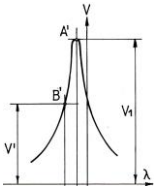
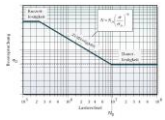
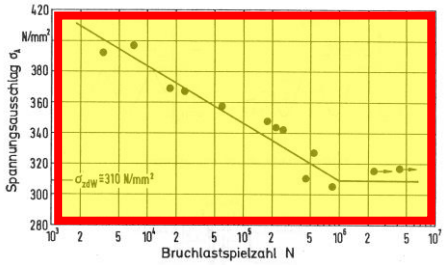


Let‘s swing!
Lassen Sie sich verschaukeln!



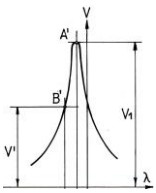
2x25 Years RUMUL



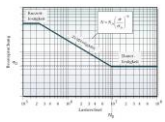
1989
and
2014

18./19. Sept. 2014

Dr.-Ing. Klaus F. Stärk
Untersiggenthal/Schweiz

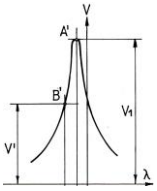


Let‘s swing!
Lassen Sie sich verschaukeln!

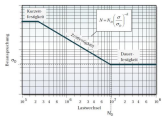


outline

1. August Wöhler and fatigue testing
2. Test rigs HCF, VHCF
3. Crack initiation, endurance limit
4. Pre-cracking and fatigue crack growth
5. Parts and component testing
6. What is most important?

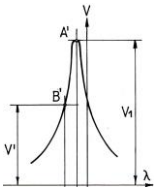


Let‘s swing!
Lassen Sie sich verschaukeln!

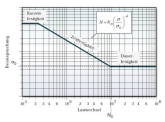


outline

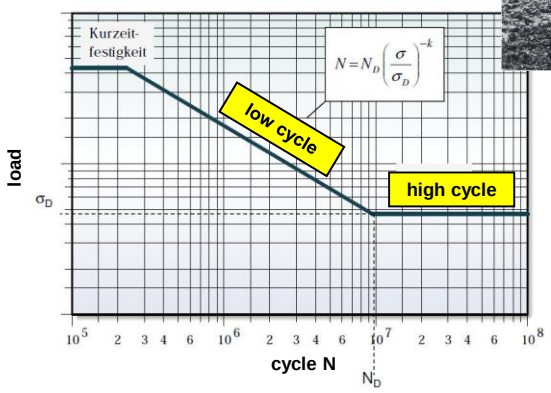
1. August Wöhler and fatigue testing

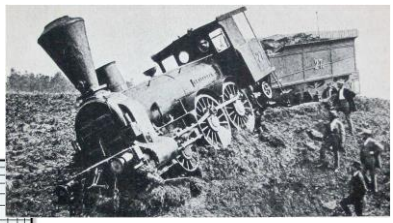


Let‘s swing!



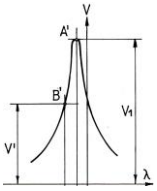
Wöhler line



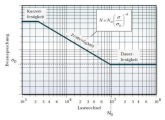


Timelkam 19.10.1875

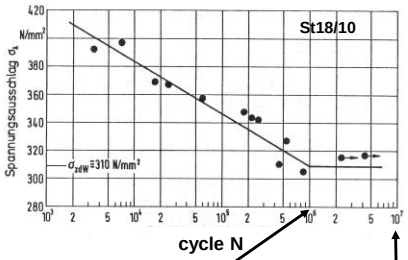
fatigue crack

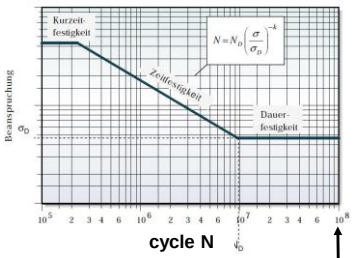


Let‘s swing!



examples

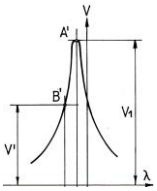




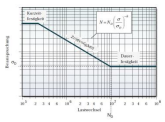
1 million cy at 100Hz = 2.8 hours

10 million cy at 100Hz = 30 hours

100 million cy at 100Hz = 12 days

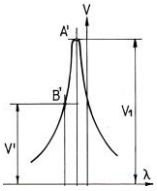


Let‘s swing!
Lassen Sie sich verschaukeln!

