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INSTITUT
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A new model for radial hydride precipitation in Zircaloy-4 claddings under decaying stress and temperature transient

J.Desquines, D. Drouan, M. Philippe

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Introduction

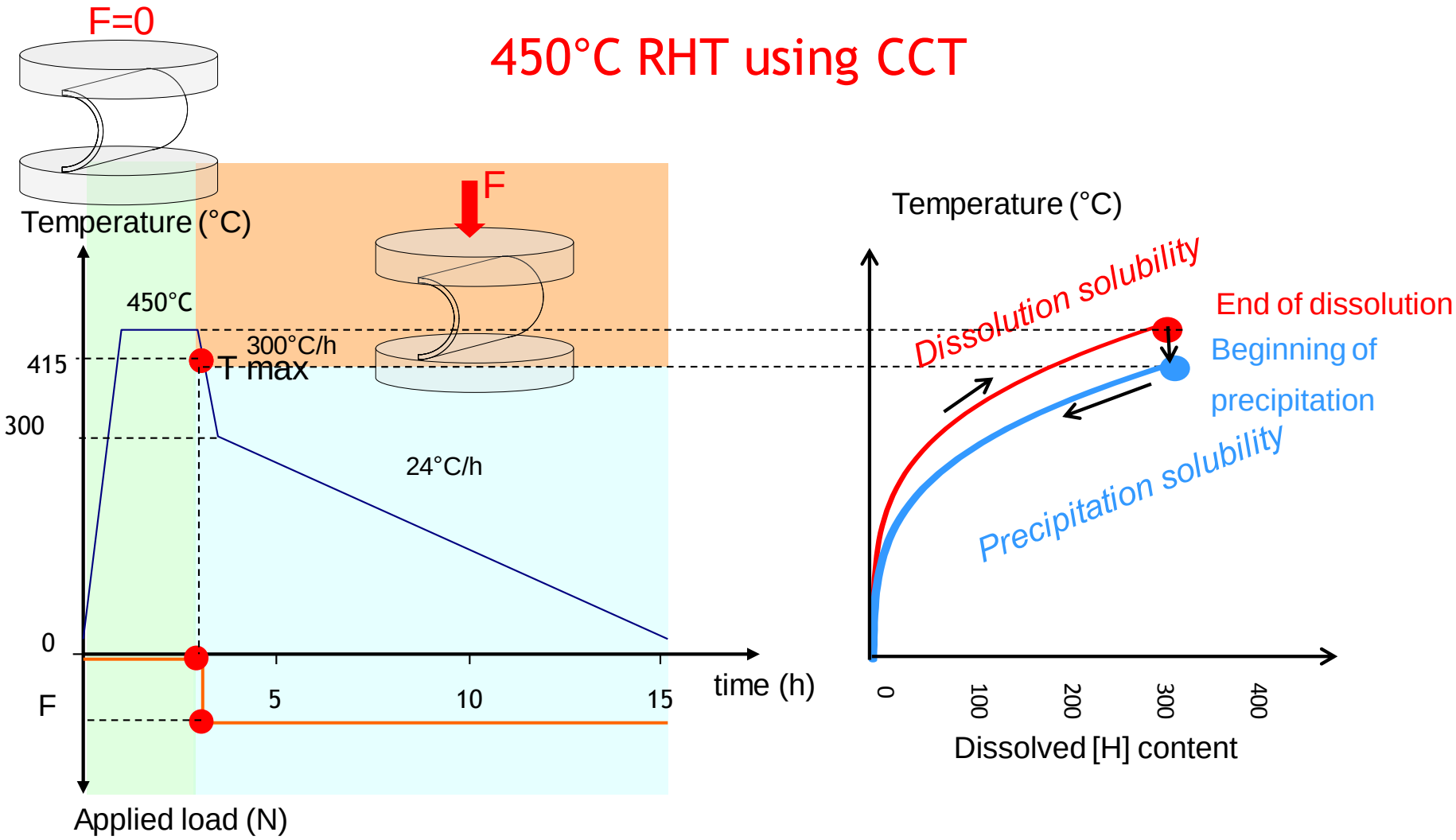
Post-test radial hydride precipitation under constant applied stress is first described and modeled.

A simple strategy to transform this model into a transient radial hydride precipitation model.

Preliminary validation tests are compared to model predictions.

