Pneumatically powered material testing devices for the extreme test conditions

HyBello

- *VTT*
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- *Webinar 24.3.2022*

Content of the presentation

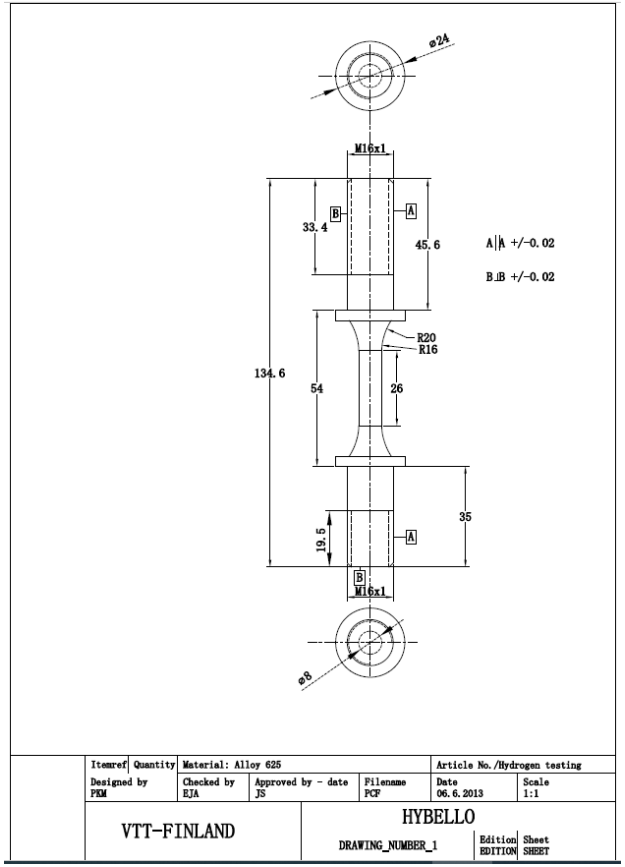
- Background
- Structure of the device
- Safety features
- Pressure adjusting loops
- PLC control
- Results
- Plans for the future

Our strategy: Materials performance in simulated extreme conditions, real failure mechanism with real stressors in real environment.

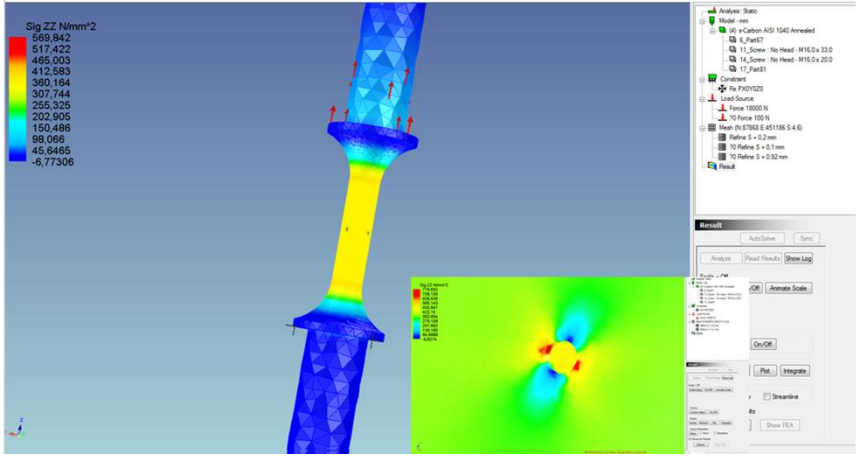
VTT Materials Performance Research Hall 1 in Espoo (altitude: -40m)

Target in EU project MATHRYCE:

Specimen:	7≤Ø≤8mm
Drilled notch:	100≤Ø≤500µm
N_f criterium:	crack a~500µm
To measure:	Δa/ΔN



- Specimen type: Drilled
- Material: 25CrMo4 QT steel
- Test type: Load controlled, R=-1
- Environment: Hydrogen gas 10-12 MPa pressure
- Frequency: 0.01 Hz, R=-1
- Temperature: at room temperature

