Design of a Pre Slit for the SPring-8 Undulator Beamlines（2）

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1. Introduction

Utilizing volumetric heating techniques, an isometric densified graphite (ISO-88; manufactured by TOYO TANSO) is adopted as the irradiated body of the pre slit on the front ends of the standard undulator beamlines to handle the very intensive photon beam. As the irradiated body is joined with a cooling holder made of oxygen-free high-conductivity copper (OFHC) by brazing, as shown in Fig.1, we had performed various evaluating tests and analysis focusing mainly on the strength of the brazed joint[1]. Here we describe;

(1) fatigue strength evaluation test of the brazed joint,

(2) comparison the results of strength evaluation tests with analysis for the practical model,

(3) vacuum performance test of the graphite.

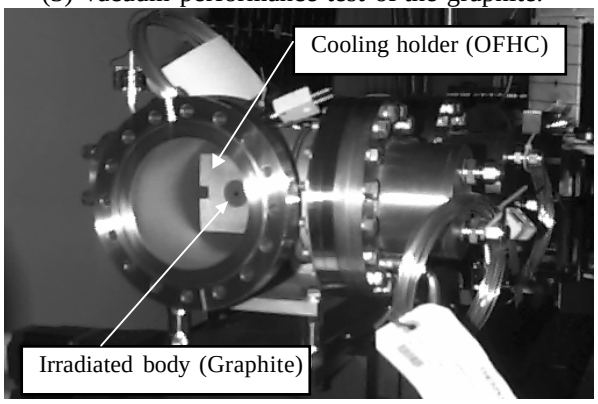


Fig.1. Picture of the pre slit assembly.

2. Strength of the Brazed Joint

2-1 Fatigue strength evaluation test

We performed the fatigue strength evaluation tests of the brazed joint for the combination of the graphite and OFHC in both tensile and shearing directions using an electro-hydraulic-servo fatigue testing machine. The shape of testpieces was the general butt joint style. The load was given by sine wave whose frequency is 5 HZ, and the stress ratio, the ratio of minimum stress (σ_{min}) to maximum stress (σ_{max}), is set at 0.1. Although some testpieces were broken while arrangement, we could obtain the fatigue curves (S-N curve) in both tensile and shearing directions, which show the relationship between the stress amplitude ($=(\sigma_{max}-\sigma_{min})/2$) and the cycles until the fracture as shown in Fig.2. As for the shearing direction, if the 10000 cycles is required for the design life, it is assumed that the stress amplitude should be less than about 1 kgf/mm^2.

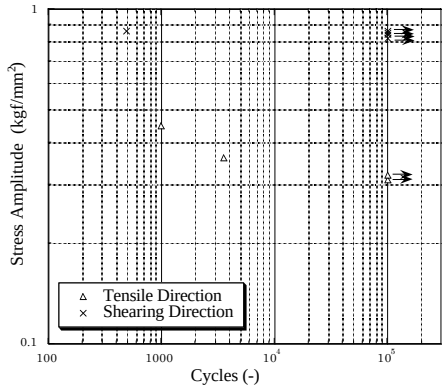


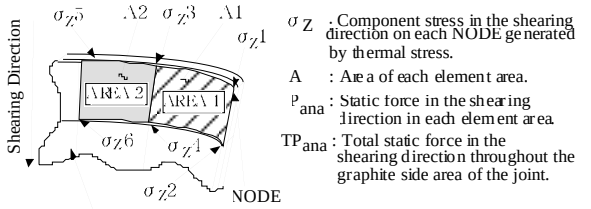
Fig.2. Fatigue curves (S-N curve) of the brazed joint for the combination of the graphite and OFHC in both tensile and shearing directions.

2-2 Comparison the test results with analysis

The ANSYS finite element analysis for the practical model was performed on the same boundary conditions as that for the prototype model[2]. The calculated maximum thermal stresses represented by Mises's equivalent stress are 1.6 kgf/mm^2 at a deflection parameter of the undulator (K) of 1.5 and 3.6 kgf/mm^2 at K=2.3 on the brazed joint, respectively. The component stress distributions on nodes in the graphite side area of the joint are also obtained, where the exfoliation of the joint was occurred on the static strength evaluation test[3]. We judged the resultant stress values and distributions by the two aspects, namely the static strength and the fatigue strength as follows;

(1) Static strength

Summing up the component forces in the shearing direction throughout the graphite side area of the joint using the component stress on each node, as shown in Fig.3, we estimated the static forces of the area generated by the thermal stress in the shearing direction at 700 kgf at K=1.5 and 1560 kgf at K=2.3, respectively. Comparing the above static forces with the value of 1730 kgf which is the necessary force to exfoliate the joint in the shearing direction obtained by the static strength evaluation test[3], it can be said that a fracture of the brazed joint in the shearing direction by the thermal stress would not occurred even at K=2.3 of highest heat load undulator operation.



$$P_{ana}1 = A1 \times (\sigma_{z}1 + \sigma_{z}2 + \sigma_{z}3 + \sigma_{z}4)/4)$$
$$P_{ana}2 = A2 \times (\sigma_{z}3 + \sigma_{z}4 + \sigma_{z}5 + \sigma_{z}6)/4)$$
$$\cdot$$
$$\cdot$$
$$TP_{ana} \quad \Sigma P_{ana}$$

Fig.3. Summing up the component forces in the shearing direction throughout the graphite side area of the joint using the component stress on each node.

(2) Fatigue strength

Comparing the equivalent stress of 1.6 kgf/mm^2 (K=1.5) whose stress amplitude is 0.8 kgf/mm^2 with the fatigue curve shown in Fig.2, we can say that the design life of the joint would be more than 10000 cycles. But, as for K=2.3, as the stress amplitude exceeds the criteria of 1 kgf/mm^2, the design life of the joint would be assumed to be less than 10000 cycles.