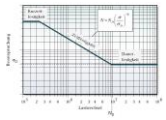


outline

1. August Wöhler and fatigue testing
2. Test rigs HCF, VHCF

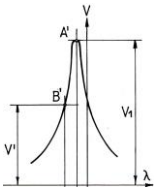


Let‘s swing!

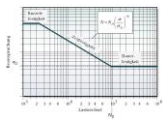


Test rigs

- **Mechanical (screw driven, eccentric, rotation mass)**
  cheap, low power consumption, low frequency <30Hz, dwell
- **Hydraulic (servo hydraulic, compressed air)**
  expensive, high energy consumption (about 100x resonant test rig) cooling, frequency <40Hz, flexible
- **Electromagnetic, resonance**
  expensive, low energy consumption, no cooling, no wear, high frequency up to 200 (1000)Hz > f > 40Hz
- **Ultrasonic, resonance**
  low energy consumption, specimen cooling, no wear, small specimens, high frequency about 20kHz



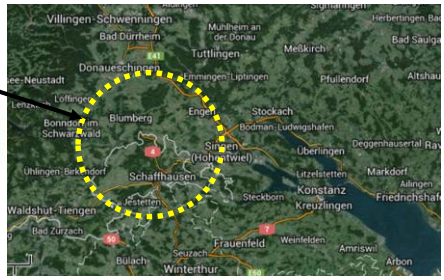
Let‘s swing!

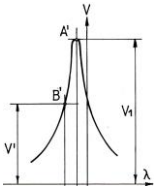


resonant testing machines

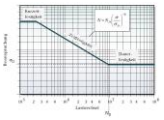
world wide in use,

but developed here



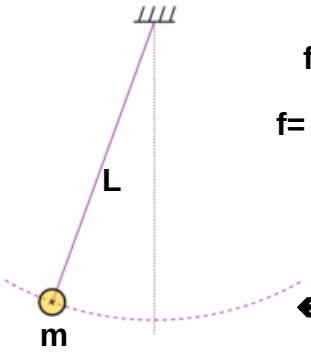


Let‘s swing!
Lassen Sie sich verschaukeln!



resonant machine

Let‘s swing!
Lassen Sie sich verschaukeln!

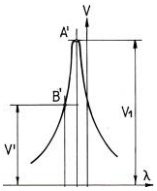


eigen-frequency

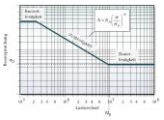
$$f = 1/(2\pi) \cdot \sqrt{g/L}$$

independent from **m** !!

🡐 🡐 manpower

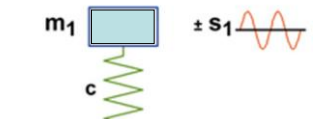


Let‘s swing!
Lassen Sie sich verschaukeln!

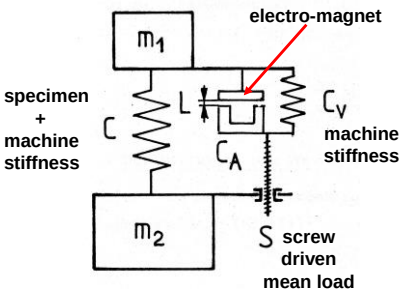


resonant testing machines

next steps

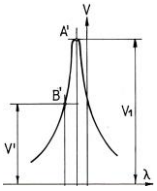


$$\omega = \sqrt{c \frac{m_0 + m_1}{m_0 * m_1}} = 2\pi f$$

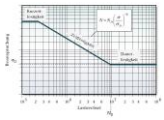


eigen-frequency

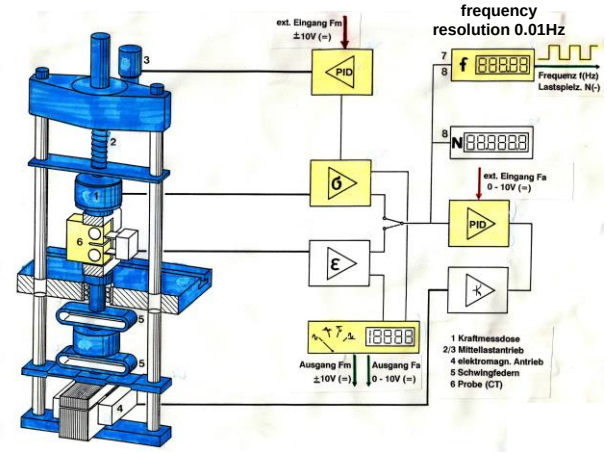
dependent on mass m_1, m_2,
machine and <u>specimen</u> stiffness (spring c)