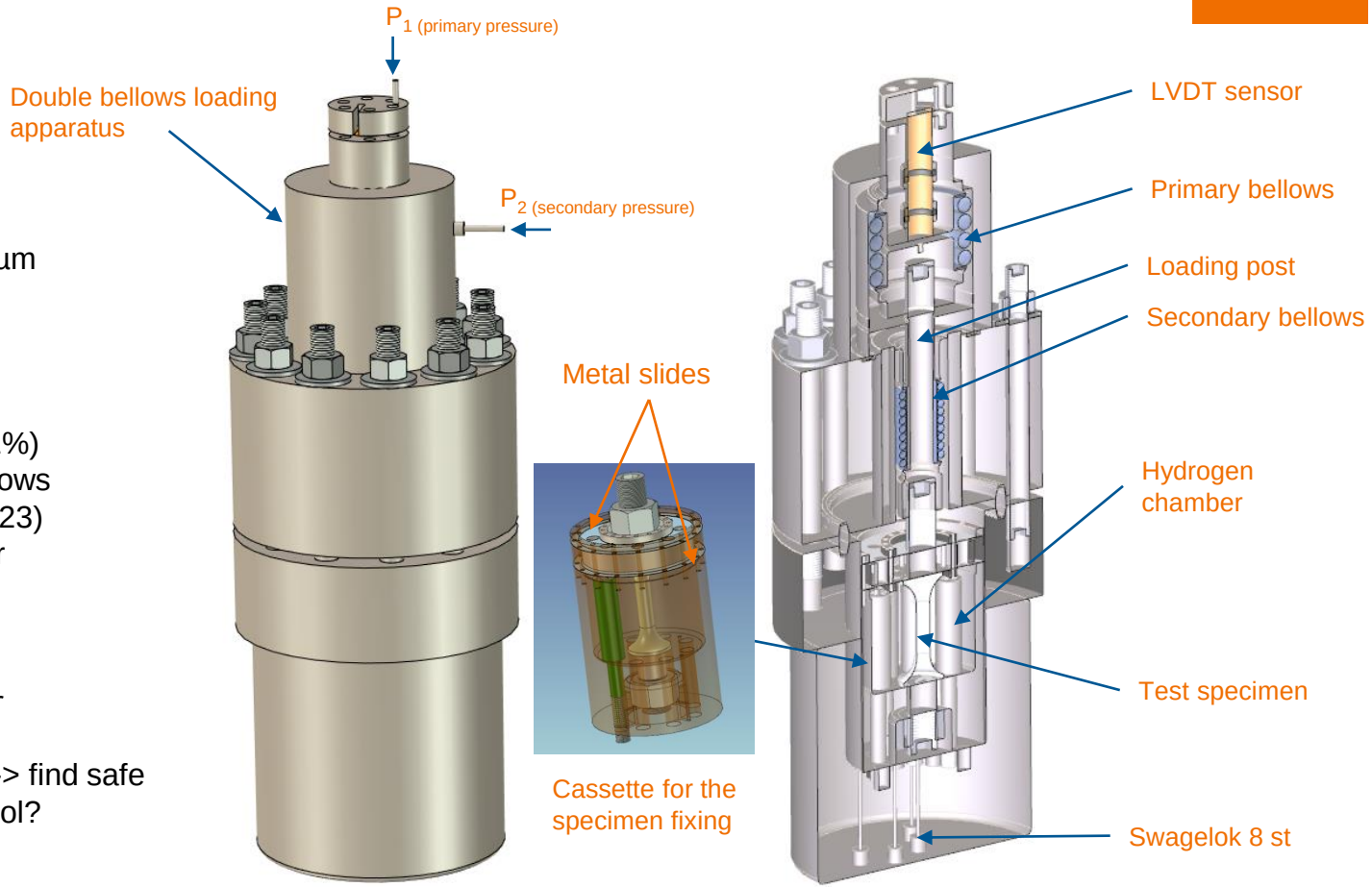


Hybello device

Target test:
Specimen: 7≤Ø≤8mm
Drilled: 100≤Ø≤500µm
Nf criterium: Crack~500µm
Instrumentation: Δa/ΔN

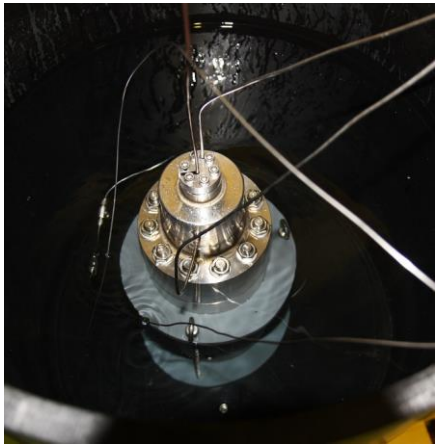
Target Equipment:
H_2: ≤350bar,≤100°C
Axial loading: ±18kN (~1%)
Internal load train: 2 bellows
Frictionless load: Δp (p123)
Medium: air, He or water
Frequency: LCF -> HCF

Safety concern:
Vessel volume: ≤0.5 liter
H_2 volume: << 0.5 liter
Infra: 220V, gas supply -> find safe place/H_2 leaks, water pool?

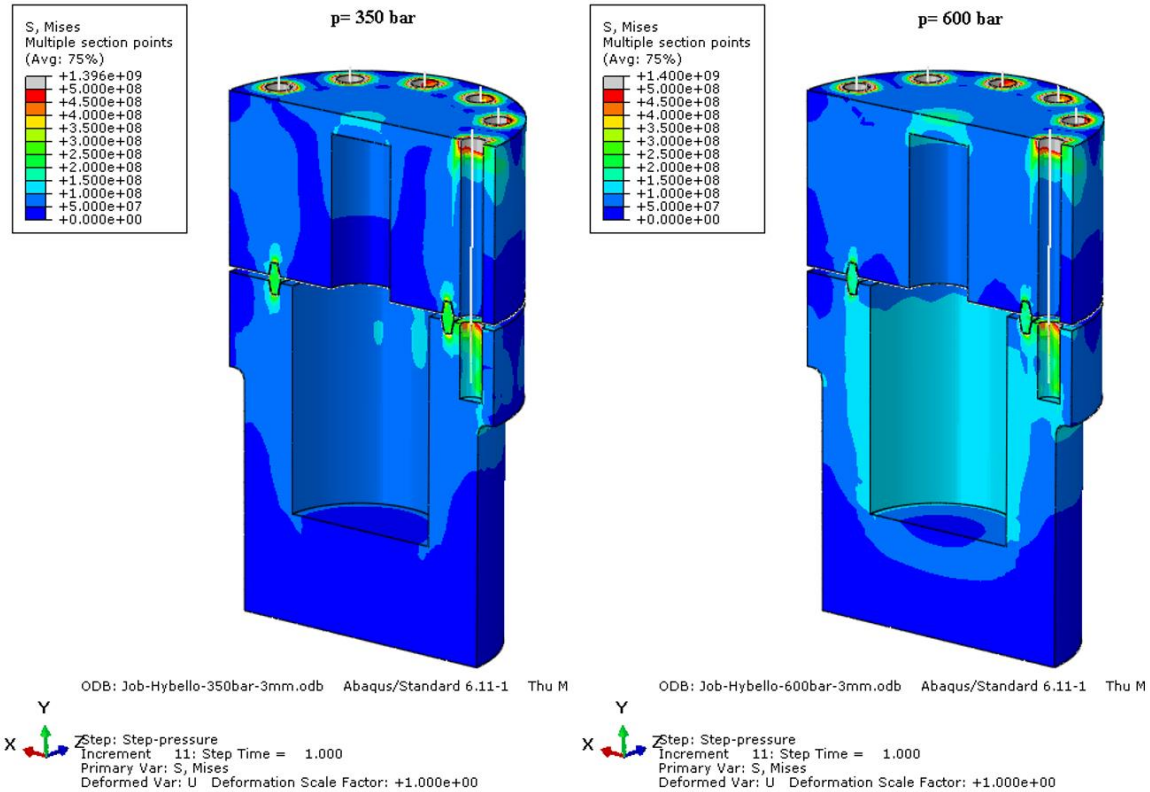


Safety concern

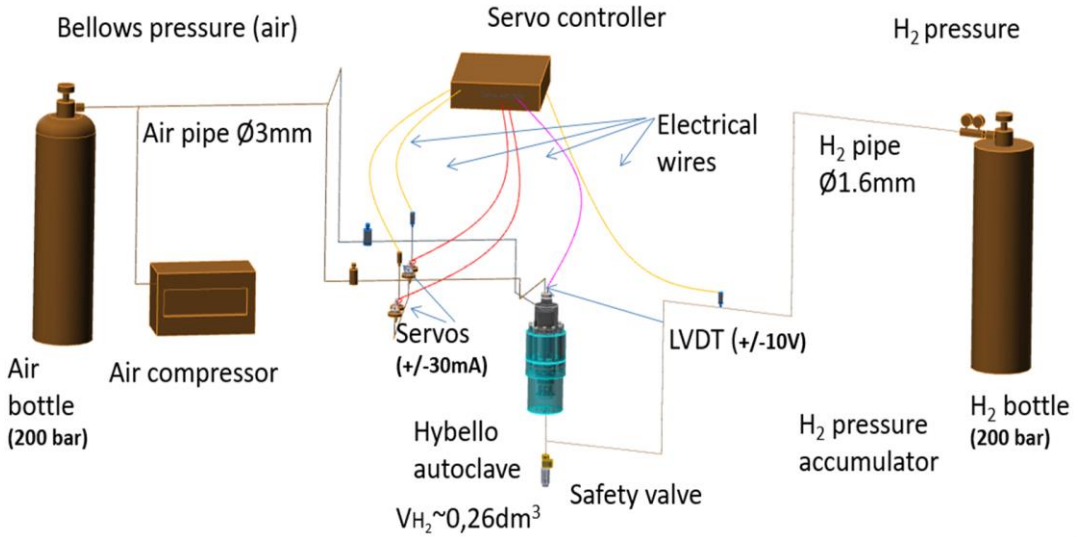
- Hydrogen volume 0.2 liter
- Up to 600 bar pressure level
- Under water tests



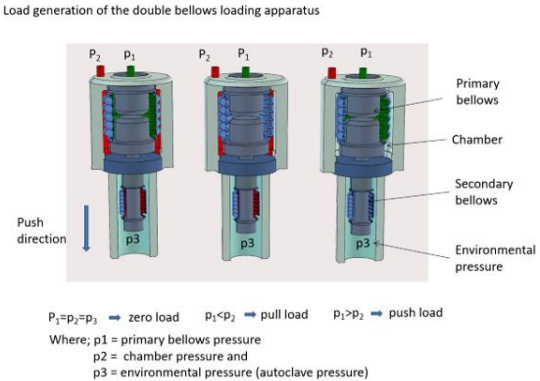
Pressurised·vessel·—·von·Mises·stress·distributions·(Pa)¶

