mal stress is the main cause of the particle emission. For doped graphites, the doped mass was firstly melted or softened in the laser shock process. Thus tendency for the thermal stress cracking would be decreased, as the softened materials decreased the thermal stress. Particle emission was suppressed, which decreased the weight loss of the doped graphites.

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2.9 The Hydrogen Embrittlement of Vanadium Alloy

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Key words Vanadium alloy Hydrogen embrittlement

Low activity vanadium alloy has long been considered as structure material for fusion reactor. Hydrogen embrittlement is a main concern for a fusion reactor. In this paper mechanical properties of the hydrogen embrittlement vanadium alloys were studied. Table 1 shows the chemical compositions of the alloys.

Tensile specimens were cut from 1 mm thick vanadium plates in annealing state. Fig. 1 shows the size and configuration of the specimen. All specimens were hung in the vacuum chamber of a hydrogenating device to charge hydrogen. The temperature of hydrogenation was 600 ℃. The hydrogen content in the specimens was measured to be high up to 1.13×10^{-8}. Tensile test was per-

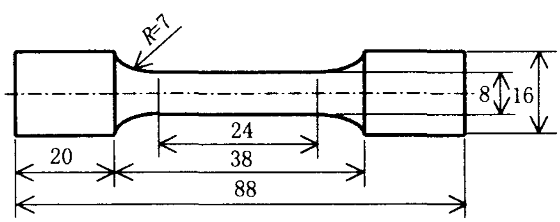

Fig. 1 The size and configuration of the tensile specimen (Unit: mm)

Table 1 The chemical composition of the vanadium alloys / $\mu g \cdot g^{-1}$

Alloy	C	Si	Cr	Ti	Al	N	O
V4Cr4Ti	0.024	0.023	3.61	4.11	0.21	0.046	0.09
V3TiAlSi	0.012	0.95	0.02	3.20	1.07	0.006	0.08
V4Ti	0.014	0.012	0.22	4.23	0.23	0.002	0.085
V4Ti3Al	0.019	0.008	0.02	4.23	2.89	0.005	0.07
V4TiSi	0.016	0.24	0.02	3.96	0.26	0.002	0.11

formed in a MTS material test machine with a tensile displacement rate of 0. 5 mm per minute.

The yield strength, ultimate strength and elongation of the alloys were measured according to the tensile load versus displacement curves. Fig. 2 showed the change of the properties with the increasing hydrogen content. Several results could be concluded from the Fig. 2, both V4Ti and V4TiSi alloys showed higher resistance against hydrogen embrittlement over other alloys. They kept ductility with the tensile elongation in the range of 6% ~ 11% even the hydrogen content reached to 1.13×10^{-8}, while other alloys had only 2. 5% in elongation. The ductility of the alloys was almost in the same level with little decrease when the hydrogen content was no more than 0.2×10^{-8}. Element Si will increase the hydrogen embrittlement of the alloys. V4Ti alloy always showed bigger elongation than V4TiSi for all hydrogen content. Hydrogen in the vanadium alloys always caused the increase in yield strength for any alloy, while the ultimate strength was little influenced.

