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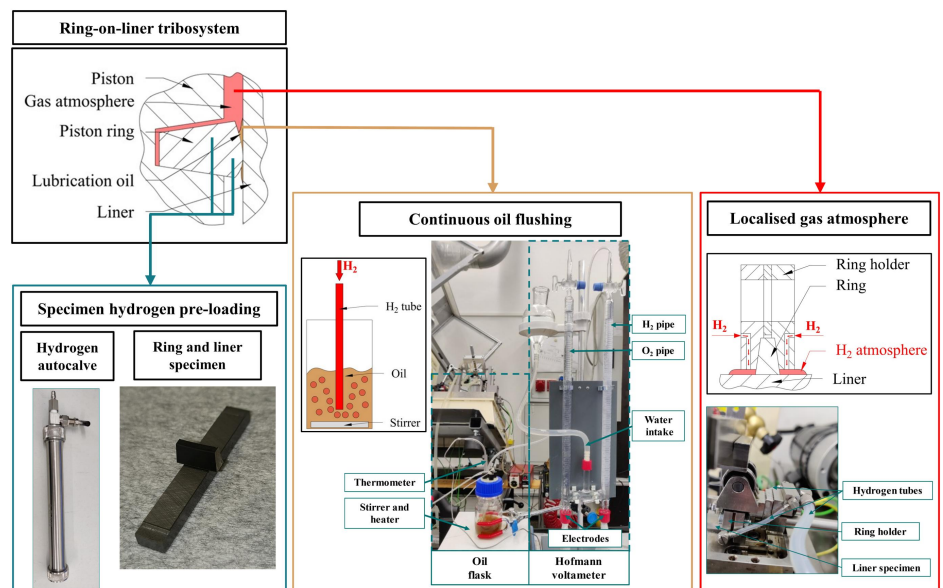
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# Experimental evaluation of a gas engine Ring-on-Liner contact under hydrogen atmosphere

Alternative fuels are important for ensuring the continued sustainable use of piston engines. Since alternative fuels such as hydrogen can alter the tribological behavior of various engine components, it is crucial to assess the different tribosystems within the engine, particularly the Ring-on-Liner contact. As the high stroke and high temperature at the Ring-on-Liner contact make the usage of pressure chambers difficult, a new novel testing methodology with a localized hydrogen atmosphere was developed for tribotesting under realistic conditions.

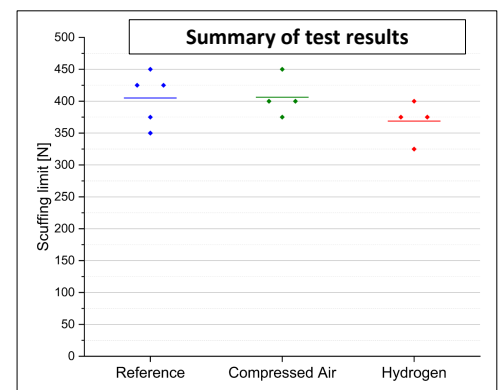
## Methodological approach

In order to create the localized hydrogen atmosphere, the fuel is sprayed directly onto the contact area of the Ring-on-Liner model test at a TE77 linear tribometer. As hydrogen also effects the oil and the specimens themselves, the oil is continuously flushed with hydrogen, and the specimens are pre-loaded with hydrogen in high-pressure autoclaves. Circulating oil between the test area and the hydrogen flushed oil flask ensures that hydrogen rich oil is sprayed onto the contact.



## Results

Scuffing tests were run with hydrogen, without gas spraying (reference), and with compressed air spraying. Analysis of all the scuffing limits shows that the limits for the reference tests and the tests with compressed air were similar which means that the spraying methodology itself had no effect on the scuffing limit, while the limits for the tests with hydrogen were slightly lower. With this knowledge, even though the difference of scuffing limits is small it is heavily advised to take special caution when using piston rings in hydrogen engines. Now that the new methodology was proven to work for alternative fuels like hydrogen, other fuels can be tested with only slight adaptation to the existing design.



