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Design Issues and Implications for Structural Integrity of Fusion Power Plant Components

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The criteria and implications for successful design, licensing and power plant operation are assessed, and imposed constraints and limitations are examined. The design of a reliable fusion power plant is dependent on the availability of licensed nuclear materials and the structural–thermal loading conditions during normal and abnormal (disruptions) events. The various conditions in a tokamak lead to structural damage and possible failure. Taking into consideration all the possible structural failure mechanisms, the most likely are combinations of fatigue and creep. Issues encountered in the fusion environment are the significant amount of irradiation creep, the large ratio of helium production to displacement damage, and the degradation of fatigue strength and ductility, effects which are even encountered at low temperatures.

Component design, and accurate prediction of lifetime, requires established material databases and design curves, specification for fabrication and testing, inspection methods, and rules and constraints for design, and in–service conditions. The issues involved are classification of components according to their functionality, physical position in the machine and safety importance, classification of loading conditions, and choice of elastic or inelastic analysis. The existing design codes guard against creep and fatigue but do not directly address neutron irradiation. The issues associated with irradiation creep-fatigue, since they impact the design and licensing processes of future fusion power plants, are presented and discussed.

The codes distinguish between failure criteria under steady and cyclic loads, and lay down rules for failure prediction under combined creep–fatigue conditions. Currently, there are no established fusion specific licensing processes or component design codes. Any limits imposed on designs or performance, are taken from existing design codes developed by the fission industry. There is a need to initiate the process of defining and developing tools for the design and licensing of fusion components and facilities to ensure nuclear safety.

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