Analysis of Hydrogen induced Failure in Tensile Tests

T. Schaffner[1], A. Hartmaier[2], T. Pretorius[1]
1. thyssenkrupp Steel Europe AG, Kaiser-Wilhelm-Str. 100, 47166 Duisburg, Germany
2. Ruhr-Universität Bochum, Universitätsstraße 90a, 44789 Bochum, Germany

Introduction: Hydrogen embrittlement is a major challenge for the development of advanced high strength steel concepts. To ensure their safe use the hydrogen induced material behavior needs to be defined. In this work, the influence of various hydrogen concentrations on specific tensile tests of a martensitic steel grade is analyzed.

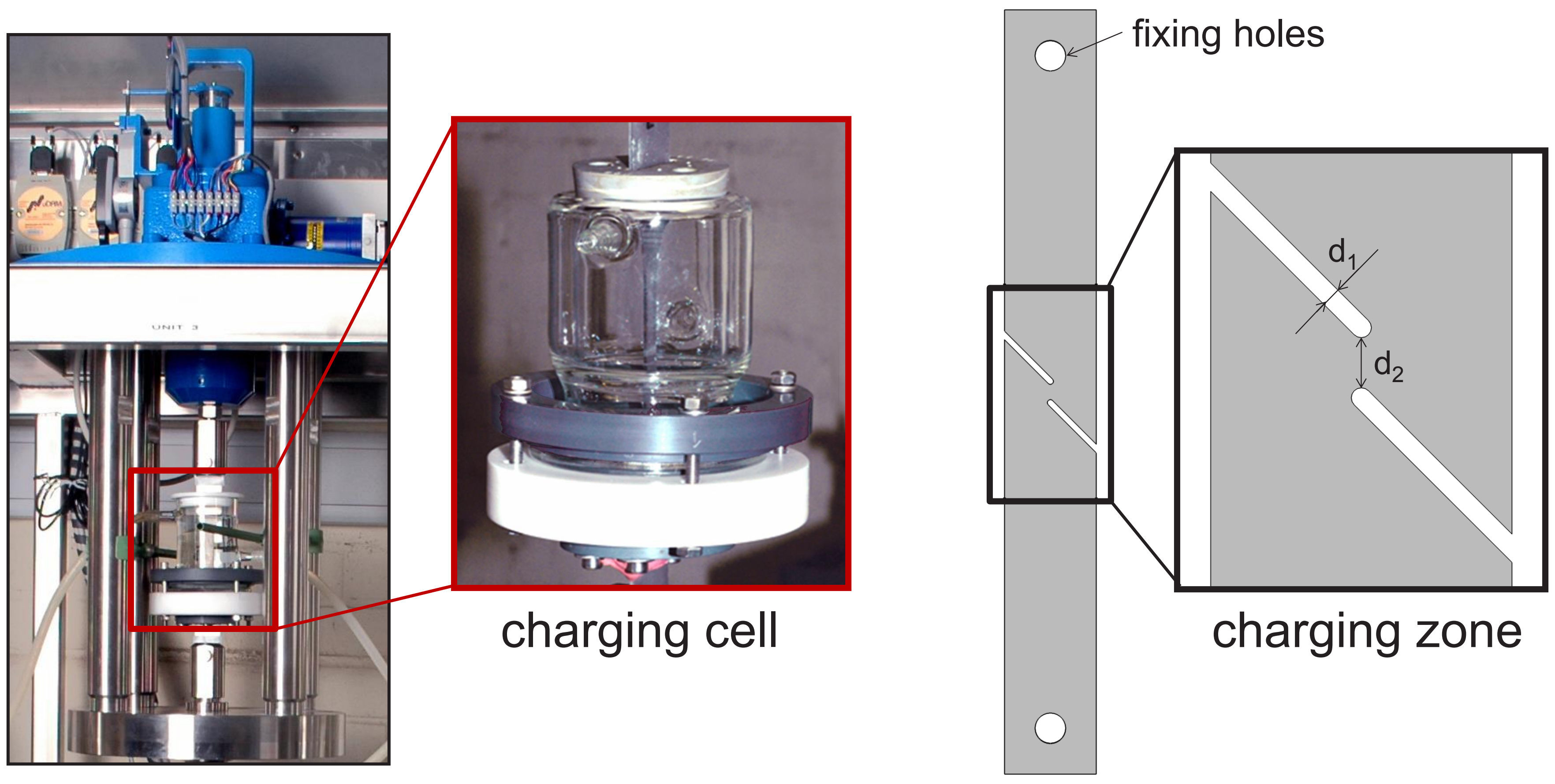

Figure 1. Test setup (left) and specimen geometry (right)

