Niobium-Base Alloys for Space Nuclear Applications

Keith J. Leonard[a], Chad E. Duty[a] and Steve J. Zinkle[a], Ross F. Luther[b], R.E. Gold[c], R.W. Buckman[d]
[a]Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831
[b]Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania 15122
[c]Pittsburgh Materials Technology, Inc. Jefferson Hills, Pennsylvania 15025
[d]Refractory Metals Technology, Pittsburgh, Pennsylvania 15236

From the beginning of the SNAP-50 to the end of the SP-100 programs of the 1960's through early 1990's, niobium-base alloys have been considered for applications in space nuclear reactor concepts. Due to their relatively high operating temperature capability, chemical compatibility, stability in nuclear environments and availability, these alloys have been natural candidates over other alloy systems. Though Nb-1Zr has received the greatest attention and has some benefit derived from a substantial data-base, its relatively low mechanical strength has led to the investigation of other higher strength Nb-base alloys. Numerous Nb-base alloys have been identified and briefly investigated since the 1960's. However, because of the combinations of mechanical strength, ductility, weldability or chemical compatibility, most have not been further considered for space reactor applications. The most promising of these candidate alloys will be discussed and compared to Nb-1Zr. These include C-103 (Nb-10Hf-1Ti), Cb-752 (Nb-10W-2.5Zr), FS-85 (Nb-10W-26Ta-1Zr) and D-43 (Nb-10W-1Zr-0.1C), which incorporate various combinations of solid solution, dispersion and precipitate strengthening mechanisms. Only the C-103 and Nb-1Zr alloys are currently commercially available, with the latter used in sodium vapor lamps.

The physical properties of these alloys and the effects of alloy additions on mechanical properties will be briefly discussed. Primary consideration will be given to the mechanical property comparisons of the alloys over their operational ranges, with heavy emphasis placed on creep properties. Though improvement in short-term creep strengths are observed for the alternative Nb-base alloys relative to that of Nb-1Zr, long-term thermal stability may negate these gains. However, the lack of test data beyond a few thousand hours limits the knowledge of these alloys. The effects of heat treatment conditions on mechanical properties will be addressed. Though not possessing the same workability as Nb-1Zr, the alternative Nb-alloys show varying degrees of weldability and machinability. This presentation will review the available literature on alternative Nb-alloys, providing an assessment of their performance for space nuclear applications.

Keith Leonard, 1-865-576-3687, leonardk@ornl.gov

This work was performed in part by the Oak Ridge National Laboratory for the U.S. Department of Energy (DOE) in support of the National Aeronautics and Space Administration (NASA). ORNL is managed for DOE by UT-Battelle, LLC, under contract DE-AC-05-00OR22725. Any opinions expressed in this paper are those of the author(s) and do not necessarily reflect the views of DOE or NASA.