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EVEDAリチウム試験ループで用いたターゲットアセンブリの二段絞りノズルの表面分析

Surface morphology evaluation of double contraction nozzle of target assembly used in IFMIF/EVEDA lithium test loop

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We plan to construct a fusion neutron source, A-FNS, where liquid lithium will be used as self-cooling target. The limit of the erosion/corrosion (E/C) thickness in the double contraction nozzle (DCN) have been tentatively defined to be 1 μm, since it is necessity to keep the surface roughness of DCN less than 6.3 μm to make a flat and stable target flow [1]. A flat liquid lithium target flow with its velocity of 15m/s had been successfully demonstrated by EVEDA lithium test loop (ELTL) under IFMIF/EVEDA project [2] over 1300 hours long until the end of ELTL operation [3]. Therefore, it is considered that the limit of the E/C thickness of DCN in A-FNS could be alleviated to the E/C thickness observed in ELTL. In the present study, the surface morphology of the inner surface of DCN used in ELTL is evaluated to observe the surface roughness and to estimate the E/C thickness to alleviate the limit of the E/C thickness of DCN for A-FNS.

A preliminary model to estimate the E/C thickness is considered. In this model, the corrosion is assumed as dealloying with forming a quality changed layer (QCL). The erosion is assumed to depend on the wall sheer stress (τ_w) and the average QCL thickness (X). From these assumptions, X could be expressed as the following equation.

$$\frac{dX}{dt} = \frac{k_c^2}{2X} - \tau_w \alpha X^{\beta} \quad (1)$$

where k_c indicates the corrosion rate. α and β are constants. From this equation, the eroded thickness, Y, can be also estimated by integrating the second term of right side by time as following equation.

$$Y = \int \tau_w \alpha X^{\beta}\, dt \quad (2)$$

Based on the estimation of the wall sheer stress, which largely differ at the location of the nozzle [4], the observation points of DCN in the present study were determined to be τ_w = 1.5, 6.9, 81 and 590 Pa.

The surface morphology is measured by a scanning electron microscope (SEM) and an atomic force microscope (AFM). To measure the thickness of QCL, the cross section is also observed by SEM and an electron dispersive X-ray spectroscope (EDX).

As the results of surface morphology observation by SEM, it is indicated that hole-like structures of approximately 0.5 μm in diameter are observed in all observation points. The populations of the holes obviously increase with higher τ_w, indicating that the E/C would be more significant in higher τ_w. As the results of surface roughness observations by AFM, the surface roughness seems unchanged or slightly decreases with increasing τ_w, indicating that the E/C would little affect the surface roughness. Based on the cross-sectional observations by SEM and EDX, the average QCL thickness (X) is measured at each of the observation points and is plotted as a function of τ_w as shown in Fig. 1. These plots are fitted by Eq. (1). The eroded thickness (Y) at each τ_w is estimated using Eq. (2) and superposed in Fig. 1. It is suggested from this estimation that the limit of the E/C thickness of DCN for A-FNS would be alleviated from 1 μm to 7 μm.

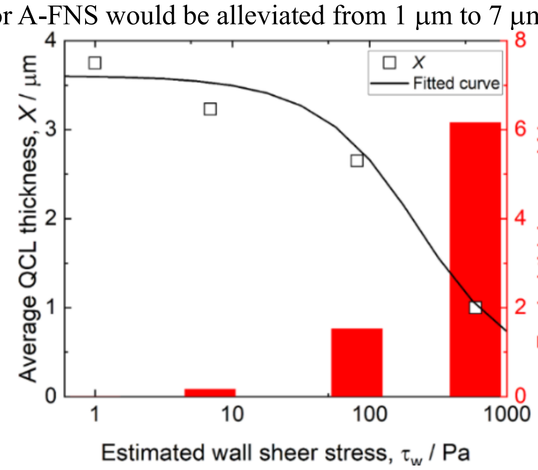

Fig. 1 Average QCL thickness and eroded thickness as a function of wall sheer stress.

[1] M. Ida et al, *J. Nucl. Mater.* 307-311 (2002) 1686.
[2] J. Knaster et al, *Nucl. Fusion* 57 (2017) 102016.
[3] H. Kondo et al, *Nucl. Fusion* 57 (2017) 066008.
[4] H. Kondo et al, *Fusion Eng. Des.* 146 (2019) 285.