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DEVELOPMENT OF NEW FERRITIC/MARTENSITIC STEEL FOR FUSION REACTOR APPLICATIONS*

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Ferritic/martensitic steels are the preferred structural materials for elevated-temperature applications for fusion power plants (first wall and blanket structures). Their major advantage is good thermal properties relative to other elevated-temperature alloys. A major shortcoming of the conventional and reduced-activation ferritic/martensitic steels is high-temperature strength, which places a limit on the maximum operating temperature. The reduced-activation steels developed for fusion applications have maximum operating temperatures of 550-600ºC. However, for increased efficiency of a fusion plant, designers require higher operating temperatures. This has led to work to develop oxide dispersion-strengthened (ODS) steels. These steels, which are strengthened by small oxide particles, are produced by complicated and expensive mechanical-alloying, powder-metallurgy techniques, as opposed to conventional processing techniques (i. e., melting and casting followed by hot working, cold working, etc.) used for present-day elevated-temperature steels. ODS steels are also plagued by anisotropy in mechanical properties caused by the processing. Therefore, a need exists for elevated-temperature ferritic/martensitic steels with higher operating temperatures than conventional steels that can be produced by conventional processing techniques.

Based on the science of precipitate strengthening (the need for large numbers of small precipitate particles) and using thermodynamic modeling to explore possible optimum compositions, a thermomechanical treatment (TMT) process was developed that increased yield stress of commercial nitrogen-containing 9 and 12% Cr martensitic steels by over 135% at 700ºC. Steels designed and produced specifically for the TMT have yield stresses at 700ºC up to 200% greater than conventional steels. The strengths of these steels were as good-as or better than the strength of the strongest ODS steels under development. Preliminary creep-rupture tests indicate a commensurate increase in rupture life. Characterization of the nano-sized precipitates in the new steels by transmission electron microscopy indicated the precipitates were up to eight-times smaller at a number density to over three orders of magnitude greater than in the conventional steels given the standard normalizing-and-tempering heat treatment.

Although these steels are still in the development stage, the preliminary results indicate the properties of the steels offer the promise of being of use in fusion and other applications that require elevated-temperature materials.

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