**Experimental and modelling approach for the optimal design of a hydrogen permeation process in a gas-Ni-Na system**

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**Highlights**

* Hydrogen introduction inside a liquid sodium loop by permeation through a Nickel membrane
* Set up of an experimental facility for the process analysis and validation
* Measurement of the stationary hydrogen permeation flux through the membrane
* Experimental and modeling approach
* Data reconciliation

**1. Introduction**

In the framework of SFRs (Sodium Fast Reactors), the contamination of the liquid sodium circulating in the secondary circuit with tritium produced in the core is one main process issue. In order to capture and recuperate this tritium, a certain amount of hydrogen dissolved in liquid sodium is necessary. Until now, the hydrogen is produced by steel corrosion and by hydrazine decomposition inside the steam generator, then it diffuses to sodium through the steel walls; to better control the hydrogen concentration, an external and independent process to introduce safely and in a controlled way a hydrogen flux into liquid sodium is necessary.

The permeation through a Nickel dense membrane has been individuated as the most suitable technical solution. Hydrogen permeation through Nickel has been widely studied when a gas phase is present on both side of the membrane [1]–[4]and some applications based on Nickel membranes were developed for SFRs to detect the hydrogen content inside sodium [5]. However, a more detailed study on hydrogen transfer from a gas phase to liquid sodium is necessary, considering not only the permeation through a Nickel membrane but also the mass transfer inside gas and sodium phases as main influential phenomena.

**2. Experimental results**

In this study, a device constituted by four Nickel tubular membranes (or “permeator”) is designed to transfer a continuous hydrogen flux from a gas mixture (Ar+H2 at 3% molar) circulating inside the tubes to the external side of the tubes (shell) by permeation. The permeator is installed on a closed sodium loop, with the capability to purify sodium and to warm it up to a temperature of 450 °C. The permeator is tested at different temperatures, gas pressures and flowrates in order to obtain different hydrogen permeation fluxes, depending on the operating conditions. It is tested both in a gas-gas configuration (i.e. shell maintained under vacuum) and in a gas-sodium configuration (i.e. sodium circulating inside the shell), in order to identify the sodium resistance effect on the global hydrogen mass transfer.

Measurements of the main process parameters (pressure, temperature, flowrate) are carried out, as well as a hydrogen concentration measurement on the gas retentate side by a gas chromatograph. Moreover, a measurement of hydrogen concentration inside the sodium loop takes place, by means of a second Nickel membrane coupled to a mass spectrometer.

A data reconciliation method is applied to adjust the values of raw measurements, taking into account the system redundancy and the instrumentation uncertainties, in order to generate reconciled data which satisfy the hydrogen mass balance.

**3. Simulation results**

Under the hypothesis of steady state conditions, a simplified model of the permeator is set up in COMSOL Multiphysics®, as an instrument supporting the experience design. It includes the permeation Richardson’s law[6] for the Nickel membrane, the hydrogen mass balances and the convective mass transport into the gas and liquid sodium phases. Thanks to this model, preliminary results can be produced by simulating the overall process.

**4. Conclusions**

The reconciled data allow comparing the calculated and the experimental hydrogen permeation flux under given operating conditions. Therefore, it is possible to validate the main hypotheses at the basis of the model and to evaluate the real influence of the operating parameters on the permeation.

**References**

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