§93. The Development of Ferritic Steels for Fusion Power Reactor Blankets

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Research and development of low-activation materials is one of the most important challenges in fusion technology for making fusion energy systems acceptable and feasible energy options for the 21st century. Presently, low activation ferritic steels (LAF), vanadium alloys and SiC/SiC composite materials are considered promising candidates. Among them, the LAF R&D is placed at the highest priority in the Japanese and the European programs.

Based on the extensive study on the effects of chemical composition and microstructure of LAF on mechanical properties and high temperature irradiation resistance within the former US-Japan collaborative FFTF/MOTA Project, two large heats (1 and 1.5metric tons) of a low activation 9Cr-2W steel (JLF-1) were produced. Plates with thickness from 7 to 25 mm and plates of these thickness with EB or narrow gap TIG welded joints have been fabricated and distributed.

Together with the materials R & D activities, many conceptual design studies using LAF are in progress. As the representing design studies, Steady State Tokamak Reactor (SSTR) and Forced Free Helical Reactor (FFHR) are introduced with the emphasis on "how LAF are applied in the reactor systems, especially for blankets". It is also intensively studied in the present work.

Based on the first all-superconducting-coils device, LHD(Large Helical Device), the blanket design for Force-Free Helical Reactor, FFHR, has been developed. The neutron wall loading was reduced to 1.5MW/m2 for the 3GW fusion output. At any rate this wall loading in the reactor lifetime of 30 years leads to the total neutron dose of about 450 dpa. At present, within the available databases, no structural materials for the main in-vessel components has been demonstrated. However, by allowing of maintenance in every 10 years, materials reliable up to 120 dpa are reasonably used. With considering engineering databases and radioactivity, a ferritic steel JLF-1 (Fe9Cr2W) was selected as the first candidate. This bottom line would be improved greatly by the potential ODS (Oxide Dispersion Strengthened) steels. The advantage of FFHR is a low pressure operation with FLiBe due to low MHD resistance and fairly low vapor pressure around 800K. The coolant inlet temperature 723 K, determined from the melting temperature and viscosity of FLiBe limits the lower limit and the upper limit, i.e., the outlet temperature is determined from creep strength of JLF-1. As shown in Fig 8, under conditions of creep strain less than 0.5% at 100 MPa for the lifetime of 120 dpa, JLF-1 is hopefully used at temperatures around 823K. There is even a possibility to operate FFHR with much lower FLiBe pressure which allows much higher temperature operation. FLiBe is quite stable and less hazardous than other liquid metal or molten salt coolant, but the compatibility between FLiBe and JLF-1 is still an open question. Preliminary data on LAFs and the current individual efforts are quite promising, but further coordination efforts and support are required to accomplish the R & D programs of LAFs.

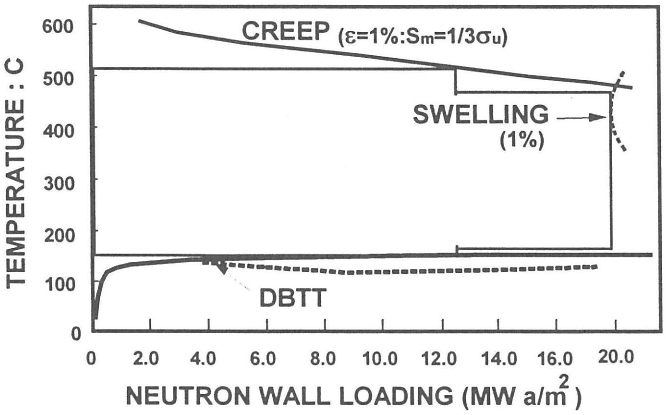

Fig. 8: A Preliminary design window for JLF-1