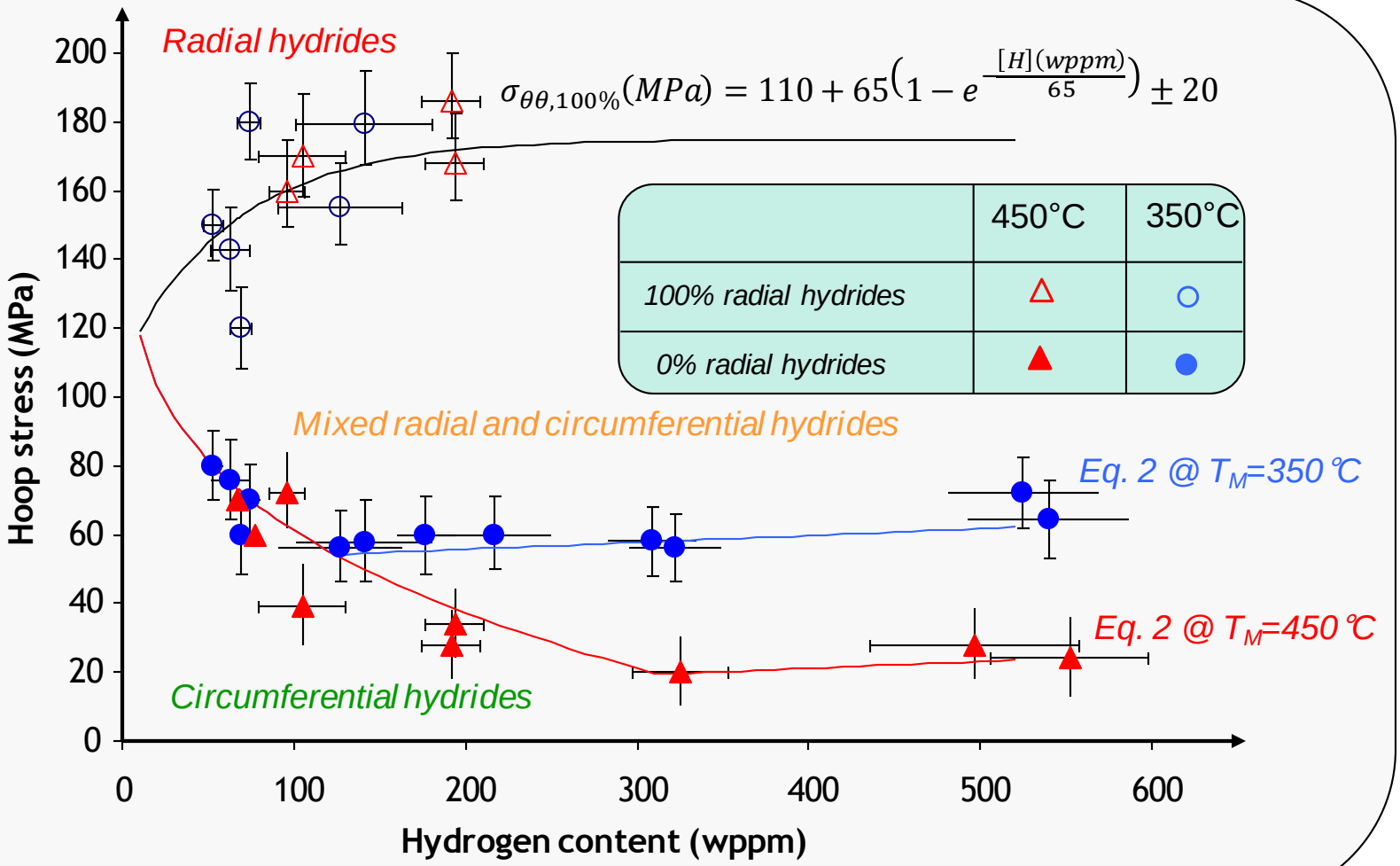
Key results relying on « C »-Shaped Compression Tests (CCT)

450°C RHT using CCT



Post-test metallography provides thresholds for incipient radial hydride precipitation and 100% radial hydride precipitation after the thermal transient.

Experimental results at Tmax=350°C and 450°C



$$\sigma_{\theta\theta,0\%}(MPa) = 0.0200[H](wppm) + 0.3862Min[T_M(°C); T_{SSD}(°C)] + 186.9 \quad \text{(Eq.2)}$$

Linear interpolation to determine the post-test radial hydride fraction ?

