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The Strategy of Fusion DEMO In-vessel Structural Material Development

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The structural material development for the breeding blanket in a future fusion reactor is regarded as the most challenging technical issue due to the significance of 14 MeV DT fusion neutron irradiation that induces high displacement damage with a significant amount of the transmutation formed gas elements such as helium and hydrogen.
The strategy of fusion in-vessel structural material development toward fusion DEMO is addressed with special emphasis on the current status and the limitations due to the reliability of data. A major issue in developing and validating structural materials for a fusion DEMO reactor are missing facilities where materials can be tested under the real in-vessel conditions of deuterium-tritium (DT) fusion. Ideally, neutron irradiation induced changes are expected to be negligible or "minor". The reality is, however, that irradiation effects are neither "negligible"nor "minor". Thus, it is essential to define the negligible and maximum level of irradiation-induced changes which could be incorporated into safety factors that are defined "empirically", and the most significant technical challenges are to develop and qualify materials based on the knowledge and data acquired in experiments not performed under "real"fusion environment but in fission neutron irradiation and various simulation irradiation experiments, and to develop and verify a framework of DEMO reactor design criteria for in-vessel components (DDC-IC).
Here we propose a new strategy based on probabilistic approaches, where the probability of failure is calculated based on the probability density function of postulated load distribution and material property distribution, as a part of the design methodology in order to mitigate the uncertainties caused by multiple sources. It is essential to conduct statistical analyses on material property data to make the data applicable to the probability based design method. Consequently, the vast amount of fission neutron irradiation data which fulfill the statistical requirements should be developed up to some critical irradiation dose levels at which the irradiation effects caused by fusion neutron spectra are expected to become very different from fission data.

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