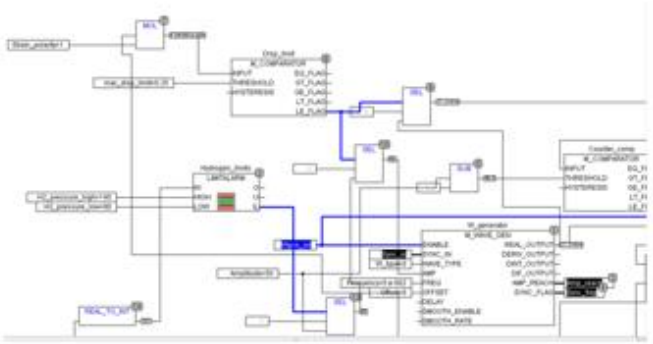


PLC Control system



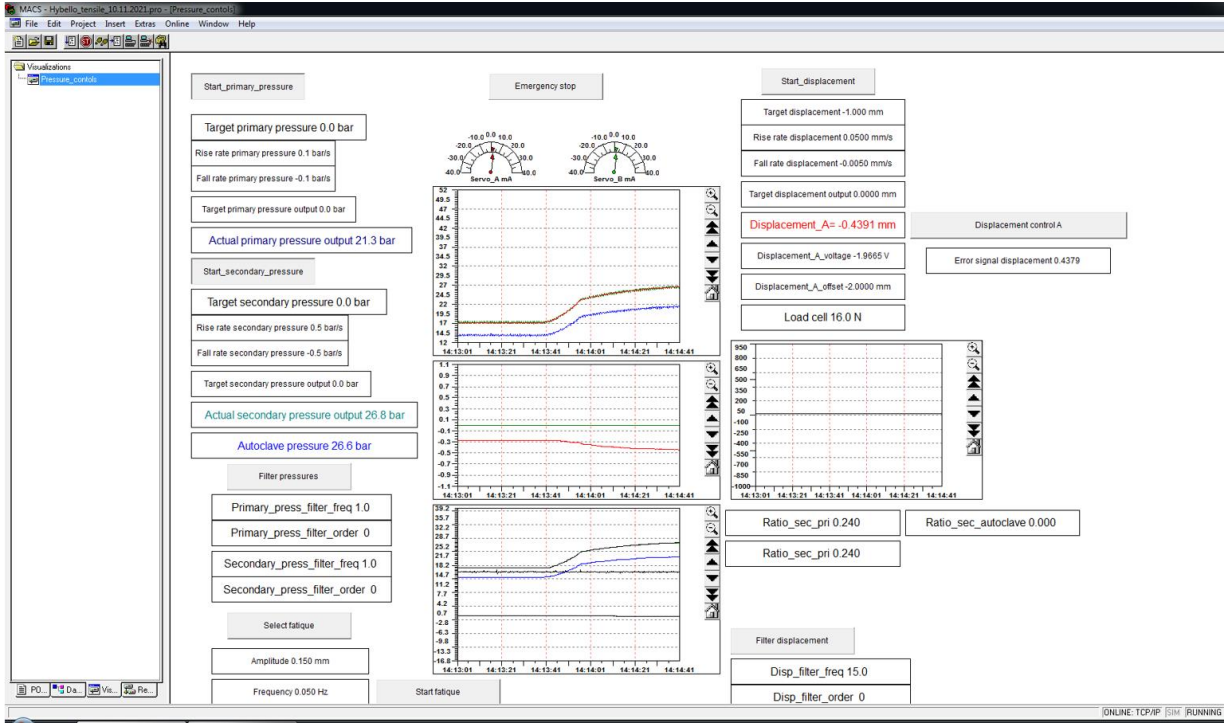
PLC control





PLC control system

- Visualization to control test parameters
- Control for the primary and secondary pressures
- Possible to create the ‘own code’ for the testing
- Ratio command
  - Master pressure -> Hydrogen pressure
  - Sleeve pressures -> primary/secondary bellows ratio
  - Pressurization of the autoclave with the zero-load level