Computational Methods: The simulation is based on a 3D *Solid Mechanics* model assuming isotropic behavior of the material properties (elasticity, plasticity and hardening). The hydrogen transport was implemented and calculated according to *General Form PDE* [1/2/3].

$$\left(1+\frac{\partial c_T}{\partial c_L}\right)\frac{\partial c_L}{\partial t}-\nabla\cdot\left(D_{eff}\nabla c_L\right)+\nabla\left(\frac{D_{eff}c_L V_H}{RT}\nabla\sigma_h\right)=0$$

Time dependent approach gives information about the change in hydrogen distribution and allows analysis of fracture areas.

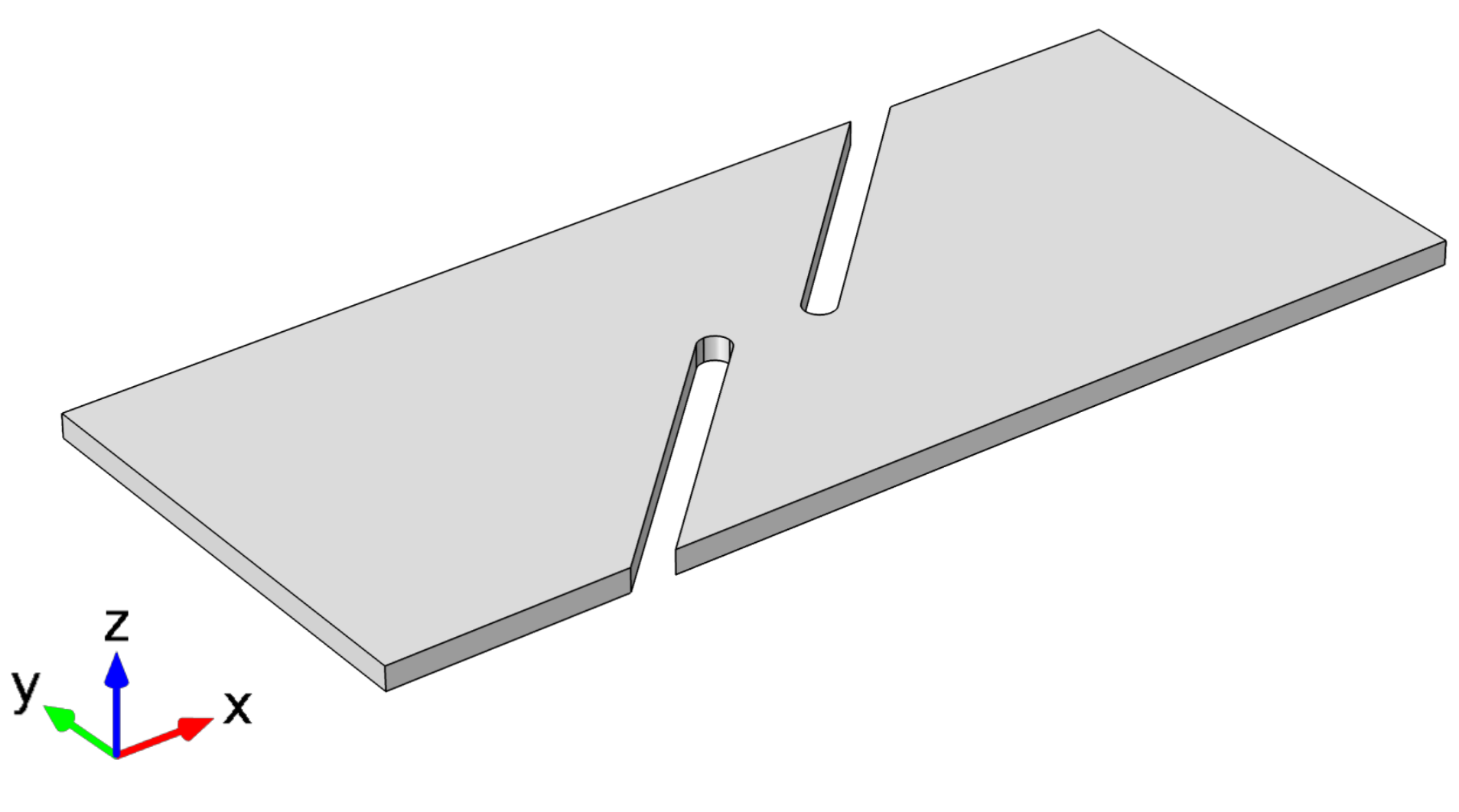

