Study on enhancing experimental procedure for assessing ARAA's hydrogen permeation properties

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1. Introduction

Advanced Reduced Activation Alloy (ARAA) has been developed as a structural material for a breeding blanket [1]. One of primary functions is to continuously generate tritium for self-sufficiency. Considering that the structural material is exposed to specific conditions such as hydrogen isotopes represented by Q (H, D and T) at elevated temperatures, the permeation of hydrogen isotopes through ARAA inevitably occurs. Therefore, establishing reliable permeation properties of hydrogen isotopes is crucial for safety assessment.

This paper presents the current database of hydrogen permeation properties of ARAA and introduces a developed procedure aimed at obtaining reliable results.

2. Experimental descriptions

Hydrogen permeation tests through ARAA were conducted based on pressure rise method and Fick's law with single layer permeation. Temperature was ramped up with constant value, minimizing distortion due to unequal thermal expansion between ARAA and test section consisting of stainless steel 316L. The pre-processing was adopted to remove oxidation layers on surfaces of specimen where the both sides of surface were exposed to hydrogen at several hours with elevated temperature. After the pre-processing was finished, Volumes of feed and permeate side were evacuated to ~10^{-6} Pa by a turbo molecular pump. And then, permeation test was initiated according to target temperature range. Samples with diameter of 19.8 mm and thickness less than 1.0 mm were prepared for the test.

Figure 1 shows the permeability results of ARAA and reference data based on RAFM steel [2-4]. The activation energy of permeation (E_p) for ARAA evaluated 37.4 kJ/mol in this work. Table 1 summarizes the Ep data between the lines in Figure 1. Additionally, a positive number of time-lag was observed for calculating diffusivity, solubility, and activation energy (E_D, E_S) compared to the reference data.

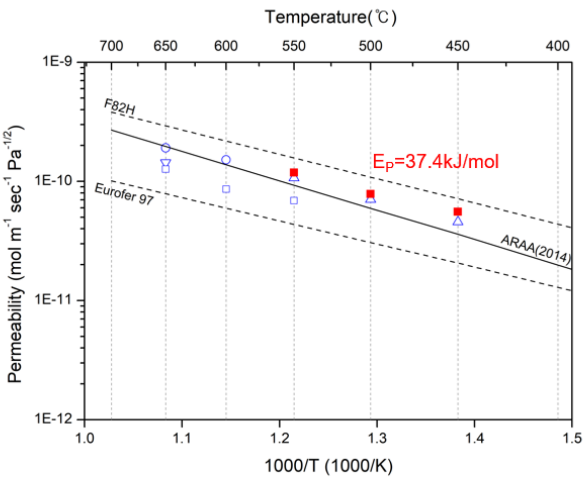

Figure 1. ARAA(VB27) permeability data compared with F82H, Eurofer 97 and ARAA(F211); The blank symbols are the results of the previous test procedure, the filled symbols are the results of the improved test procedure.

Table 1. The Ep data of ARAA and other RAFM steels; ARAA in row 2 is evaluated by the blank symbols in Figure 1.

Sample	Φ_0 ($\times 10^{-8}$)	E_P (kJ/mol)	Temp. (K)
ARAA	3.87	40.5	723-923
ARAA [2]	9.45	47.4	523-873
Eurofer 97 [3]	1.03	37.4	373-723
F82H [4]	4.90	39.3	373-523

3. Conclusions and future work

This paper reports on the improved consistency and reduced discrepancy in the hydrogen permeability of ARAA. The data will serve as a basis for the development of a permeation barrier for future work. Additionally, it is expected to contribute to breeding blanket design as part of safety assessment.

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