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A statistical design method for steady state creep applied to Grade 91 components

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Current methods for the design of high temperature fast reactor components are deterministic, often based on deterministic structural analysis compared to factored design material data. These methods often produce very conservative designs and the exact design margin – for example, the probability of premature component failure – often cannot be easily quantified. A statistical design method for high temperature components could better quantify the design margin in current deterministic design methods, provide a basis for tuning the design margin in structural design methods to produce more efficient, but still adequately safe, components, and provide regulators and designers increased confidence in the predicted life of fast reactor structural components. This contribution describes a complete statistical design and analysis method for primary load, steady state creep in high temperature reactor components. The method has two parts: a steady state creep analysis method based on a Stokes flow solution and statistical methods for quantifying the distribution of rupture life and creep rate in Grade 91. The Stokes flow analysis greatly reduces the time required to simulate the steady-state stress distribution corresponding to a given set of loading conditions. The statistical creep rate and rupture distributions provide the underlying data for the design analysis. The complete method applies the Monte Carlo approach to sample the creep rate and rupture stress distributions, providing a probabilistic assessment of the life of the component. Here the method is applied to a Grade 91 structural component in the context of a sodium fast reactor. The statistical analysis can be compared to a deterministic design analysis to quantify the design margin in terms of the component reliability.

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