Figure 2. Simulation domain

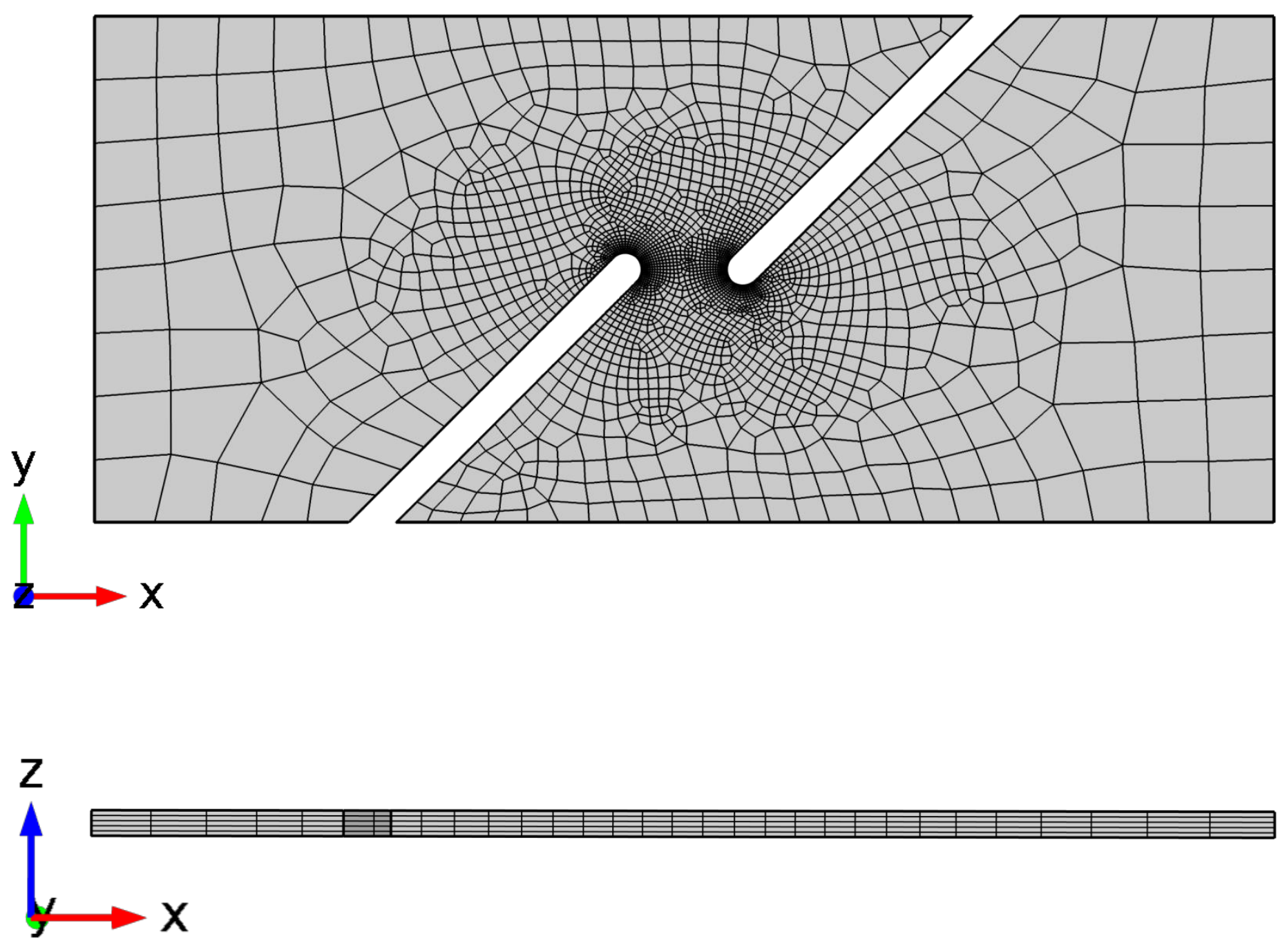

Figure 3. Simulation mesh

Property	Symbol	Value
Young´s modulus	E	200 GPa
Poisson´s ratio	ν	0.3
Density	ρ	7850 kg/m^3
Yield strength	R_p	1090 MPa
Tensile strength	R_m	1250 MPa
Uniform elongation	A_g	3.3
Fracture elongation	A	6.5
Effective diffusivity	D_{eff}	$4.5 \cdot 10^{-11}$ m²/s
Notch distance	d_1	5 mm
Notch width	d_2	2 mm

Table 1. Material properties

Results: The fracture behavior was influenced by the local hydrogen content. Comparing the experimental and simulated results, the change of the fracture position could be estimated and visualized.

