§3. Mechanical Strength Properties of Tungsten Material at High Temperature

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Tungsten will be used as armor material of the first wall/blanket and divertor because of its low sputtering yield and hydrogen retention. Operation temperature of the first wall/blanket will be 350～550°C because of irradiation creep and swelling of reduced-activation ferritic/martensitic steel used as the blanket structure material. In the present work, tungsten coatings on reduced-activation ferritic/martensitic steel (RAF/M) F82H substrate (F82H: Fe-8Cr-2W), which is a leading structural material candidate for DEMO, by Vacuum Plasma Spray (VPS), have been produced and high heat flux experiment have been carried to investigate thermo-mechanical properties of tungsten at high temperature.

Reduced activation ferritic/martensitic steel substrate was coated by vacuum plasma splaying technique (VPS). The substrate material was F82H, (Fe-8Cr-2W) developed by JAEA. The thickness of the coating layer was 0.6 mm. The sample sizes used in the experiments was 10mm x 10mm x 5.6 mmt. The VPS-W surface was mechanically polished before the high heat loading experiments.

The samples were mechanically fixed on copper block actively cooled with water in a electron beam high heat flux experimental device. The experiments were conducted at three irradiation conditions; (1) Heat flux of 7.5 MW/m^2, duration of 180 s, (2) cyclic irradiations of 60 second-irradiation with a heat flux of 12 MW/m^2 and 140 second-rest with 30 cycles in total and (3) 7 s irradiation with a heat flux of 40 MW/m^2 and 230 second-rest with with 30 cycles in total. Before and after the irradiation, the sample surface was observed with a scanning electron microscope (SEM).

The temperatures of the surface and the F82H gradually increased and reached about at about 700 °C and 500 °C corresponding to the heat flux, respectively in experimental condition (1). Maximum operation temperature of F82H is 550 °C from a viewpoint of irradiation creep and swelling by neutron irradiation. In this experiment, steady state heat loading experiment for 180 s has been performed under the condition that temperature of the F82H was below the maximum operation temperature of F82H. SEM observation after the heat loading experiment showed that no modification was observed.

In experimental condition (2), the electric current started to increase at the same time as the irradiation started and was almost constant during the irradiation. The surface temperature gradually increased and reached about 750 °C and started to decrease when the irradiation ended. On the other hands, the temperature of the F82H was gradually increased when the irradiation started and reached the peak temperature. When the irradiation ended, the temperature gradually decreased. The peak temperatures did not change during the cycle heat loading. These results indicate that no failure occurred at the interface or in the VPS-W coating during the cyclic heat loading. After the cyclic heat loading, SEM observation has been carried out. Fine surface modification was observed, however, macro-cracks and exfoliation between the joint interface of the VPS-W/F82H were not formed after the heat loading experiments. These results indicate that the thermal and adhesion properties between the joint interface of the VPS-W/F82H were good under heat loading of surface temperature .at 700 °C.

In experimental condition (3), the peak temperatures of VPS-W surface increased from about 1300 °C to 1700 °C as cyclic number increased. On the other hand, the peak temperature of F82H decreased from 450 °C to 300 °C as cyclic number increased. These results mean that departure of temperatures happened and exfoliation for parallel direction occurred. Figure 1 shows SEM image of cross section after the cyclic experiment at 40 MW/m^2. It can be seen that exfoliation occurred at interlayer of the VPS-W coatings at about 50μm from the interface of the VPS-W and the F82H. In addition, cracking was observed on the VPS-W surface and penetrated to bottom layer of the VPS-W, which was exfoliated. These results indicate that the thermal stress caused exfoliation between the VPS-W layer at first, then, the cracks occurred by the cyclic heat loading. In addition, it is considered that exfoliation occurred at near interface which large thermal stress was applied and weak interlayer existed.

These results indicate that the VPS-W coated F82H has high potential of these coating as plasma-facing armor under thermal loading of the first wall. On the other hand, exfoliation has occurred at interlayer of the VPS-W coatings near the interface of the VPS-W and the F82H by cyclic heat loading of surface temperature at 1300 °C. This means that strengthening of the VPS-W interlayer will be necessary for improvement of thermal property of the VPS-W coated F82H.

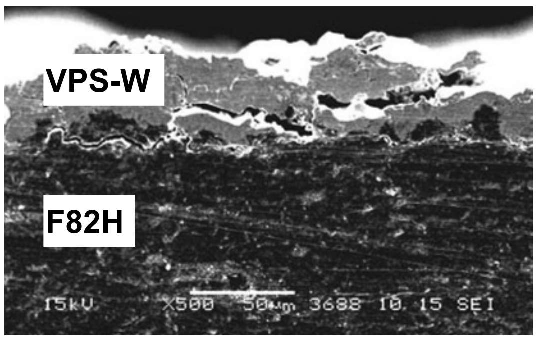

Fig. 1 SEM image of cross section near interface between VPS-W and F82H of sample after heat loading of experimental condition (3)