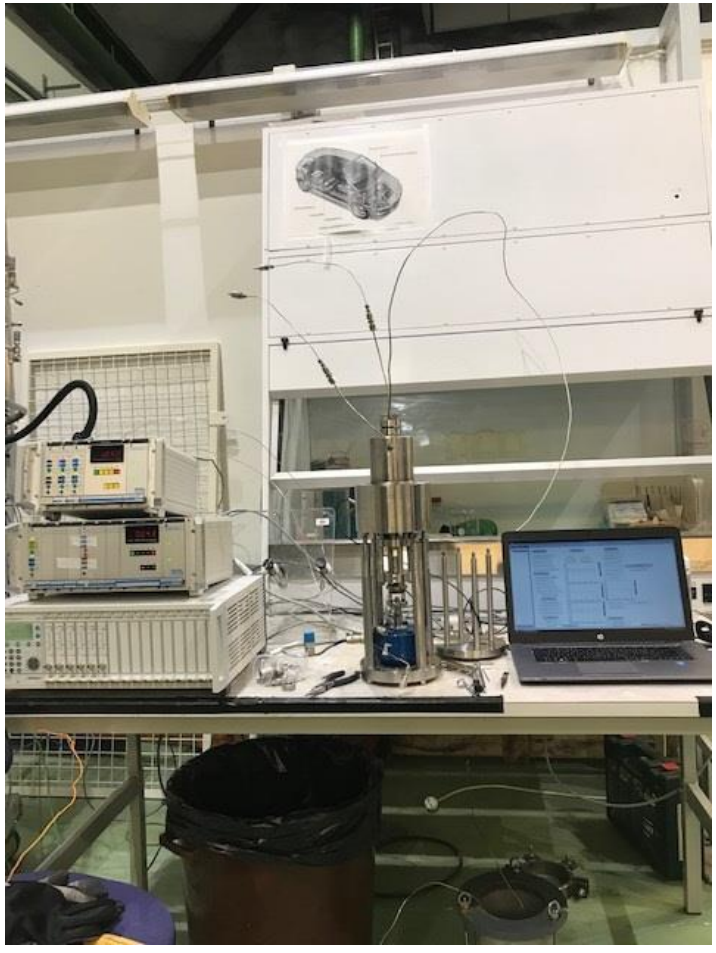


Rumul and MTS test devices

- Reference tests with MTS and Rumul
- Camera to detect the crack growth
- High frequency fatigue tests

Camera

Reference data ->
Hybello tests

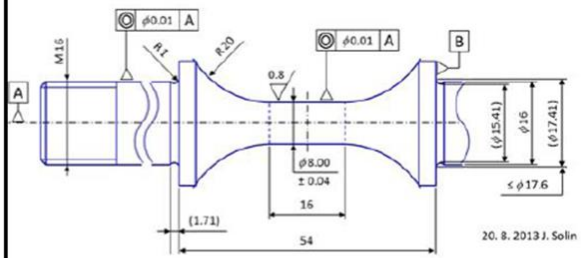


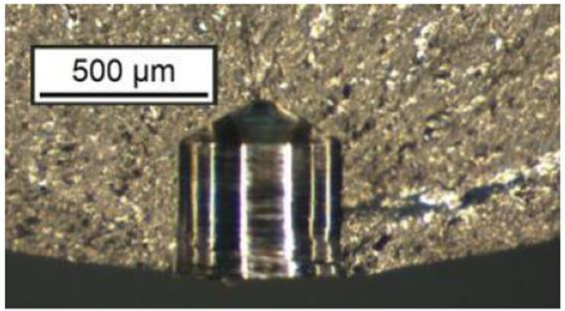
Results

Test preparation:

- Cleaning of the specimen
- The device then was closed and sealed, after which the chamber was pumped to a vacuum and then flushed with nitrogen gas twice.
- After this, the same flushing procedure was used with ultra-pure (99.99999 %) hydrogen gas.