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### Research focus:

- Tribological impact of alternative fuels
- Scuffing under high load and temperature
- Tribological behaviour of the Ring-on-Liner tribosystem

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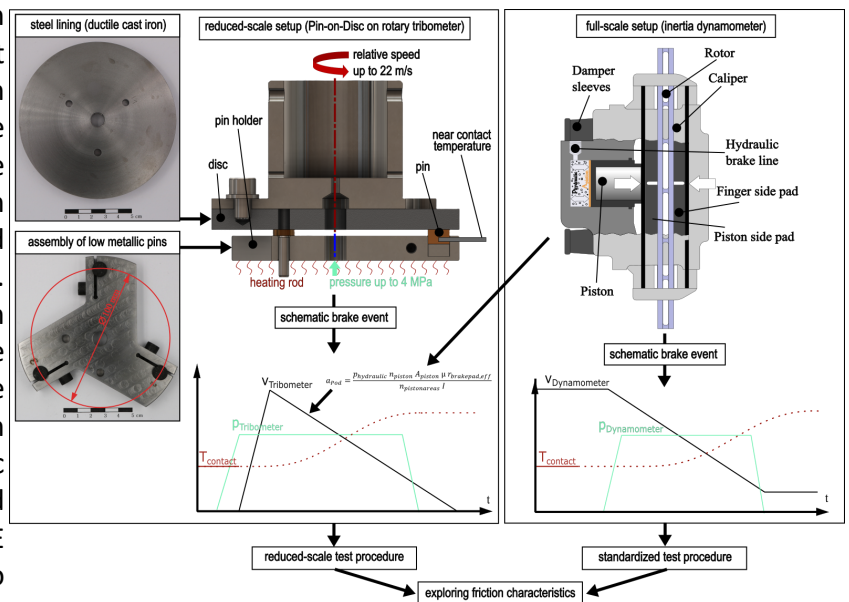


# Analyzing disc brake friction characteristics in reduced-scale experiments

In recent years, brake pad testing has attracted growing scientific interest, particularly in view of the upcoming EURO 7, which will impose emission limits from tires and brakes. Reduced-scale brake tests offer significant cost reductions during development process by enabling preliminary evaluations before full-scale component testing. This study presents a scaling approach for disc brakes based on the SAE J2522 standard test procedure.

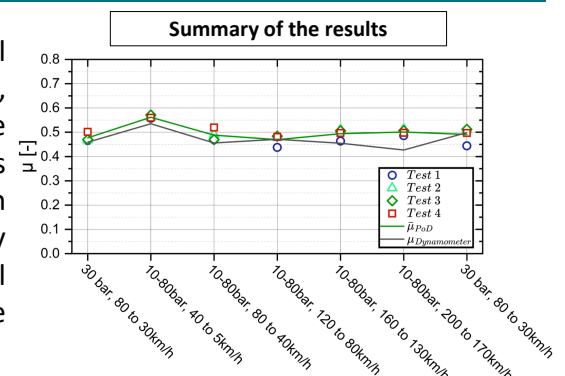
## Methodology

This study investigates the coefficient of friction using two test setups: a pin-on-disc model test on a tribometer and a component test on an inertia dynamometer. The data of the reference test on the inertia dynamometer following the SAE J2522 standard was provided by an automotive OEM. A low-metallic brake pad and a ductile cast iron disc was used for both setups. The scaling method calculates deceleration based on energy per contact area to ensure comparable conditions. The pressure, relative sliding speed and initial temperature remain consistent across both setups. The pin on disc tests focused on pressure-controlled cycles and covered the first 312 brake events of the SAE J2522 standard, enabling direct comparison to the reference test.



## Results

The four repeated tests conducted on the pin-on-disc model demonstrate that the model test results are reproducible. Furthermore, comparing these results with those from the reference test on the dynamometer reveals that similar outcomes can be obtained. At speeds exceeding 120 km/h, the model test results exhibit slightly higher mean friction coefficients than those from the dynamometer test. This study allows experiments to be conducted under controlled environmental conditions (e.g. water, saltwater and gas) and facilitates the measurement of particle emissions in a reduced-scale model test.



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### Research focus:

- Scaling methods in tribology
- Friction characteristics of component and model tests
- Disc brake performance under controlled conditions



# Multivariate AE-Based Crack Growth Estimation Using Bayesian Regression

## Continuous Acoustic-Emission Features for Paris-Regime Crack-Growth Monitoring

### Introduction:

Fatigue crack growth in metallic structures generates characteristic acoustic-emission (AE) activity. Although AE is highly sensitive to crack-front dynamics, its quantitative integration into fracture-mechanical models remains limited. This work introduces a calibration framework that links continuous AE features to crack-growth behaviour in Paris regime II. Two complementary descriptors — **Short-Time Energy (STE)** and **Spectral Centroid (SC)** — are extracted from continuous AE waveforms and correlated with the stress-intensity-factor range and crack-growth rate. A Bayesian regression model combines both features to obtain robust, uncertainty-aware predictions of crack growth.