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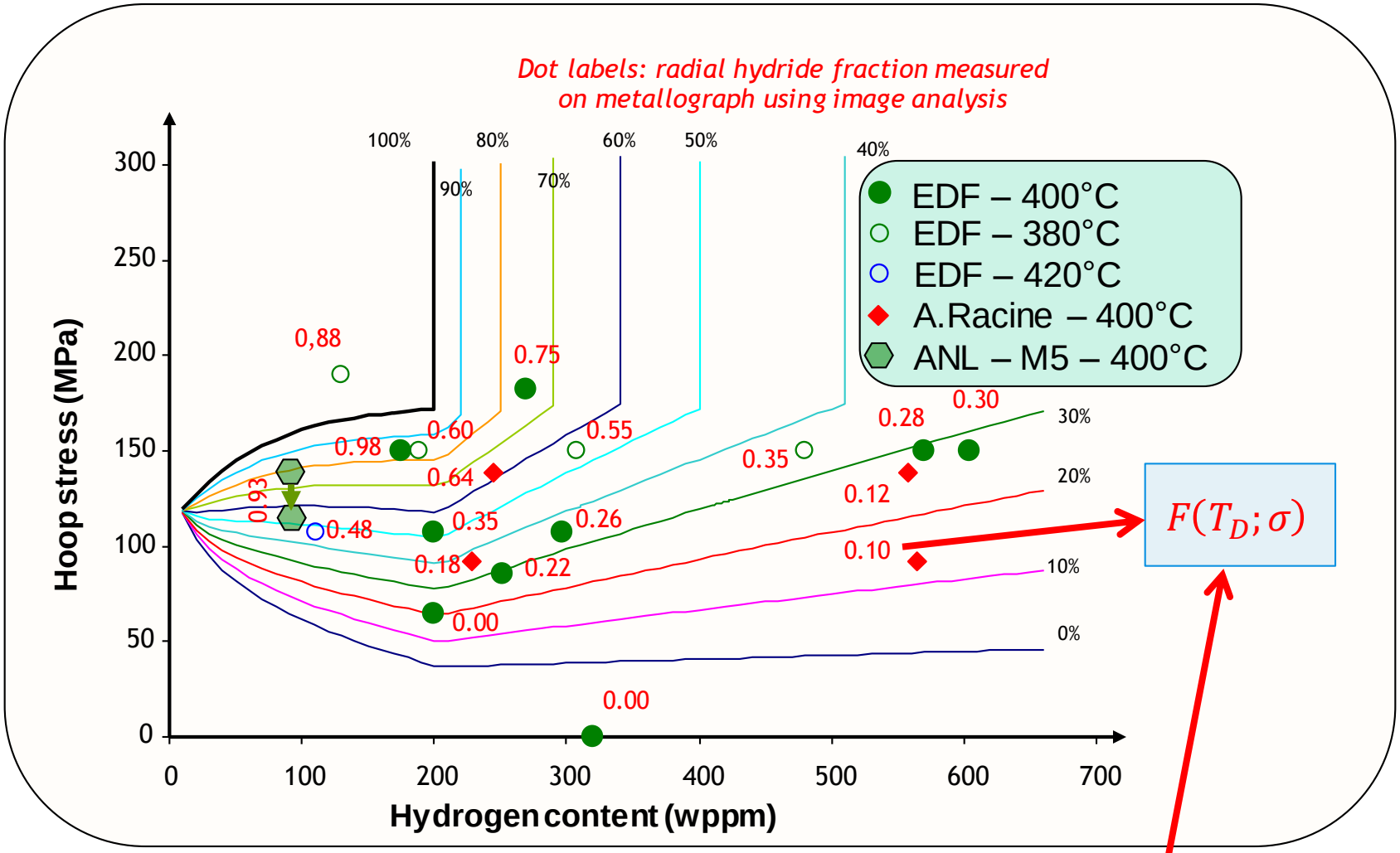
Post-test Radial hydride fraction using linear interpolation



Linear interpolation provides a good assessment of post-test radial hydride fraction