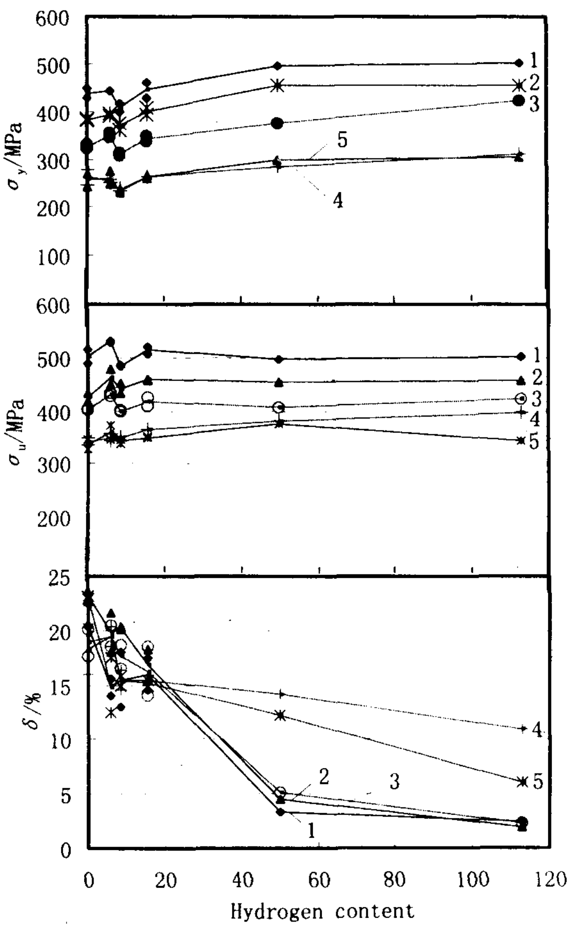

Fig. 2 The dependence of mechanical properties on the hydrogen content of the alloys tested at room temperature

1——V3TiAlSi, 2——V4Ti3Al, 3——V4Cr4Ti, 4——V4Ti, 5——V4TiSi.

The influence of hydrogen on the mechanical properties was caused by the increase in the resistance of dislocation mobility. Yield strength will increase and elongation will decrease due to the increase in dislocation mobile resistance. The ultimate strength will be not influenced because it is dependent mainly on the feature and structure of the matrix metal. The difference between the yield strength and the fracture strength (there it is approximately equal to the ultimate strength) will decide whether ductile fracture or brittle fracture will take place. When yield strength is smaller than fracture strength for a material loaded, yield and plastic deformation will firstly take place in the material. The fracture will be ductile. In the opposite, the stress in the material loaded will first reach to the fracture strength. Brittle fracture will take place with little deformation in the material. So the ratio of yield strength (σ_y) over ultimate strength (σ_u) could approximately reflect the ability of the alloy against hydrogen embrittlement because yield strength will increase and get to the value of ultimate strength with the increasing hydrogen content. The smaller the ratio, the better property against hydrogen embrittlement the alloy would have. Table 2 listed the radio of the vanadium alloys without hydrogen at room temperature. It was obvious that both V4Ti and V4TiSi had smaller σ_y/σ_u ratio.

Table 2 The radio of yield strength over ultimate strength of the vanadium alloys tested at room temperature

alloy	V3TiAlSi	V4Ti3Al	V4Cr4Ti	V4Ti	V4TiSi
σ_y/σ_u	0.87	0.9	0.81	0.77	0.76

2.10 MHD Effects Caused by Cracks in Coating Pipe

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Key words Liquid metal MHD effects Coating cracks

1 MHD test section

MHD coating pipe with cracks used in this study is showed in Fig. 1 in Ref. [1]. Here, the signature V1 stands for the electric potential on electrode D1. Similarly, the electric potentials on electrodes D2, D3, D4 and D5 are V2, V3, V4 and V5, respectively. The electric potential V5 on electrode D5 has been chosen as the electric potential reference point, and V15 stands for the potential difference between electric potential on electrode D1 and electric potential on electrode D5, i. e. V15 = V1-V5. Correspondingly, V25 = V2-V5, V35 = V3-V5, V45 = V4-V5, respectively. To simulate a couple of cracks on insulating coating, a soft short-circuit copper wire must be used to link tightly electrode D1 and electrode D5 together, and D15 is used to indicate this couple of cracks. The length of copper wire is 420 mm, its cross-section area, S is 0.75 mm^2, 6 mm^2, 75 mm^2, respectively. The D15 &D34 indicates two couples of the cracks, i. e. one soft short-circuit copper wire is connected between electrode D1 and D5, another soft copper wire is used to link electrode D3 and electrode D4 simultaneously. In the same way, D35-25, D35-14 and D14-35 indicate the correspondent cracks.

2 Experimental analysis

MHD pressure drop Δp and the potential differences ΔV, i. e. V15, V25, V35 and V45 have been studied under some stable magnetic flux density B. The curves in Fig. 1 to Fig. 3 show the comparison of the experimental results for MHD effects with the theoretical prediction of insulating pipe.

For two couples of simulated cracks of D15-34 in Fig. 1: comparison of MHD pres-