### Experimental Setup:

Fatigue tests were performed on S235JR steel under fully reversed loading ( $R = -1$ ) at **2 Hz**, **30 Hz**, and **82 Hz** using a servo-hydraulic test rig (STR) and a resonance pulsator (RP). Continuous AE signals were recorded at **3.57 MHz** using two broadband sensors. Crack length was measured via crack gauge foil. AE features were computed using a sliding-window approach and mapped to crack-growth data within Paris regime II.

- $\Delta K$  — Stress-intensity-factor range; crack-tip loading parameter in Mode I.
- $da/dN$  — Crack-growth rate; incremental crack extension per load cycle.
- STE — Short-Time Energy; energy-related descriptor of AE activity.
- SC — Spectral Centroid; frequency-weighted indicator of AE spectral shift.
- $C_{rel}$  — Relative spectral centroid; normalized inverse SC used for regression.

### Isolation Paris Regime II:

The Paris regime was isolated using a moving-window regression on the  $\log(\Delta K) - \log(da/dN)$  curve. This ensures that AE features are calibrated only within the stable crack-growth region where fracture-mechanical behaviour is reproducible.

### STE vs. Crack-Growth Rate

STE reflects the energy content of the continuous AE signal. Across 2 Hz, 30 Hz, and 82 Hz tests, STE shows a clear positive trend with  $da/dN$ , indicating stronger AE activity as the crack grows. Frequency-dependent differences arise from machine dynamics and sensor bandwidth.

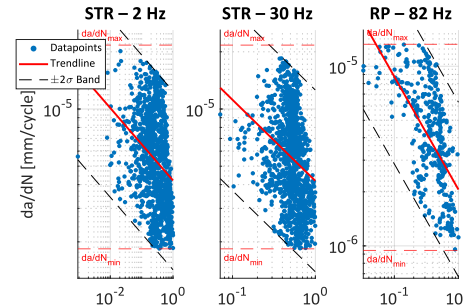
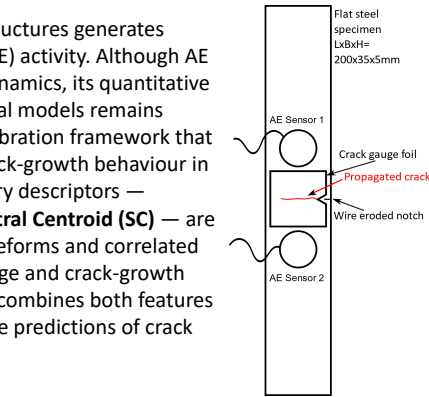


Figure 3: Spectral Centroid (SC) decreases with crack-growth rate, indicating a shift of AE energy toward lower frequencies.

### SC vs. Crack-Growth Rate

SC captures the frequency distribution of AE signals. As crack length increases, frictional crack-face interactions become more dominant, shifting spectral energy to lower frequencies. This produces a robust negative correlation between SC and  $da/dN$ .

### 3D OLS + Bayesian Regression Surface

A multivariate Bayesian regression model integrates STE and a normalized SC descriptor. The Bayesian formulation provides posterior distributions for all parameters, enabling uncertainty quantification and improving predictive stability compared to classical ordinary least-squares (OLS) fitting.

STR 30Hz AE2 – Bayesian regression with OLS reference surface

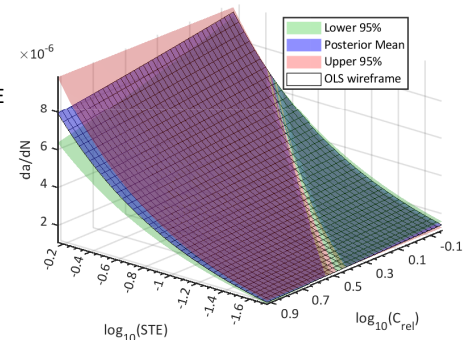


Figure 4: Combined regression surface using STE and relative SC. Bayesian regression yields smoother surfaces and narrower uncertainty bands than OLS.