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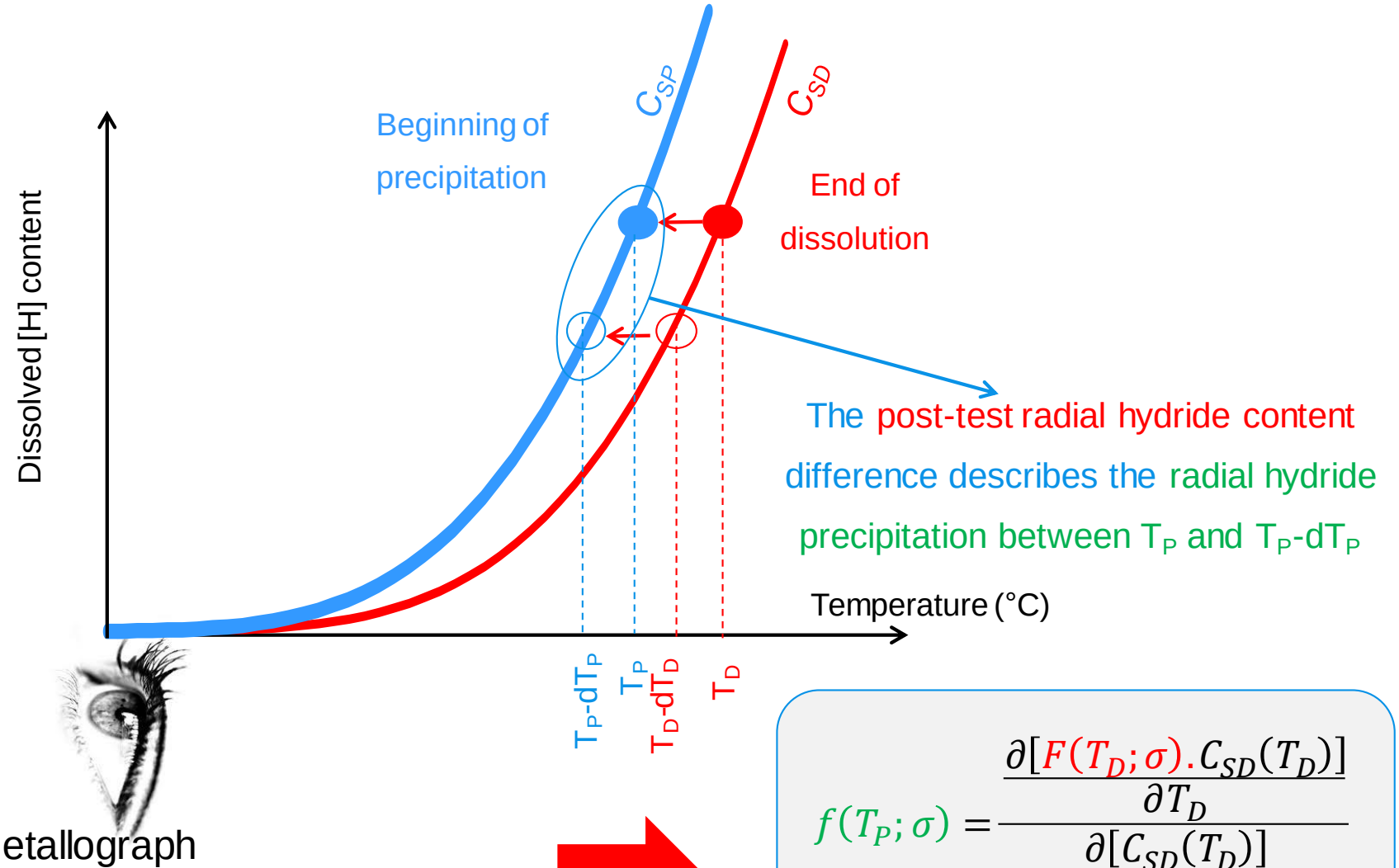
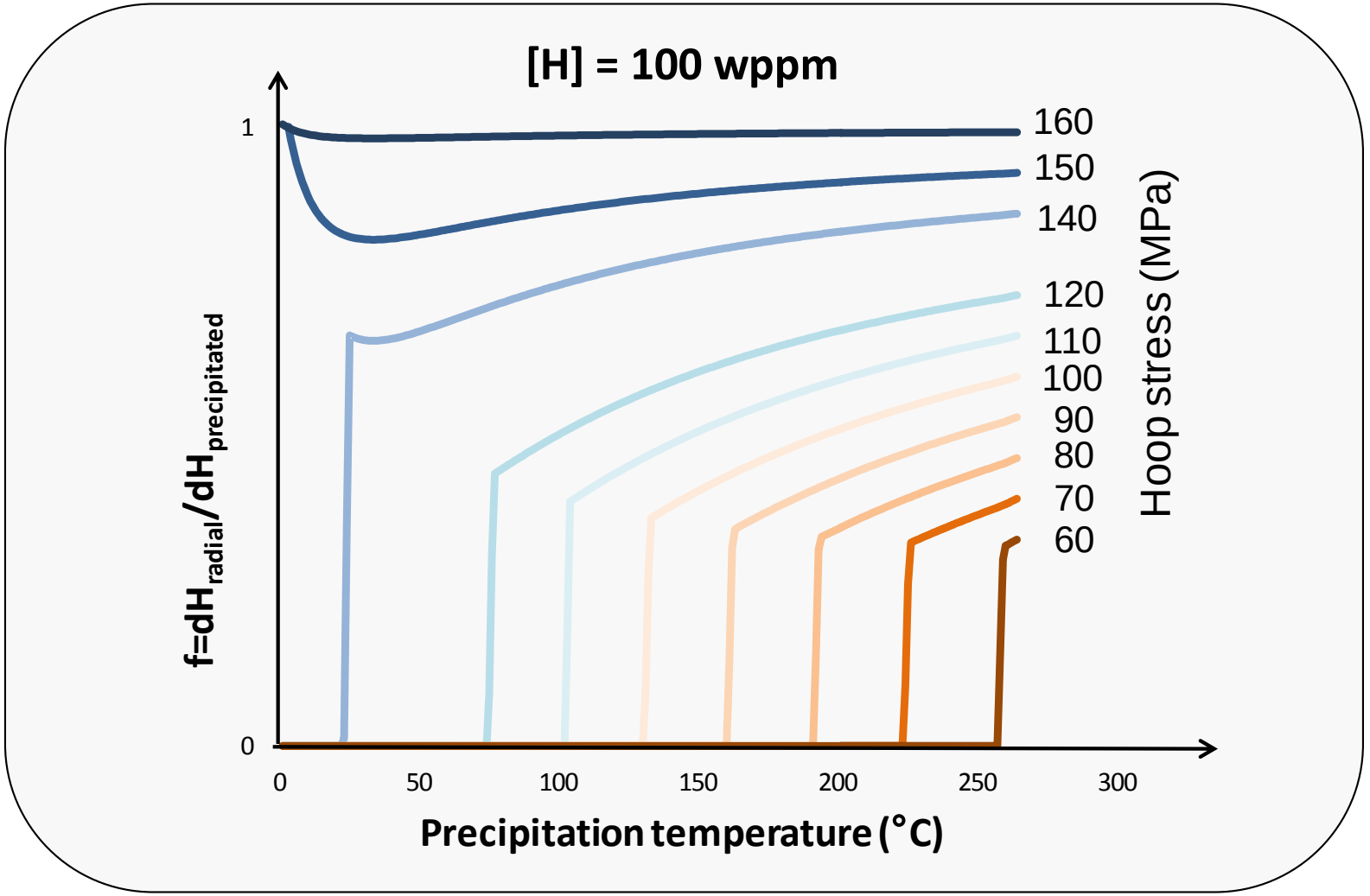
Basic considerations to determine the transient radial hydride precipitation