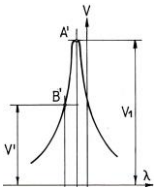


Let‘s swing!

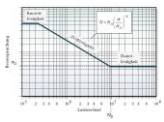


resonant testing machines

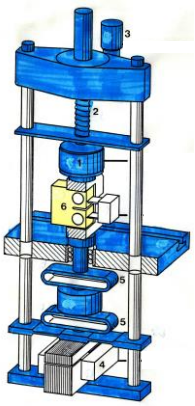




Let‘s swing!



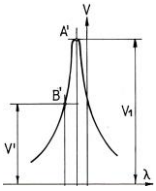
The resonant test rig



What do we need

- for specimen
- for part or
- for component

testing?



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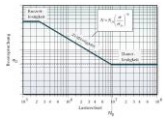
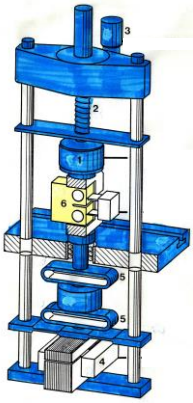
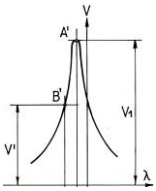
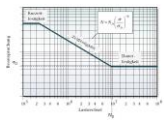


The resonant test rig





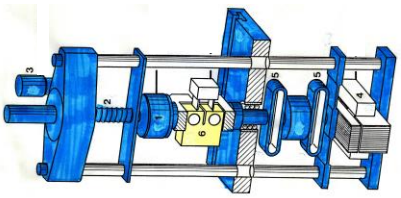
Let‘s swing!



The resonant test rig

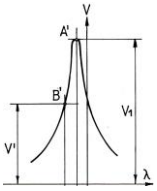
“horizontal” test rig

Mikrotron



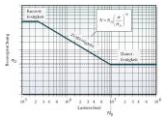
for electric heat chamber

and corrosion testing!



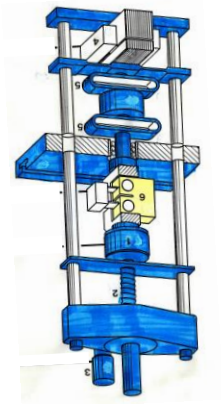
Let‘s swing!

The resonant test rig

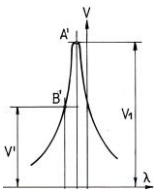


Testronic

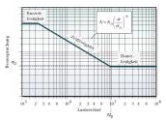
for specimen, part or component testing



on “top”



Let‘s swing!
Lassen Sie sich verschaukeln!



outline

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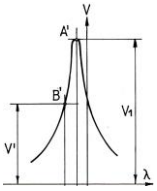
2. Test rigs HCF, VHCF
3. Crack initiation, endurance limit



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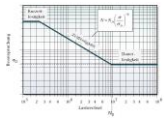
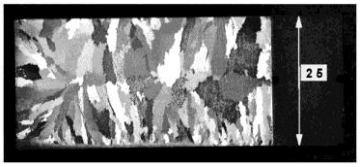
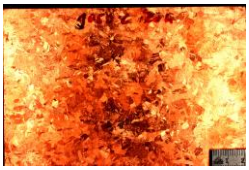


specimen testing

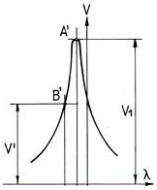
MarM247cc



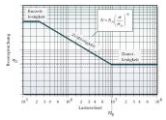
OF-Cu



individual !