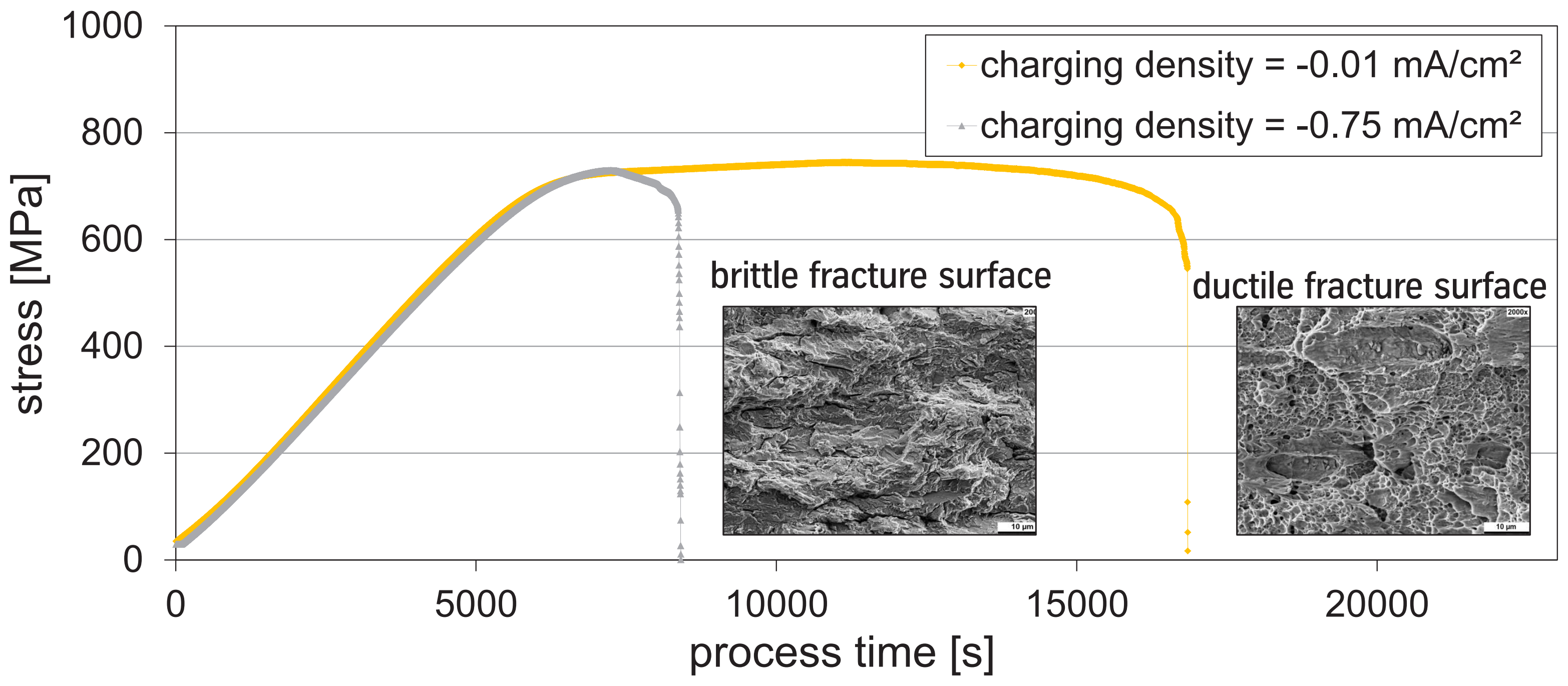

Figure 4. Stress curves for different charging densities

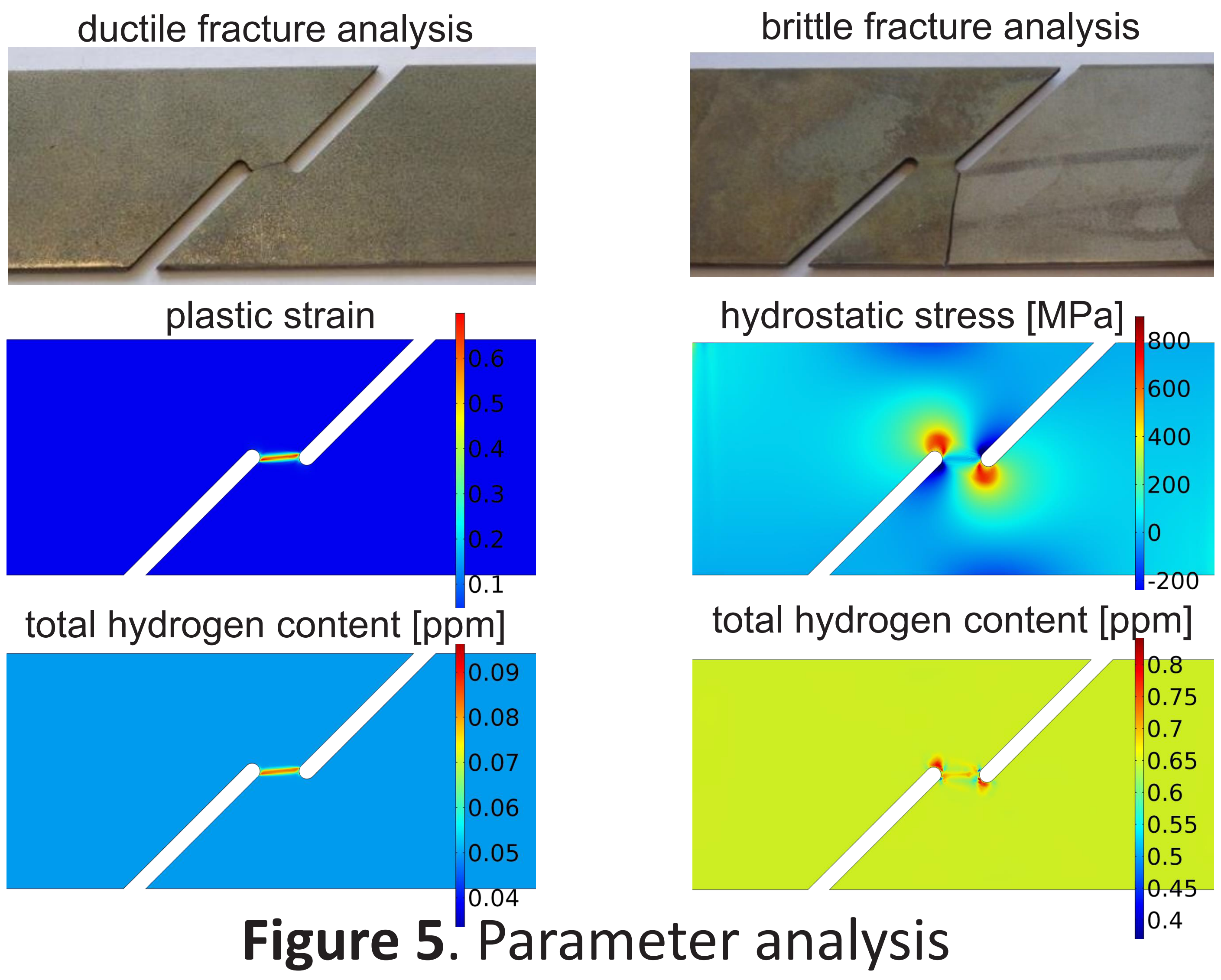

Figure 5. Parameter analysis

Conclusions: Simulations of hydrogen transport in dynamic processes clarify hydrogen induced fracture. The critical component areas can be localized only if all crucial parameters are taken into account: stress level, plastic strain and local hydrogen concentration. The prediction of a material failure criterion with respect to the hydrogen concentration will be investigated in further studies.

References:

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