Determination of the transient radial hydride precipitation



$$f(T_P;\sigma) = \frac{\frac{\partial[F(T_D;\sigma).C_{SD}(T_D)]}{\partial T_D}}{\frac{\partial[C_{SD}(T_D)]}{\partial T_D}}$$

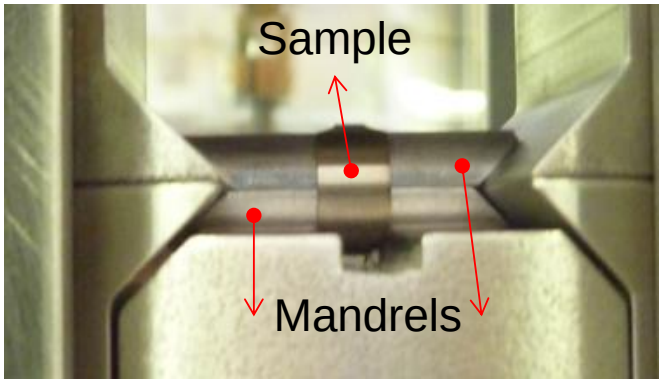
Illustration of the transient radial hydride precipitation



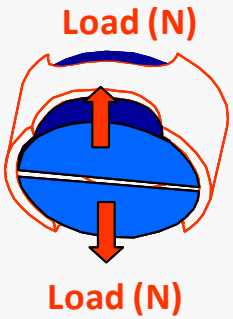
An assessment of the transient radial hydride precipitated fraction can be simply derived from post-test examinations

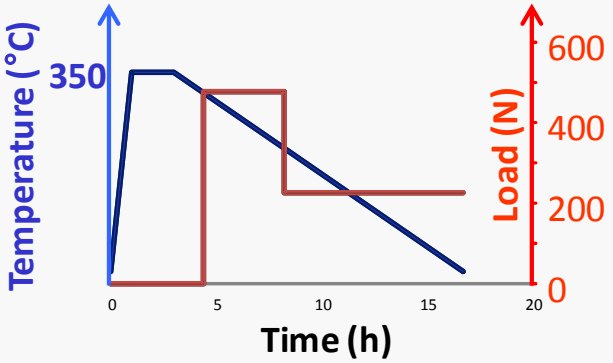
Experimental characterization of the transient radial hydride precipitation

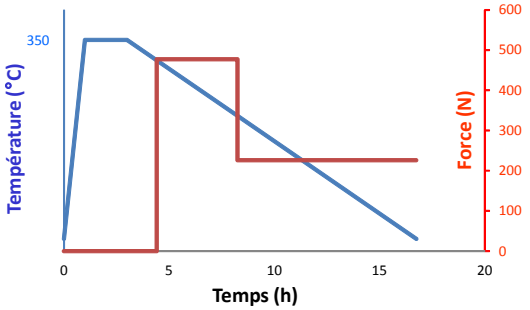
Ring tensile testing with decreasing load