3. Vacuum Properties of the Graphite

As the graphite is essentially porous, we made a vacuum performance test of the graphite using an ultra-high vacuum test stand by comparing the states of pressure descent and ultimate pressures of the test stand after the bakeout between with and without samples. Figure 4 shows the schematic diagram of the test stand and the detail of sample geometry. The main pumping system of the test stand is composed of titanium getter pump (TGP) and sputter ion pump (SIP), and the pressure is monitored by two type of gauges, namely Bayard-Alpert nude gauge (BAG) and extractor gauge (EXG).

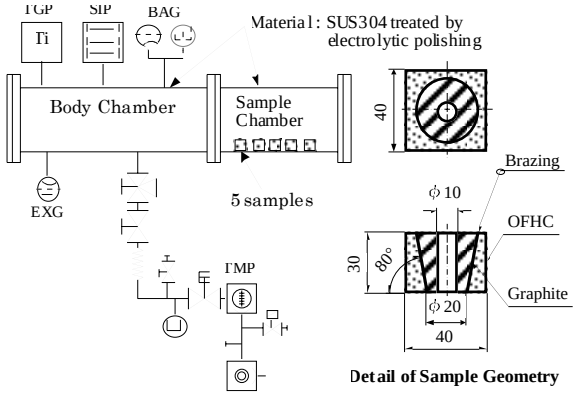


Fig.4. Schematic diagram of the ultra-high vacuum test stand and the detail of sample geometry.

The samples were manufactured by the same procedure as the practical use indicated in Table 1, because vacuum properties of a product shall be influenced significantly by how was treated during each manufacturing process, especially machining and cleaning.

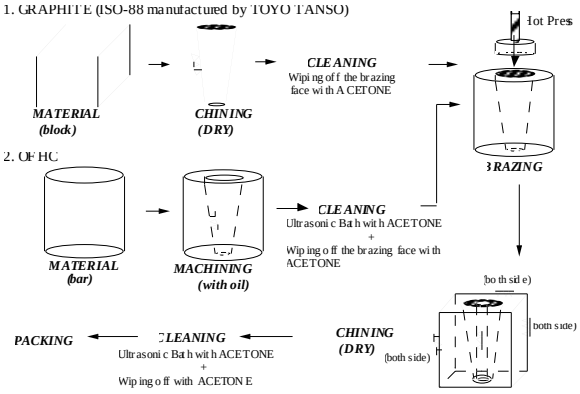


Table 1. Flow chart of the manufacturing process of the samples for the vacuum performance test.

Figure 5 shows that the states of pressure descent after 250˚C x 48 hrs bakeout with and without samples. Considering the effect of dark current, the value of BAG was revised to be the gauge indicated value minus 2 x 10^{-11} Torr. The pressure in case of with samples is decreased to 1.3 x 10^{-11} Torr (EXG) or 7.2 x 10^{-11} Torr (BAG) in about 90 hrs after the bakeout, when the ultimate pressure is observed in case of without samples. Continuing the pumping at room temperature, the pressure is decreasing slowly but sometimes at a stretch, and reaches the ultimate pressure, which equals to that in case of without samples in about 400 hrs after the bakeout. Drastic change at about 350 hrs is caused by the rapid change of the room temperature from 18 ˚C to 28 ˚C.

Consequently, although the pressure descent rate in case of with samples is milder then that in case of without samples, from a viewpoint of a thermal desorption, this graphite is competent for a structure material of front ends components on condition that it is treated by the prescribed procedure. Furthermore, although the test stand is not the type which can measure a material's outgassing rate quantitatively, we try to estimate that of the graphite. Assuming that

1) the outgassing rate of the chamber material (SUS304 treated by electrolytic polishing) is 3 x 10^{-12} Torr•l/sec•cm^2 which equals to the value obtained when pumping at room temperature in about 24 hrs after 250˚C x 30 hrs bakeout[4],

2) the outgassing rate of OFHC is less than that of SUS304 treated by electrolytic polishing,

3) the outgassing rates of SUS304 and OFHC are inversely proportional to a pumping time,

the outgassing rate of the graphite is estimated at 8.5 x 10^{-11} ~ 1.4 x 10^{-10} Torr•l/sec•cm^2 when pumping at

room temperature in about 180 hrs after 300˚C x 48 hrs bakeout[5].

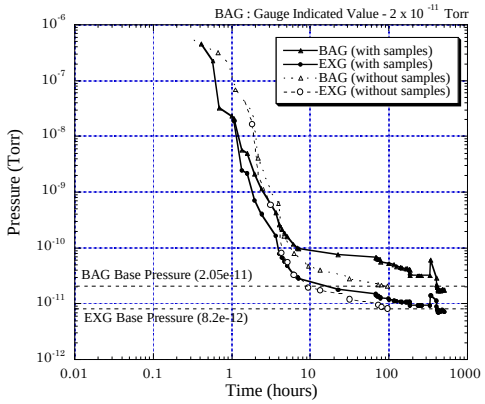


Fig.5. Measured pressures by BAG and EXG after 300˚C x 48 hrs bakeout in case of with and without samples.

References

[1] S.Takahashi et al., SPring-8 Annual Report 1995, P183

[2] S.Takahashi et al., SPring-8 Engineering Note, FE-011-95 (1995.11.28).

[3] S.Takahashi et al., SPring-8 Engineering Note, FE-010-96 (1996.9.10).

[4] J,R,Young, J. Vac. