§67. Development of Low-Activation Materials for Steady-State Helical Reactors

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Successful development of low-activation material is the key for the realization of fusion energy. There are a few candidate low activation materials while none of them have performance adequate for power reactors. Ferritic steels and vanadium alloys are probably the most promising candidates for DEMO, and other materials such as SiC/SiC and intermetallic compounds may also be considered potentially capable of being used in fusion power reactors but probably will not be ready for DEMO.

A new conceptual design of a helical power reactor called Force-Free Helical Reactor, FFHR, is underway lead by National Institute for Fusion Science. A number of material issues have been raised in this activity during the material selection phase. In the present paper, performance of candidate materials anticipated under fusion-relevant conditions is evaluated in the light of the design concept of FFHR.

Liquid breeder system was chosen in order to simplify the blanket changeout procedure in the relatively complex geometry of helical reactors. Ferritic steel/ FLiBe system was chosen as first option of structural material/ coolant/ breeder combination. The choice of FLiBe was mainly because of safety reasons; avoiding high pressure components associated with water- or gas- cooled systems and potential liquid metal fire hazard. Although the low activation version of ferritic steels are still to be qualified before they can be applied for actual reactor construction, intensive database and industrial support for these materials is one of the largest advantage. The weak point of these materials are their limited operation temperature range leading to relatively low thermal efficiency. Effects of error fields induced by the ferromagnetism of ferritic steels on plasma is another concern and this issue should be addressed promptly before adopting this material for FFHR.

Material systems using vanadium alloys as structural material are second option. FLiBe is the breeder/ coolant material also in this option, and compatibility of vanadium with FLiBe is to be overcome by using coating or cladding. Appropriate path should be provided to avoid hydrogen accumulation from the plasma and transmutation in order to avoid possible hydrogen embrittlement. Vanadium alloy- liquid lithium self-cooling concept is still another option under consideration. In this concept, hydrogen is effectively removed from vanadium alloys by flowing lithium. Systems using vanadium alloys would enable better reactor performance, while the compatibility with coolant and industrial maturity of vanadium alloys were factors judged to be inferior to ferritic steels.

There are a number of issues other than those related to compatibility. Helium effects on the radiation response of these materials seem to have greatest uncertainty. In vanadium alloys, DHCE technique has been recently applied to study the effects of helium injected concurrently with neutron irradiation. Although the test matrix was not large enough to cover all issues in question, it has been concluded that helium does not cause disastrous effects on the mechanical properties of vanadium alloys at low temperatures. For ferritic steels where similar techniques are not applicable, helium effects will remain an open question until intense 14MeV neutron source becomes available. Other critical issues raised in the material selection of FFHR will be discussed based on recently accumulated database.