Thermal-mechanical transient

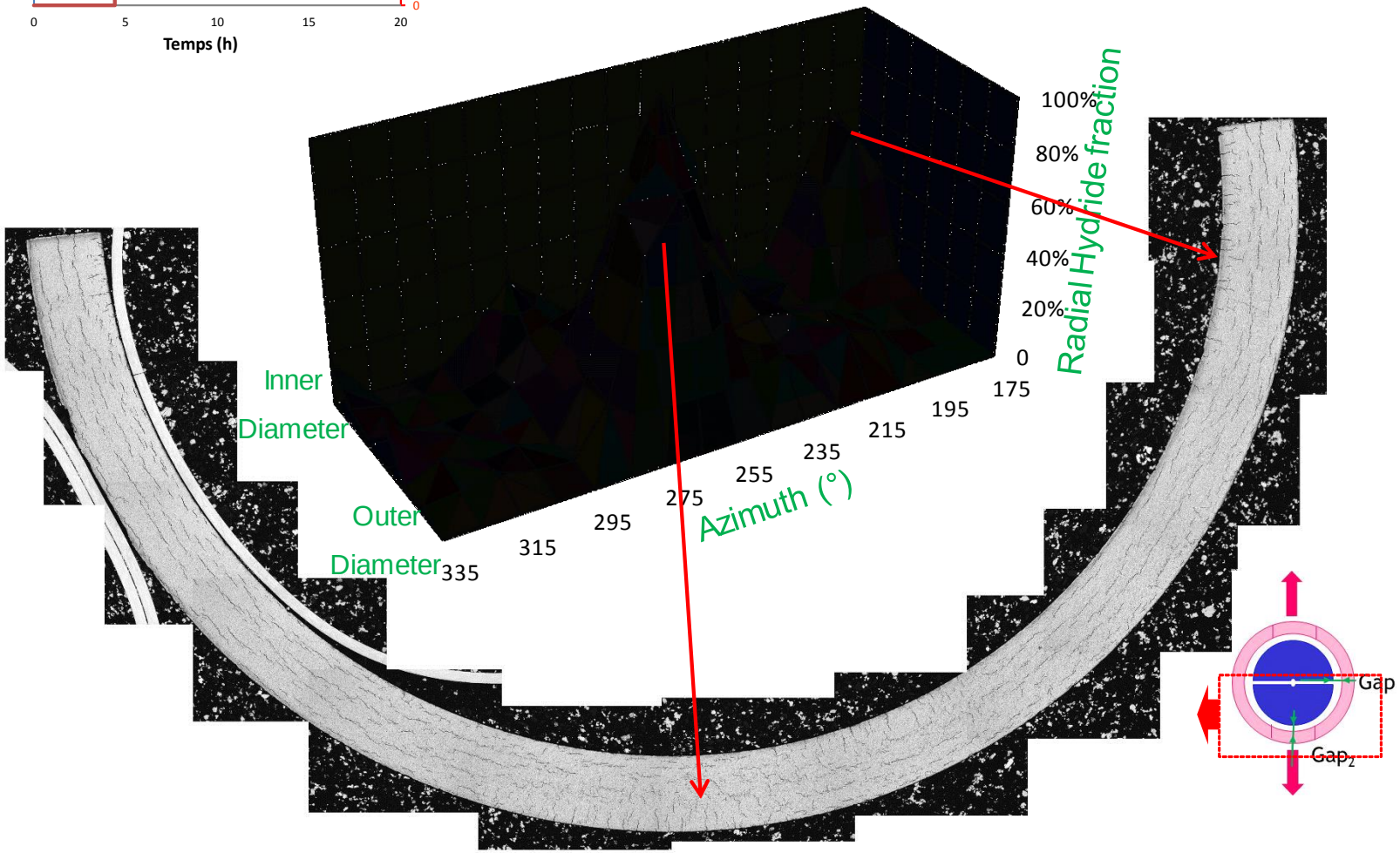






Post-test metallograph

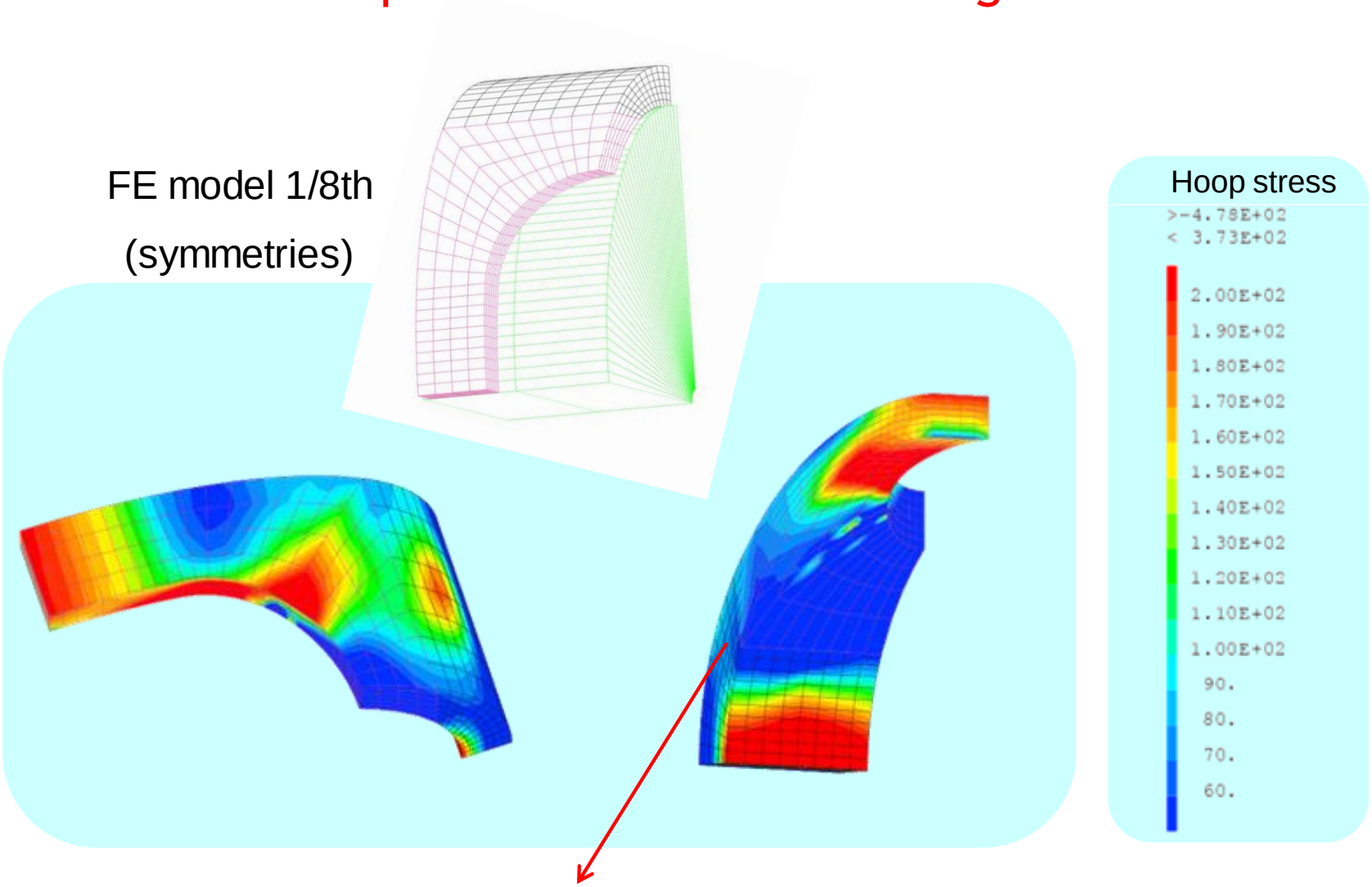
Sample	Gap_2 (µm)	Gap (µm)
RST-10	6	3



3D hoop stress calculation during the transient

FE model 1/8th

(symmetries)



