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Karlsruher Institut für Technologie

22-27 September 2019 Budapest, Hungary ISFNT14

EUROfusion

Experimental determination of hydrogen transport parameters of 316L steel in the two-side purge permeation setup Q-PETE

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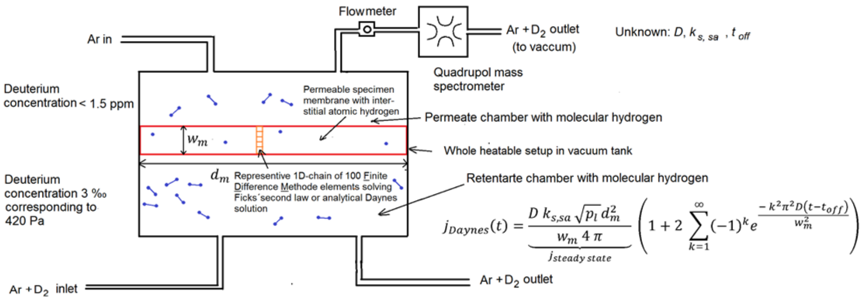
The Q-PETE (Hydrogen Permeation and Transport Experiment) at KIT has been build as a model experiment for Tritium transport in a future fusion power plant. This experiment will investigate the hydrogen isotopes permeation through structural materials with specific relevance to the HCPB (helium cooled pebble bed) DEMO blanket breeder zone. The experimental setup consists of two purged chambers separated by a permeation membrane (later made of Eurofer, currently 1.4404 or 316L has been investigated). The permeated hydrogen is detected (time resolved) in an Argon transport gas with a mass spectrometer. Central objective is the direct determination of material data. The determination of permeation parameters like diffusivity and Sieverts' constants is usually performed by modelling experimental results with a solution of a differential equation, 2nd Fick´s law applied to a flat membrane. Mostly permeation disk experiments (without purge, measuring the pressure rise) were performed in the past assuming a vanishing hydrogen concentration in the permeate chamber. An analytical solution exists under this condition. It can partially improved using the interstitial atomic hydrogen state in contrast to the bi-atomic molecular gaseous phase in the permeate chamber, where it is "detected". Emanation of any hydrogen isotope into a hydrogen containing volume (generating rediffusion) can be at the moment only numerically considered. This contribution shows a first experimental result of the Q-PETE experiment.



$$j_{Daynes}(t) = \underbrace{\frac{D\,k_{s,sa}\sqrt{p_l}\,d_m^2}{w_m\,4\pi}}_{j_{steady\,state}} \left(1 + 2\sum_{k=1}^{\infty}(-1)^k e^{\frac{-k^2\pi^2 D(t-t_{off})}{w_m^2}}\right)$$

Fig. 1: Principle sketch of the Q-PETE experiment: A specimen separates a volume in a retentarte and a permeate chamber. A hydrogen isotopes diffuses through the specimen and increases the hydrogen content in the permeate chamber. New is the decrease of the "loading" pressure in the retentarte chamber to 420 Pa, range of former experiments between 10^4 to $1.5\ 10^5$.

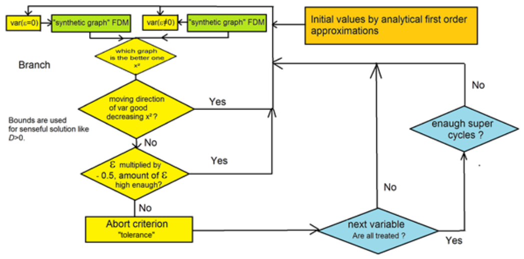


Fig. 2: The analytical Daynes permeation equation is a nonlinear transcendent equation with three variables and also the same by numerical FDM solution. But the solution of the inverse problem is necessary: The way back from a measured graph to the desired parameter by B&B branch and bound algorithm.

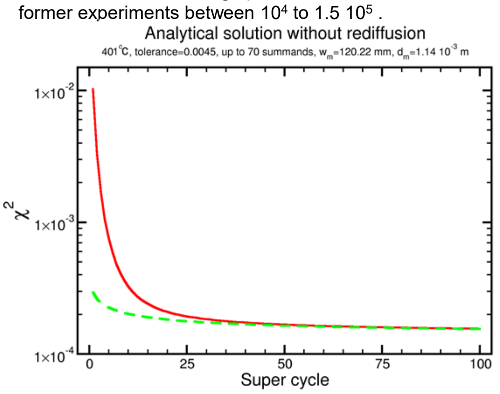


Fig. 3: Relative Standard Deviation graph during fitting process according Fig.2.