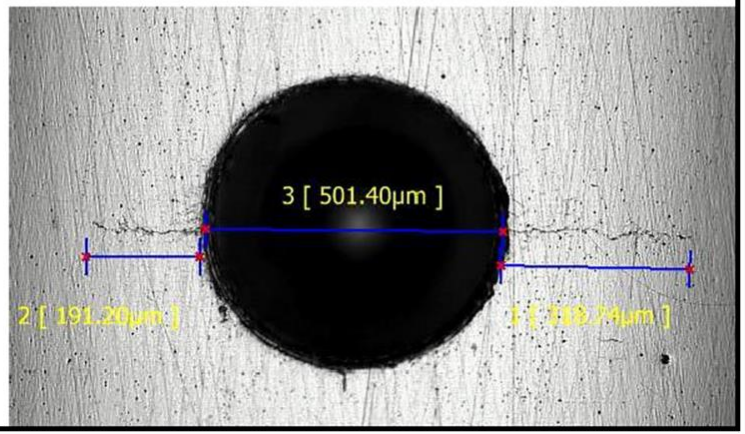
HyBello specimen



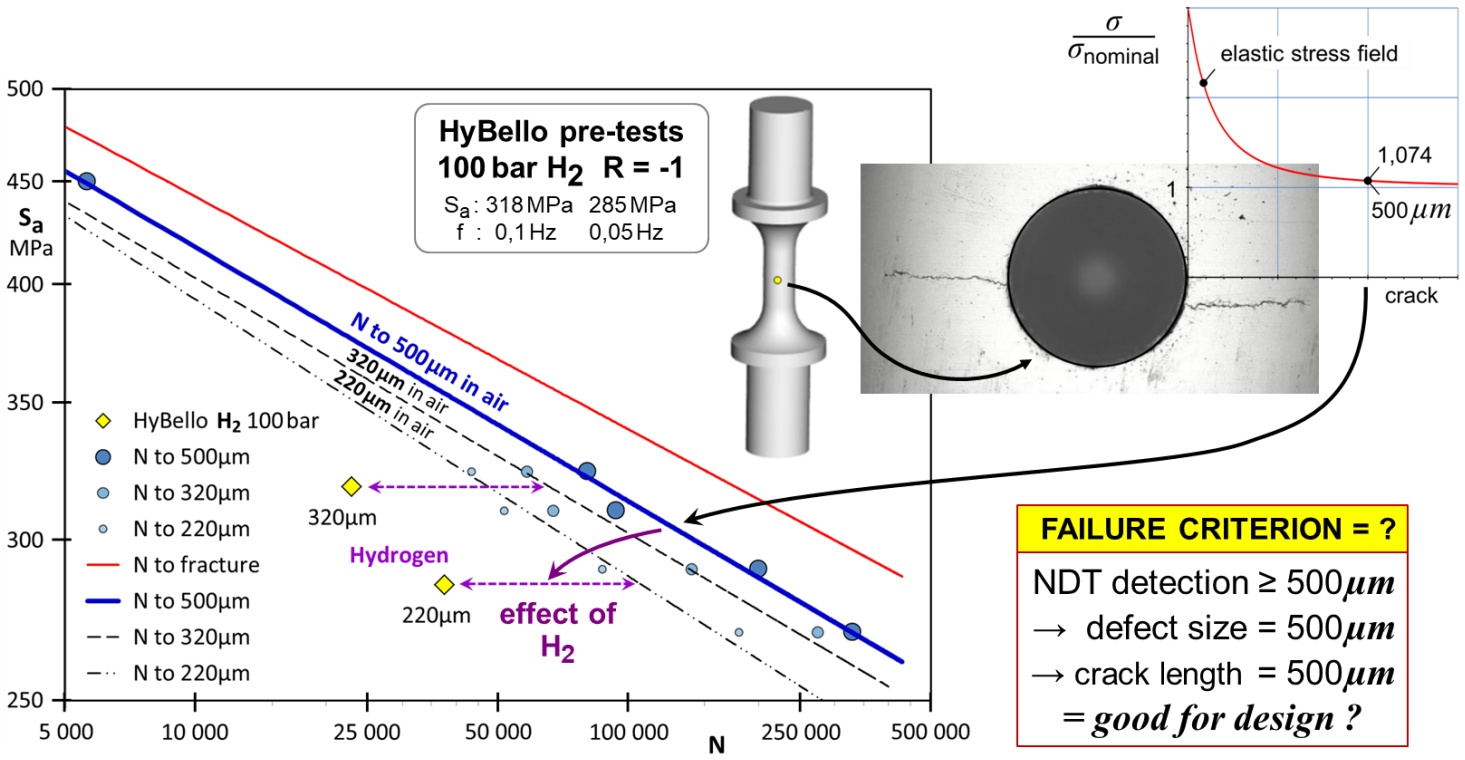


ϕ500 µm x 500 µm drilled notch in center of specimen.

190 + 500 + 320 µm crack at the drilled notch in specimen 8.1 after test in HyBello.



Results



FAILURE CRITERION = ?

