§102. Neutron Irradiation Effects on Joining and Coating of Fusion Blanket Materials

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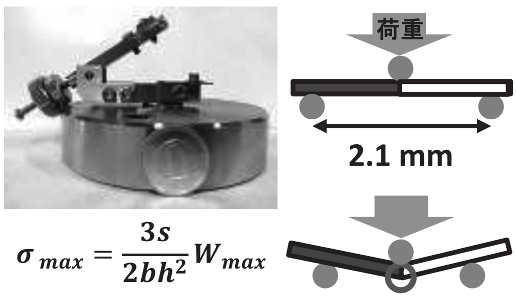
Tungsten armor has been considered to be critical for long term operation of fusion reactor because it suffers severe irradiation damages by highly energetic particles irradiation together with high heat loading. The estimated thermal heat loading is more than 20 MW/m^2 for diverter of Tokamak-DEMO reactors. Since tungsten is less ductile, cyclic heat loadings may cause fatigue rupture through thermal stress applied by the difference in the coefficients of thermal expansion between W-armor and structural material, namely, system component.

Heat load tests were carried out for W-armored structure component made of vacuum plasma sprayed (VPS) tungsten with a reduced activation ferritic steel. VPS-W with 1 mm thickness was coated on a reduced activation ferritic steel, F82H, with 5 mm thickness. No surface crack was observed after 100 cycles of electron-beam heat loadings at 4.8 MW/m^2, while 16 cycles of the loadings at 5.5 MW/m2 resulted in cracking on the surface of W-armor (20 sec. for heating, 20 sec. for constant loading and 240 sec. for cooling). However, the reduction of plate thickness of F82H from 5 mm to 3 mm increased cyclic heat resistance to 6.0 MW/m2. It was found that surface cracking occurred when the surface temperature increased higher than 1150 K irrespective of amount of heat load. Table 1 shows the relationship between surface temperature and occurrence of VPS-W cracking.

Finite element method analyses of thermal stress at the surface of tungsten during heat loading tests clearly showed that occurrence of cracking was determined by balancing heat loading and cooling, suggesting that the soundness of W-armor can be controlled by system integration, especially by considering cooling rate of system components, as well as material performance of W-armor itself. The application of an ODS steel as substrate of W-armor enables to increase the spraying temperature for VPS process, which is considered to be effective to make a high performance VPS-W with a higher density.

The bonding strengths of the VPS-W/steel joints (2.4mmw x 0.5mmt x 5.0mml) were evaluated by miniature three-point bend tests with a specially designed fixture of spans of 2.1mm at room temperature (Figure 1). Three-point bend testing has an advantage that the specimen geometry is rather small and adequate to evaluate the strength of the joints. The flexural rate was 1 x 10^{-3} mm/s.

Fig.2 shows the bending strength of VPS-W on the substrate of ODS steel (upper) and RAF steel (bottom). The bending strength is higher in the VPS-W on ODS steel than in that on RAF steel.



$$\sigma_{max} = \frac{3s}{2bh^2} W_{max}$$

Fig.1: Miniaturized bending test jigs to evaluate bonding strength.

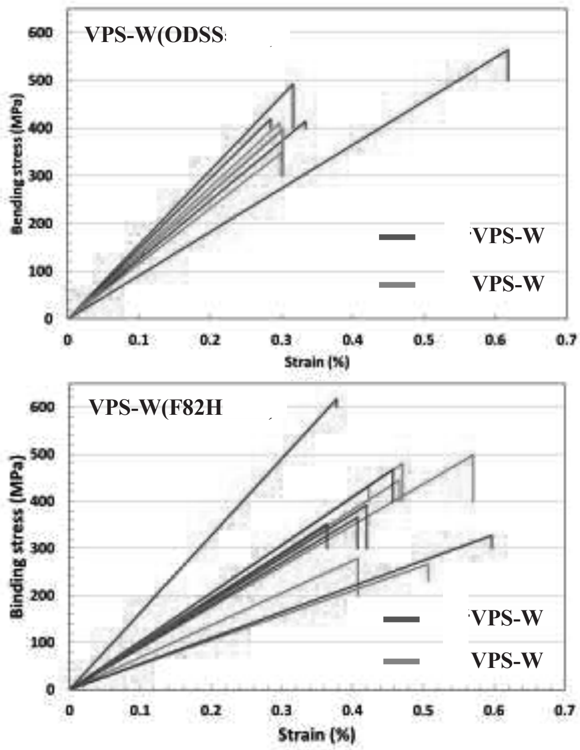


Fig.2: Bending strength of VPS-W on ODS steel and RAF steel.