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High heat loading properties on tungsten coated low activation material
タングステン被覆低放射化材料の高熱負荷特性

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Heat loading experiments on tungsten coated reduced activation ferritic/martenstic (RAF/M) F82H (Fe-8Cr-2W) by produced by Vacuum Plasma Spraying (VPS) have been carried out. In addition, quantitative analyses about temperature profile and thermal stresses have been carried out using the finite element analysis (FEA) to evaluate thermal property. Distribution of thermal stress at a heat flux of 8 MW/m^2 has been quantitatively calculated by the thermal analyses.

1. Introduction

Reduced-activation ferritic/martensitic steel (RAF/M) is a leading structural material candidate of the first wall/blanket and the cooling channels of the divertor structural material for DEMO. Furthermore, tungsten (W) coatings/jointing on RAF/M is planning to be used because of low erosion yield and good thermal properties of tungsten [1].　However, CTE of RAF/M is about 2 times larger than that of W. As a result, thermal stress would be applied between them by temperature increase when the heat loading from plasma is exposed to W surface.

In the present works, W coatings on RAF/M have been produced by Vacuum Plasma Spraying (VPS) and heat flux experiments on them have been carried out to evaluate their possibility as a plasma-facing armor in the fusion device. In addition, quantitative analyses about temperature profile and thermal stress have been carried out using the finite element analysis (FEA) to evaluate thermal property.

2. Experimental

W coatings with a thickness of 0.6 mm on reduced-activation ferritic/martensitic steel (RAF/M) F82H (Fe-8Cr-2W) have been produced by Vacuum Plasma Spraying (VPS).　The W coated F82H was machined to the dimensions of 10 mm × 10 mm× 5.6 mmt (W: 0.6mmt, F82H: 5mmt) followed by mechanical polishing.

Heat load experiments on the W-coated F82H using an electron beam have been carried out by an electron beam irradiation test simulator of the Research Institute for Applied Mechanics, Kyushu University. Schematic illustration of the electron beam irradiation experiments is shown in Fig. 1

Samples are fixed on a water-cooled Cu block using a sample retainer with an aperture of 6mm. Electron beam at 20 keV is irradiated on the center of tungsten.

Heat flux is evaluated using a net electric current, which is measured by applying a bias voltage of 100 V to the samples to suppress secondary electrons induced by the electron beam irradiation. Ejection of thermal electrons from the heated surface is also suppressed by the bias voltage.　Surface temperature of the W surface is measured with optical pyrometers. Temperatures of F82H and the Cu block are also measured with thermocouples. The position for measurement point of F82H is also indicated in Fig. 1. In addition, gas emission from the heated sample is measured using QMS. Before and after the irradiation, the sample surfaces are examined by SEM. Weight loss of the sample is also measured with an electronic balance.

3. Thermal and stress analyses

The thermal and elastic stress analyses have been performed for the W/F82H using the finite element code ANSYS to evaluate quantitative thermal property. Fig.2 shows the model using in the present analyses. Only quarter of the geometry is considered due to symmetry. Symmetric boundary condition is defined at symmetry plane of the model. For thermal conductivity, coefficient of thermal expansion, elastic modulus and Poisson ratio of W and F82H, temperature dependence data has been used [2,3]. It is reported that thermal conductivity and elastic modulus of VPS-W decreases to 30%～50% and 20%～50% of pure W, respectively [4]. Therefore, in the present works, values of thermal conductivity and elastic modulus of VPS-W are used as 40% and 35% of pure W, respectively. The other physical values are used that of W. Steady-state temperature profile and stress at heat flux of 8 MW/m^2 are calculated when base plane of F82H is 20°C.

4. Result of thermal and stress analyses

Fig.3 shows Mises stress distribution near boundary of W and F82H at a heat flux of 8 MW/m^2. In this case, it is found that stress of 620 MPa is applied near boundary between W and F82H. Fig. 4 shows stress profile of X and Y directions. It is indicated that stress of F82H near W is applied to direction of center of the sample, and stress of W near F82H to direction of outside increases with the approaching to outside of the sample. In addition, stress is applied to direction from F82H to W near boundary of W and F82H of outside.

5. Future plans

Temperature profile will be required to be coincident with the experimental data by varying the physical parameter of W, and the contact condition of F82H and the active cooling Cu. Accurate evaluation of thermal property of the sample will be also required by comparison with stress calculated and observation of the sample after the experiment.

References

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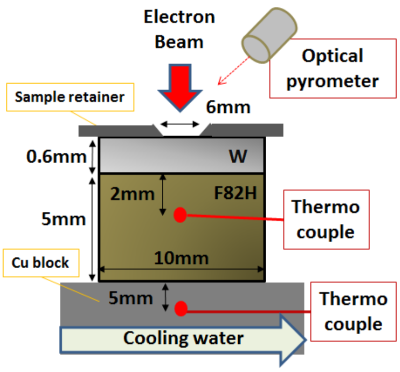

Fig.1 : Schematic illustration of the electron beam irradiation experiment

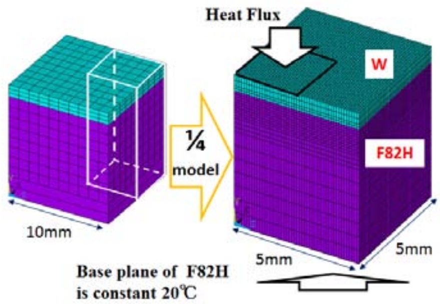

Fig.2 : 1/4 model using FEM

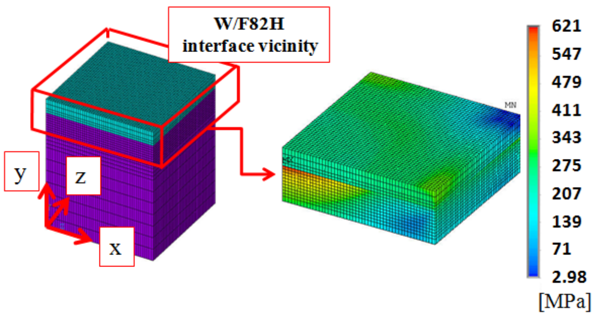

Fig.3 : Mises stress distribution at a heat flux of 8MW/m^2

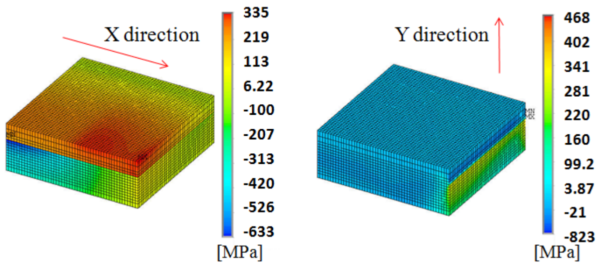

Fig.4 : X and Y direction distribution of stress