§54. Preliminary Design and R & D Issues of Blanket Structural Materials for Force Free Helical Reactor (FFHR)

Matsui, H. (Tohoku Univ.)
Muroga, T., Sagara, A., Motojima, O.

In the current design study of FFHR, LiF-BeF_2 (FLiBe) is selected as a breeder/coolant material. The replacement frequency of the blanket structural materials is required to be minimal during the reactor lifetime. The irradiation conditions of the structural materials anticipated by the reactor design side are 1.5MW/m^2 and 30years (45MWa/m^2) and 400-600°C[1]. The objectives of the present study is to design materials system which is consistent with the reactor design and to define issues of researches supporting the materials design activity.

Some advanced low activation materials, ferritic alloys, vanadium alloys, SiC/SiC composite and Ti-Al intermetallic compound, were considered. The merits and demerits of these materials applied to FFHR structural components were examined.

Two candidate materials, low activation ferritic alloys(e.g. JLF-1) and vanadium alloys were compared and were chosen as the primary and the alternative candidate material, respectively. The issues relating to these materials for use in FFHR were identified, e.g. improved high temperature strength for low activation ferritic alloys and chemical compatibility with FLiBe for vanadium alloys.

The R&D issues for developing the blanket structural materials were examined and the preliminary investigation concerning the following three issues were carried out.

(1) Activation at high neutron exposure level.
(2) Compositional change by high level neutron irradiation.
(3) Accumulation of high level of transmutant helium.

The radioactivity of some elements at high neutron exposure level (45MWa/m^2) were calculated considering pathway reactions. The results showed that significant amount of long-lived radioactive nuclides were formed from Si and Ti. As for V, Cr, Fe and W, however, the influence of the pathway reaction was shown to be negligibly small. It was also indicated that the impurity, especially Nb, Mo and Ag, should be reduced to very low level to satisfy the waste disposal guideline.

As to the compositional change by transmutation, the impact of W to Re/Os, V to Cr and Cu to Ni were examined. Irradiation of vanadium in HFIR was carried out as accelerated simulation of Cr generation during irradiation. The specimens were strongly embrittled after irradiation. This change was attributed to the increase in the Cr level.

The microstructure-based methodology to suppress helium accumulation effects were investigated. Based on the study on Fe-Cr-Ni ternary doped with P and Ti, which produce high density of needle-shaped precipitates during irradiation, partitioning of helium in the matrix at high density of interfaces is shown to be very effective in suppressing the helium accumulation effects on void swelling and mechanical properties.

The present study has shown the importance of neutronics-based calculations which provide realistic estimates of activation and transmutation at high exposure levels, as well as the role of controlled irradiation experiments simulating both gaseous and solid transmutation effects.

Reference

1) Sagara, A., Motojima, O., Watanabe, K., Imagawa, S., Yamanishi, H., Mitarai, O., Satow, T., Tikaraishi, H., FFHR Group, Fusion Engineering and Design 29 (1995) 51.