§17. A Study of Strengthening for V-4Cr-4Ti Alloy by Mechanical Alloyning

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V-4Cr-4Ti alloy has been identified as the first candidate structural material for Li blanket component in a fusion reactor, because of its low activation property, high strength at elevated temperatures, and good compatibility with liquid Li. However, in order to improve thermal efficiency of the blanket by higher temperature operation, it is necessary to enhance the creep strength of this material. A thermomechanical treatment combines work hardening followed by precipitation hardening was shown to be efficient to enhance the creep strength of V-4Cr-4Ti alloy in stress region above 180MPa, but not efficient below 180MPa.

Recently, a nano-particle dispersion strengthening technique has been applied widely on fusion structural materials including vanadium alloys. The pinning of dislocations by the dispersed nano-particles largely increases the strength of the materials at both RT and high temperatures. However, the research activities on dispersion strengthening of V-4Cr-4Ti are still not enough.

In this study, a new series of V-4Cr-4Ti alloys have been fabricated with nano-particle dispersion coupled with grain size refining by mechanical alloying (MA). Y is used as the scavenger for N and O impurities. With TiC, SiC, Ti3SiC2 as dispersion particles, and WC/Co as the milling ball materials, MA process of V-4Cr-4Ti alloys with Y addition has been studied with different milling time. The dissolution behaviors of alloying elements in V matrix and dissolution effects of dispersion carbides on alloy hardness are discussed.

Results show that the collision-induced dissolution rate of Y into V matrix is higher than that of Cr, and, the dissolution rate of Cr is higher than that of Ti, as shown in Fig. 1.

The strengthening of the V-4Cr-4Ti alloys increases with increasing MA time. After annealing at 1200°C for 1hr, the strengthening increases with increasing MA time, especially above 10hrs (as shown in Fig. 2). The poor dissolution of Ti3SiC2 (marked as TiSiC) particles leads to less hardening for the V-4Cr-4Ti alloys, because it may retard the solid solution hardening and further nano-particle dispersion strengthening. It is considered that the dissolution of Ti could be an important factor to stabilize the microstructures of obstacles in the mechanical alloyed V-4Cr-4Ti. Y-rich and especially Ti-rich nano-particles are considered to be important particles to strengthen the V-4Cr-4Ti alloys.

Fig. 1. Possible dissolution history of Ti, Cr and Y in V matrix.

Fig. 2. Hardness of Y and carbides added V-4Cr-4Ti alloys after annealing at 1200°C for 1hr.