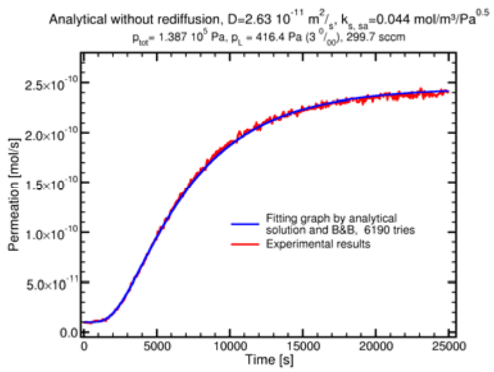


Fig. 4: Experimental result and fitting graph for the analytical „Daynes" solution. Results are compared in Fig. 5 and Fig 8

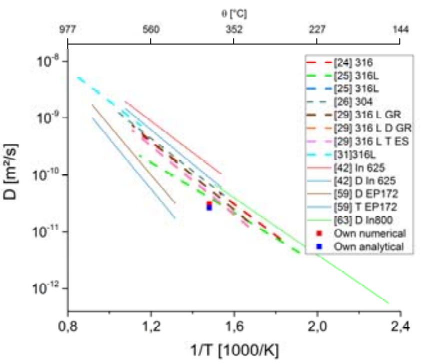


Fig. 5: Comparison of results accor-ding report F. Arbeiter et al. Development of Tri. Tran. Mod. at BU level for HCPB Karlsruhe 2016.

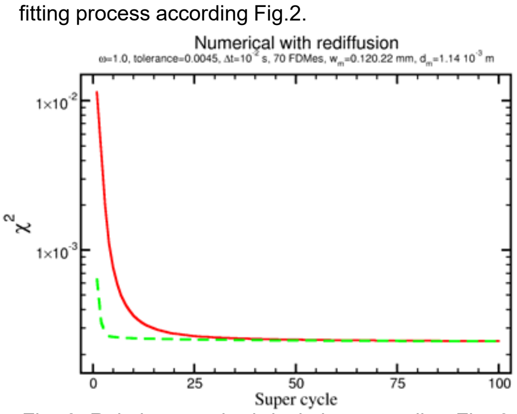


Fig. 6: Relative standard deviation according Fig. 3, here using the FDM based model with rediffusion.

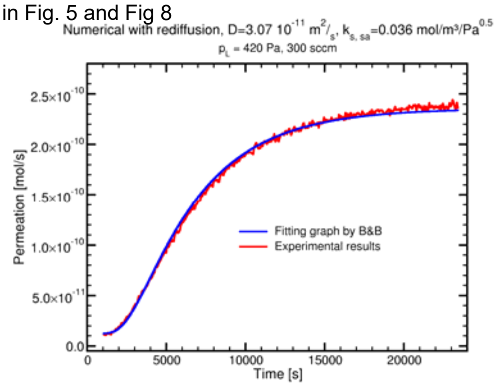


Fig. 7: Experimental results and fitting graph of the FDM model adjusted by B&B.

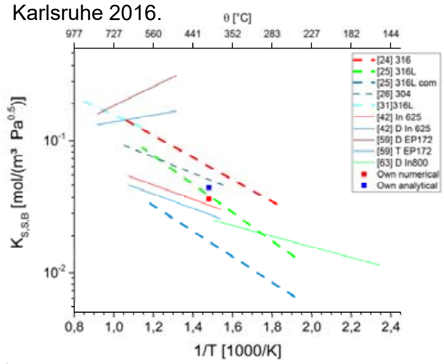


Fig.8: Comparison of results of the Sieverts´constant, see Fig. 5.

Conclusion: The here presented first results are successful in improvement of FUSION relevant Hydrogen permeation experiments by decreased loading pressure, true flow experiment, increased sensitivity and improved analysis of experimental results.

We thank also for funding of mathSEE project at KIT

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.