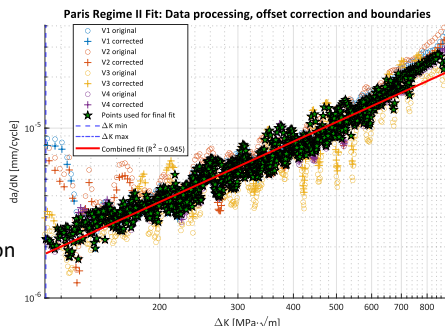


Figure 1: Identification of Paris regime II using log-log regression of  $\Delta K$  vs.  $da/dN$ . Only the stable linear region is used for AE calibration.

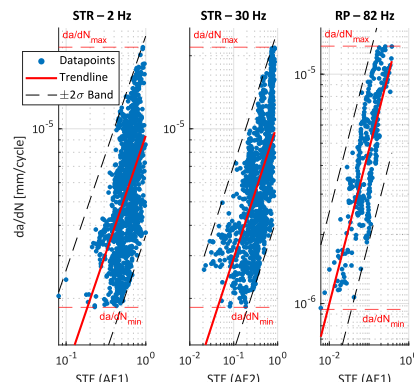


Figure 2: Short-Time Energy (STE) increases monotonically with crack-growth rate across all loading frequencies.

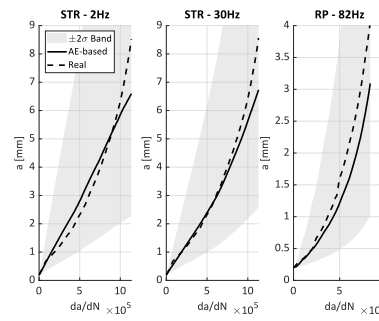


Figure 5: Reconstructed crack-length evolution using the Bayesian surrogate model compared to experimental measurements.

### Crack-Length Reconstruction (Bayes vs. Real)

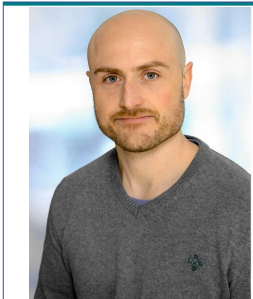
By integrating the posterior-predicted crack-growth rates, the Bayesian model reconstructs the crack-length evolution with high accuracy. Across all machines and frequencies, the AE-based prediction closely follows the measured crack growth, demonstrating suitability for continuous structural-health monitoring.

### Conclusion:

Continuous AE features contain sufficient fracture-mechanical information to quantify crack growth in Paris regime II. STE and SC exhibit stable, monotonic trends with  $da/dN$ , and their combination in a Bayesian regression framework significantly improves predictive robustness. The resulting surrogate model enables accurate crack-length reconstruction and provides uncertainty bounds suitable for real-time monitoring applications.

### Research Focus:

- Acoustic Emission
- Fatigue Crack Growth
- Bayesian Regression

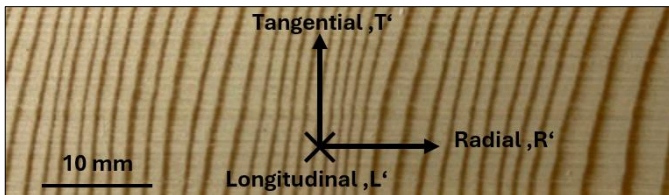


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# Orthotropic material- and damage modelling of biomass materials

“*Picea abies*” (European Spruce)

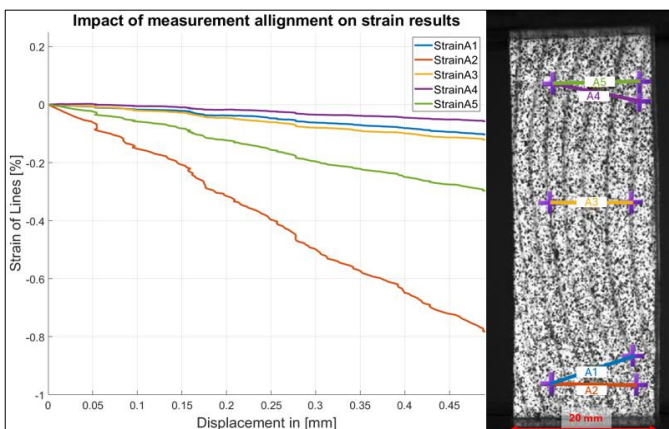
Forests cover nearly 48 % of Austria’s total area, with a continuous growth rate of approximately 1 m<sup>3</sup> of wood per second. While there are 65 indigenous tree species, Norway spruce (*Picea abies*), also known as the European spruce, accounts for 57 % of the total timber stock. Economic factors and cost-efficiency have driven a trend toward using wood in industrial and technical applications, ranging from automotive and railway engineering, to furniture and bicycle design.