NDT detection ≥ 500μm

→ defect size = 500μm

→ crack length = 500μm

= ***good for design ?***

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FATIGUE CRACK INITIATION AND PROPAGATION IN CR-MO STEEL HYDROGEN STORAGE VESSELS – RESEARCH ON DESIGN FOR SAFE LIFE

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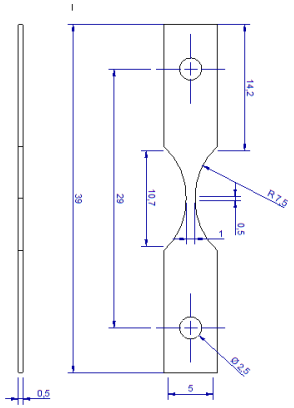
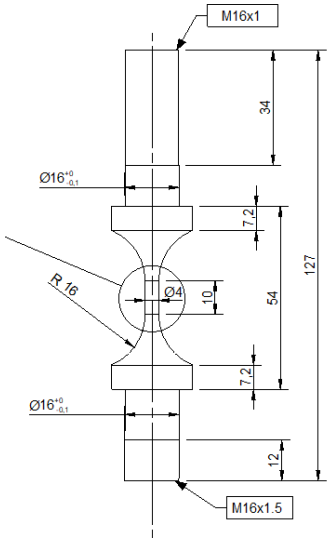
Modified Hybello 2022

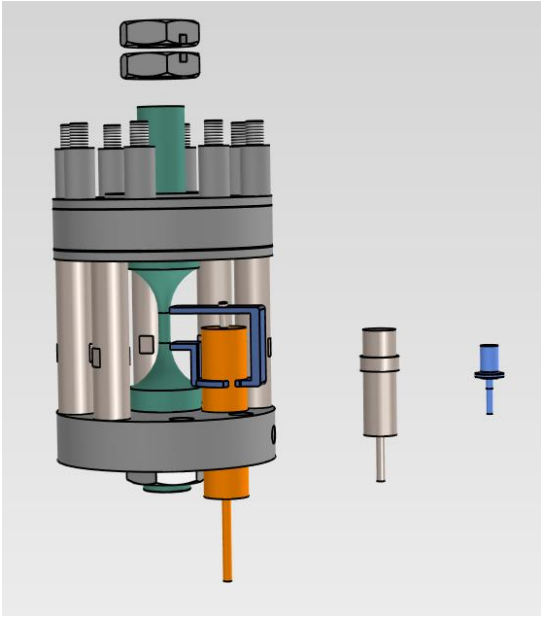
- Low cycle fatigue and tensile tests
- Avoid complex calibration system -> online load measurement system by the load cell



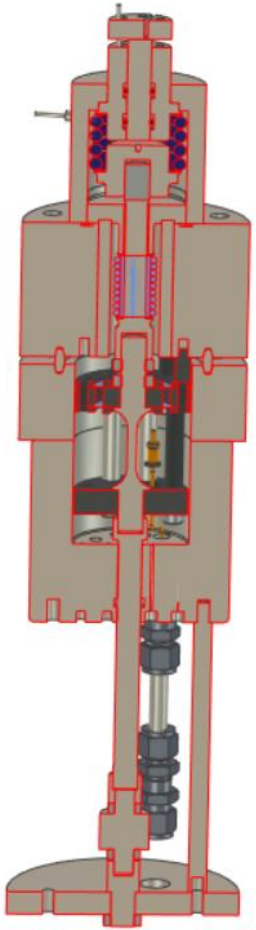
Tensile



Fatigue



Strain measurement system



Summary

- A prototype DB based pneumatically powered Hybello with a miniature sized autoclave capable of performing loading for tensile type testing in hydrogen environment has been designed, built and pre-tested.
- The accuracy of the load and pressure calibration over the tested load range (0…3000 N)) was approximately ±2.5 % from 1000 N to 3000 N load level.
- The designed pressure control program worked well during the pressurization of the autoclave (keeping automatically the test load at zero) and during the test. The measured load and displacement accuracy was ± 1% from the measured value.
- The material selected for the gaseous hydrogen environment tests was 25CrMo4 QT steel, which was tested at 23°C and 10-13 MPa hydrogen pressure level(s). The specimen type was Φ8 mm fatigue pre-holed specimen and a Φ6 mm notched fatigue specimen.
- The effect of the hydrogen atmosphere was measured in the initiation and crack growth from small holes and notches. The acceleration caused by the hydrogen atmosphere was observed clearly when compared to tests performed in air as shown.
- The purpose of the modified device is to perform strain-controlled experiments.