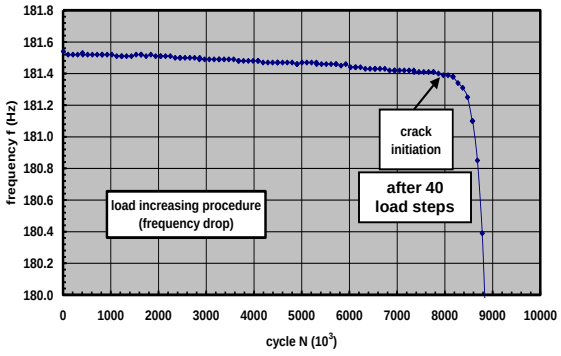


Let‘s swing!



frequency ➔ a function of stiffness.

An dis-advantage?



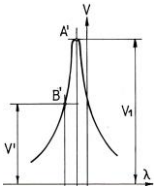
load in-creasing test (LIT) for example:

block 200.000 cycles

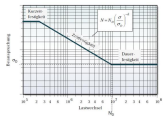
load in-creasing 2%

“rough” endurance limit in

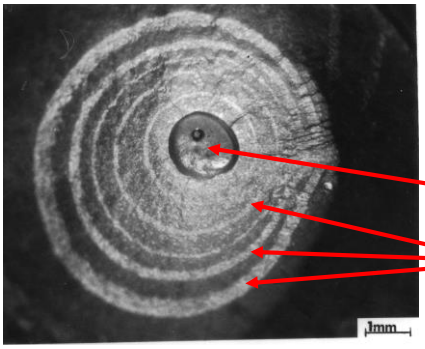
one test



Let‘s swing!



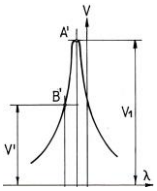
frequency drop measurement combined
with load in-creasing procedure



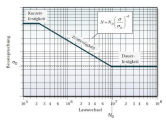
determination of fatigue limit of individual defects, notches or surfaces

weld pore

“beach marks”



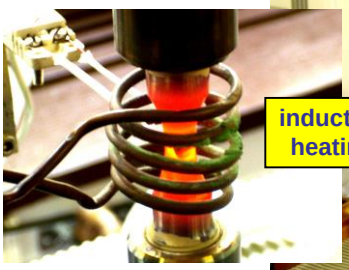
Let‘s swing!



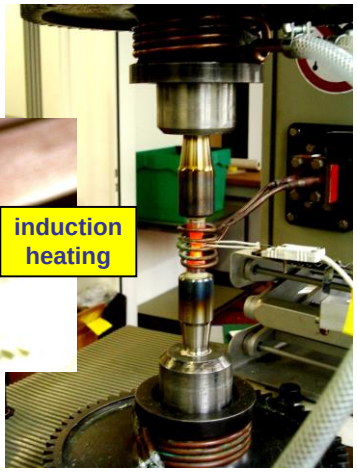
frequency ➔ a function of stiffness.

“hot” Testronic 100 kN (900°C)

load increasing test (LIT)

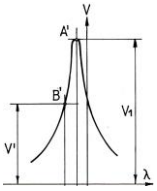


induction heating

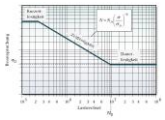


rough endurance limit in

one test

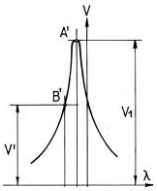


Let‘s swing!
Lassen Sie sich verschaukeln!

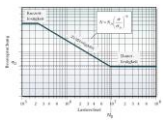


outline

1. August Wöhler and fatigue testing
2. Test rigs HCF, VHCF
3. Crack initiation, endurance limit
4. Pre-cracking and fatigue crack growth



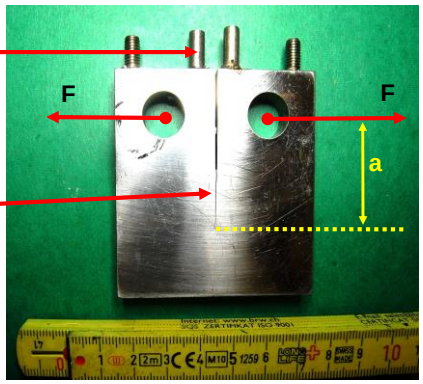
Let‘s swing!