However, as Gibson and Ashby (1988) noted: “Wood is complicated stuff.” Beyond its strong orthotropic nature, its mechanical properties are significantly influenced by loading direction, strain rate, growth rate (density), moisture content, temperature and natural defects such as knots.

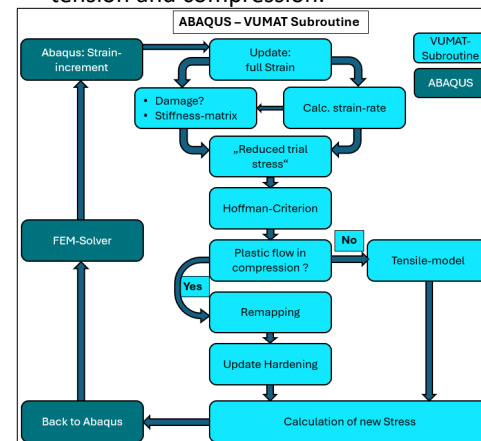
To facilitate and evaluate the design of technical components, advanced numerical simulations are essential. A standard industry approach is the use of LS-DYNA with the MAT-143 material model, which is effective for crash simulations with moderate deformations.

Standard models often reach their limits when capturing extreme states. To accurately predict the behavior during large deformations, such as crushing or shredding of wood, and to parameterize a specific type of wood, advanced wood models including damage mechanics are needed.

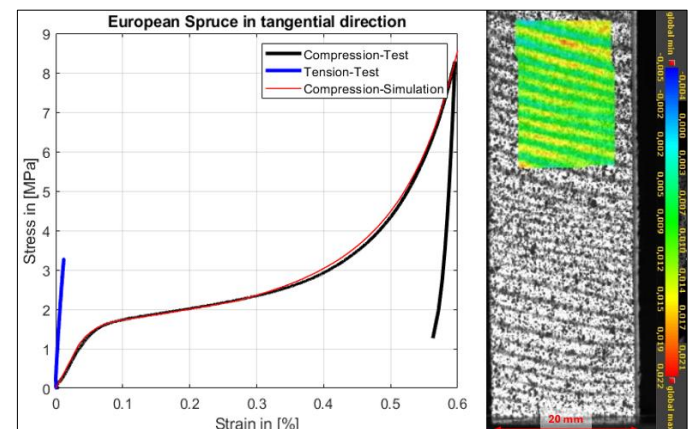


Such an advanced material model can be achieved by incorporate the following main features in an explicit subroutine for ABAQUS solver:

- The Hoffman criterion is used for all three directions separately.
- Kinematic- and isotropic hardening are used with plastic flow in compression.
- The damage in compression is controlled by the Poisson’s-Ratio.
- Use of different material properties for yielding under tension and compression.



To parameterize the material model, uniaxial compression-, tension- and shear-tests are evaluated for all three directions. These tests are conducted and the strain is measured by an optical extensometer, to obtain the course of the Poisson ratio.



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**Research focus:**  
Process optimization for recycling biomass materials

**Research partner:**  
 **KOMPTECH**



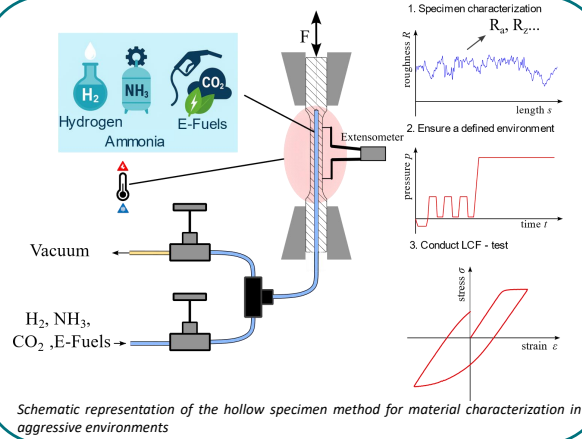
# The interaction of notch intensity and hydrogen environment under fatigue loading

## Testing based Assessment

Hydrogen embrittlement, the loss of mechanical integrity caused by absorbed hydrogen, threatens the safety and durability of components operating in such environments. Reliable evaluation therefore requires established testing protocols and robust assessment methods.