The stress is extracted along this surface at any time step of the transient

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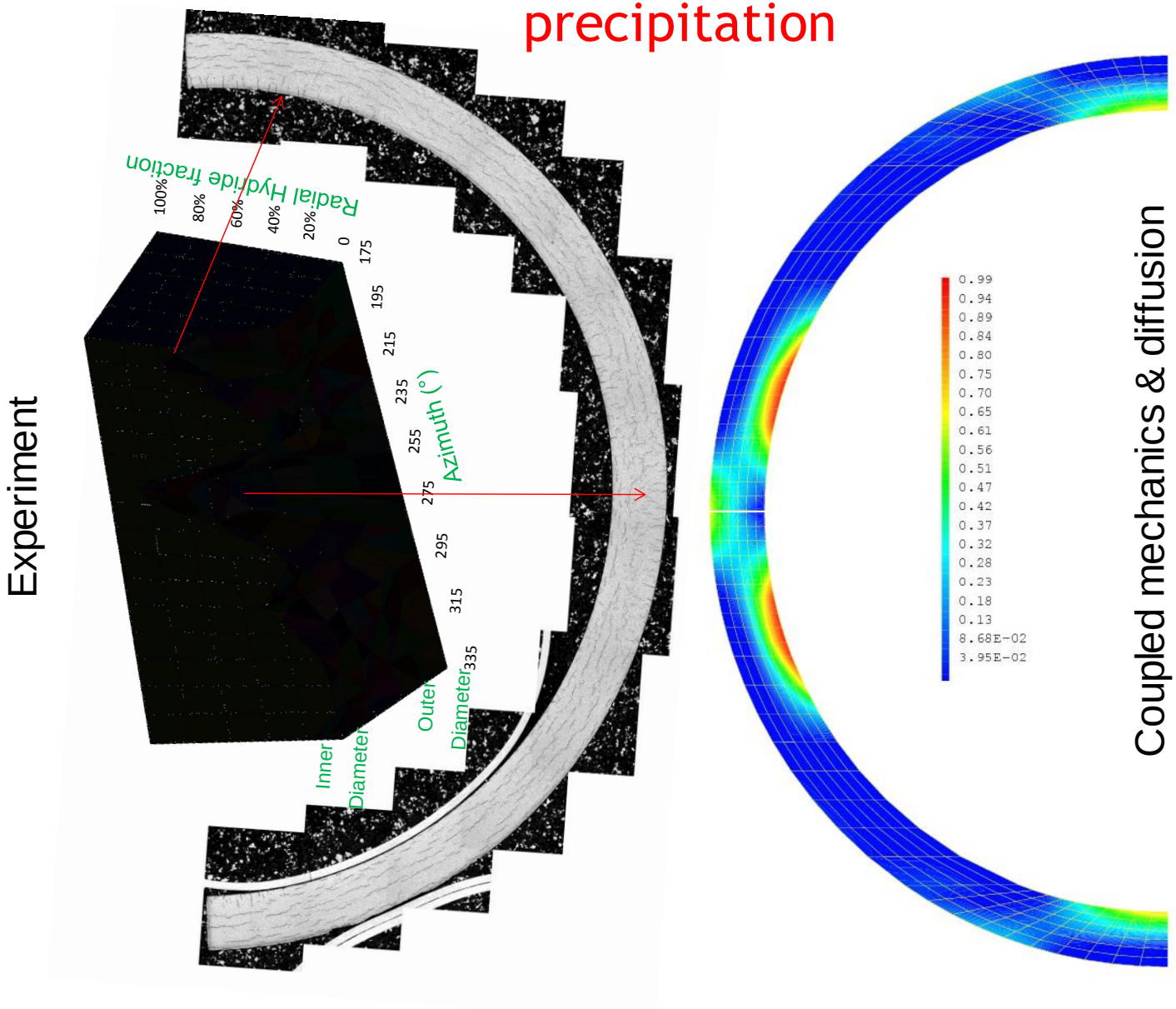
2D simulation of diffusion and transient radial hydride precipitation



Conclusions

A new model applicable to decreasing stress and temperature transient was developed relying on post-test examinations of radial hydride precipitation tests under temporarily constant stress.

Some validation tests with decreasing stress were performed using ring tensile tests.

The modeling provides acceptable results when compared to experimental data.

However a strong sensitivity to the mandrel sample gap was evidenced using coupled mechanical & diffusion simulations.

A better controlled stress level is required to achieve full validation of the proposed model.