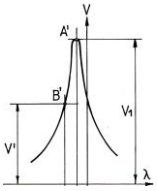
frequency drop measurement combined with load de-creasing procedure

potential drop pins

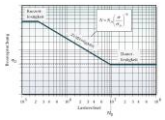
fatigue crack



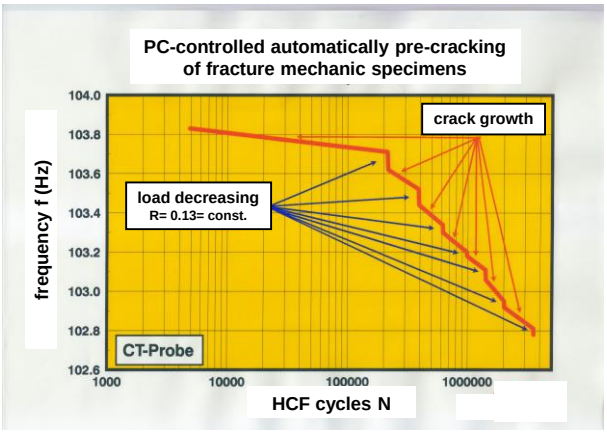
determination of crack growth threshold and fatigue pre-cracking of fracture toughness specimens



Let‘s swing!

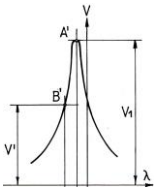


resonant testing machines

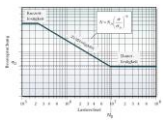


controlled frequency reduction = pre-defined crack growth

simple specimen testing is boring



Let‘s swing!
Lassen Sie sich verschaukeln!



outline

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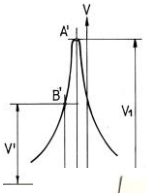
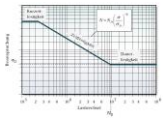
5. Parts and component testing

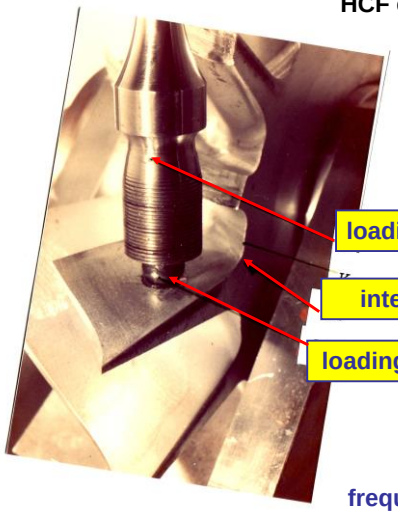


Let‘s swing!

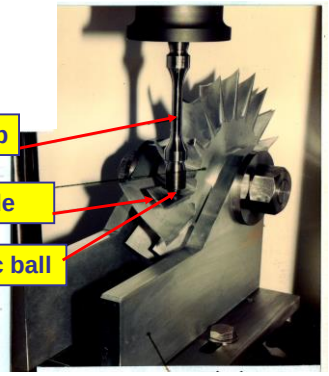


integral turbocharger compressor wheel

HCF endurance limit



Fractronik 100kN

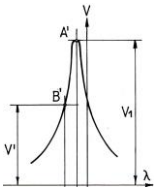


loading stamp

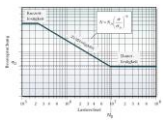
integral blade

loading ceramic ball

frequency drop ➔ crack initation



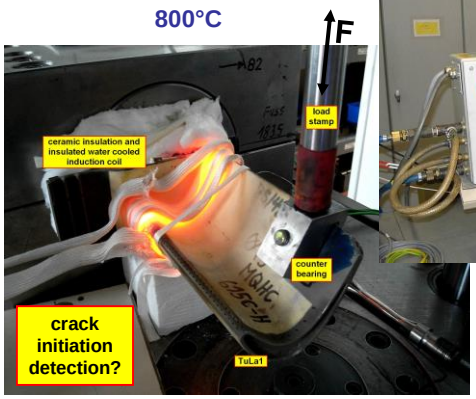
Let‘s swing!