To quantify embrittlement under cyclic loading, we combine two complementary approaches:

- Low-cycle fatigue (LCF) tests to characterize intrinsic material susceptibility to hydrogen when significant cyclic plastic strain occurs.
- High-cycle fatigue (HCF) tests on internally notched hollow specimens to investigate the effect of local plasticity at stress raisers (e.g., notch roots) and to study the interaction between notch intensity (e.g.,  $K_t$ , notch-root radius) and the hydrogen environment.



### Results - LCF

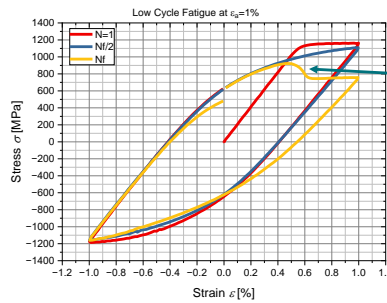
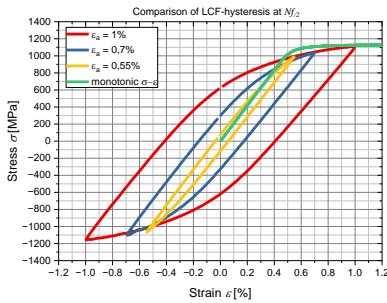
#### LCF - Tests:

$\dot{\epsilon} = 0.1\%/s$   
 $l_0 = 12.5\text{ mm}$   
 $D_0 = 7.5\text{ mm}$   
 $d_0 = 2.4\text{ mm}$

HS ... hollow specimen  
CS ... conventional specimen

No significant difference in fatigue life between HS and CS in ambient air

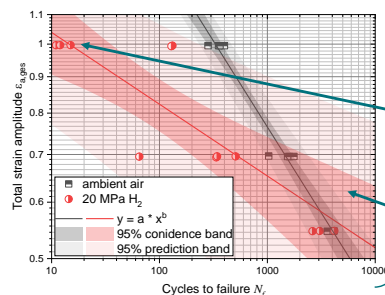
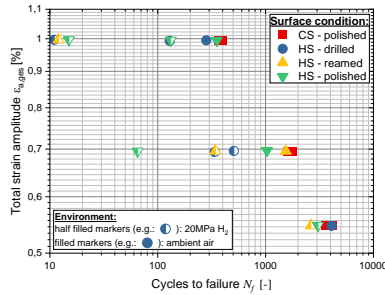
No significant difference in fatigue between HS surface characteristics



Brittle fracture at  $N_f$  under low cycle fatigue loading.

#### Fatigue assessment:

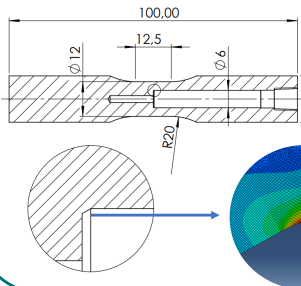
- Combined hardening model to simulate local elasto-plastic material behavior on notches.
- Investigation of time dependent parameters ( $f$ ,  $t_{hold}$ ) in hydrogen.



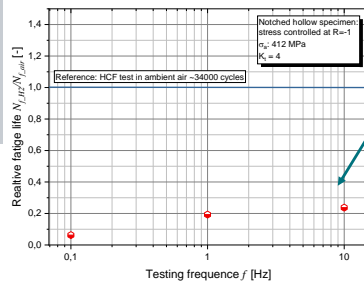
High reduction in fatigue life due to hydrogen at high total strain amplitudes

Large scatter for HS tests in 20 MPa hydrogen

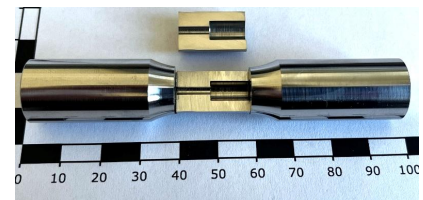
### Results HCF: Internal notched hollow specimen



local high stressed region (notch root)



Significant dependency of fatigue life on the testing frequency of notched specimens.



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Research Focus: Environmentally Assisted Fatigue and Durability: Testing and Assessment

voestalpine

ONE STEP AHEAD.

BÖHLER

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