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Irradiation effects on lifetime of first wall structure materials for CFETR

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China Fusion Engineering Test Reactor (CFETR), designed as a bridge connecting ITER and DEMO, was proposed to achieve long-term stable operation with 30–50% duty time factor at low fusion power (50–200 MW). First wall of CFETR services on the conditions with high surface heat flux and intense neutron irradiation. The existing structural design rules for first wall mainly involved stability analysis, which neglected the primary failure mechanisms related to service time such as creep, fatigue and irradiation effects. With the approaching of CFETR engineering, it is important to analyze the effects of swelling, embrittlement, irradiation creep, and irradiation fatigue on the lifetime of the structure materials. It is the main purpose of this work, based on the existed neutron irradiation data of three kinds of candidate structure materials (ferrite/martensite steel, austenite steel and oxide dispersion strengthened steel) and finite element simulation on the service conditions of first wall for helium cooling solid breeding blanket.

Since the maximum irradiation doses in CFETR are 10dpa and 50dpa in lifetime of designed phase-I and phase-II respectively, according to the development roadmap of nuclear fusion energy in China, so the irradiation swelling would not be the most important issue compared to the creep for long service time requirement. The irradiation creep lifetime was evaluated with Larson-Miller Parameter model, and the irradiation fatigue lifetime was predicted with S-N curves. The allowable irradiation creep lifetime decreases with increasing of surface heat flux (0.3-0.7 MW•m-2), first wall thickness (1-5 mm) and inlet coolant temperature (300-500 ℃). For the current CFETR conceptual design condition, the lifetime is not limited by irradiation creep, which indicated the room for lifetime improvement and design parameters optimization.

Eligible for student paper award?

No

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