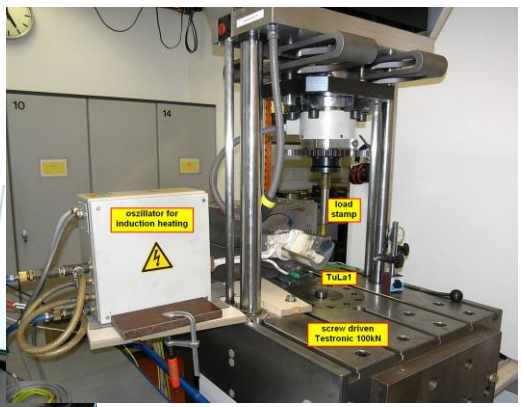
component testing

Testronic 100kN

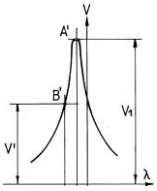
load controlled turbine blade at 800°C



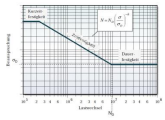
crack initiation detection?



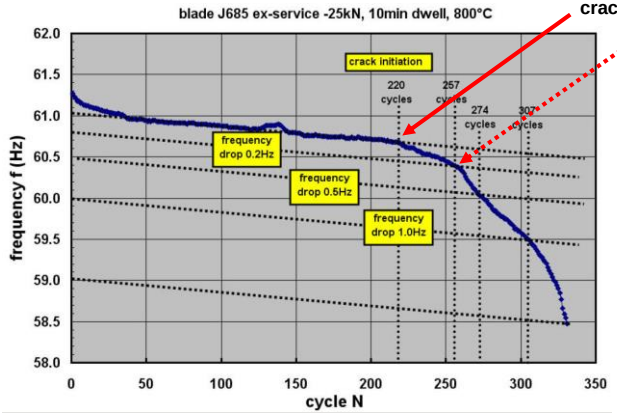
LCF- HCF part testing with induction heating



Let‘s swing!

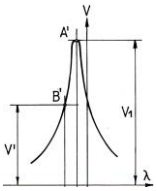


load controlled LCF
bending mode with dwell at 800°C

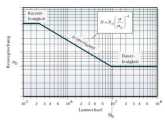


and

crack initiation detection by frequency drop in short HCF blocks after each LCF cycle

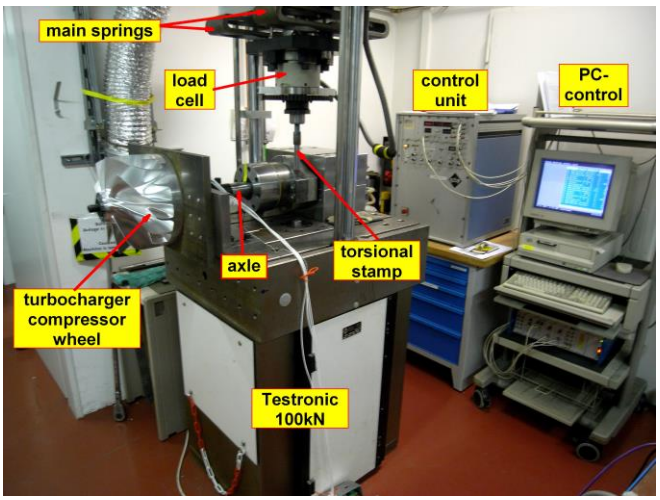


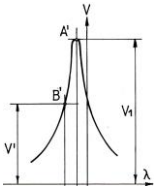
Let‘s swing!



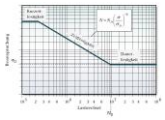
component testing

torsional loading of turbocharger wheel up to 4.500Nm at 50Hz

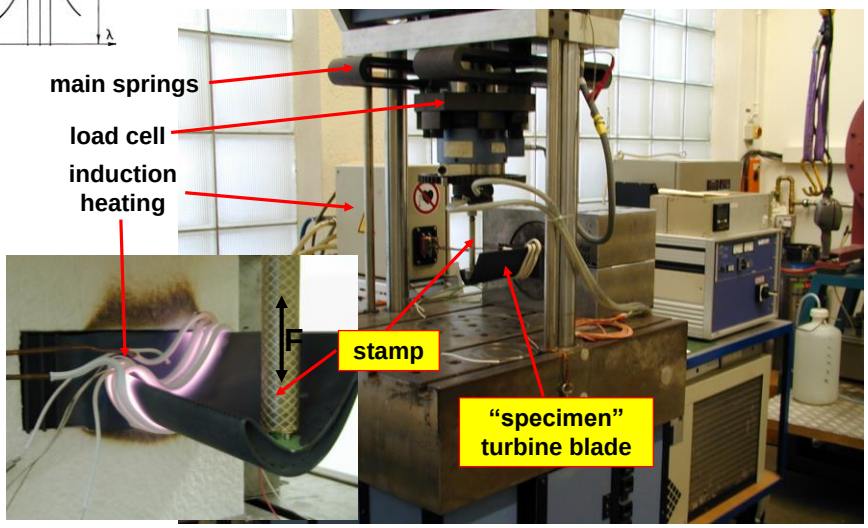


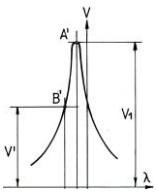


Let‘s swing!

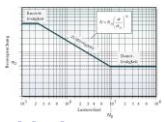


Testronic 100kN



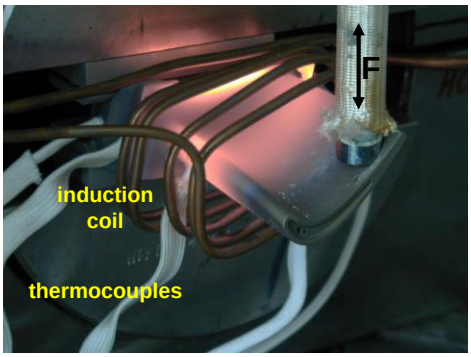


Let‘s swing!



component testing

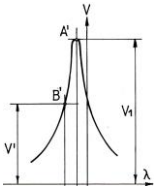
gas turbine SX HP
blade at 900 to 1000°C
bending mode



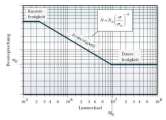
hot

compressor blade
with strain gauges
bending mode

cold

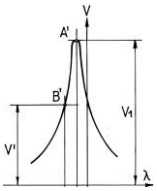


Let‘s swing!
Lassen Sie sich verschaukeln!

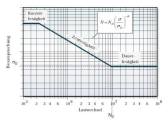


outline

1. August Wöhler and fatigue testing
2. Test rigs HCF, VHCF
3. Crack initiation, endurance limit
4. Precracking and fatigue crack growth
5. Parts and component testing
6. What is most important?



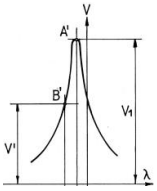
Let‘s swing!



What is most important?

- **Money, money, money?**
- **An intelligent test rig**
  (precise, simple to handle, no wear, high life period)
- **High frequency**
  100Hz= 2.8 hours for 1 million cycles
- **An economic test rig**
  (low energy consumption, no cooling water)
- **Service!**

service! service! service!



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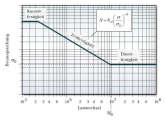
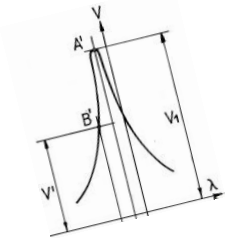
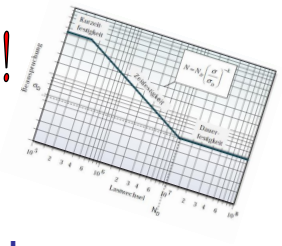


Thanks very much!



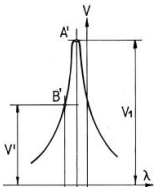
It's your turn now !!



Wish you a beautiful boat trip!

Dr.-Ing. Klaus F. Stärk
Untersiggenthal/Schweiz

klaus.staerk@swissonline.ch
www.staerk-erdwaerme.ch



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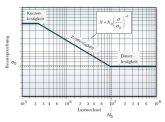

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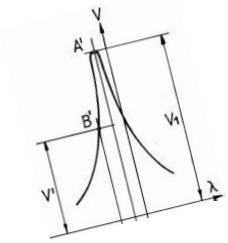

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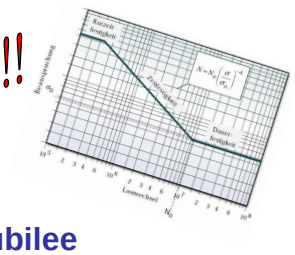

Remark:

For the 75 years jubilee

I will not be available!

Dr.-Ing. Klaus F. Stärk
Untersiggenthal/Schweiz

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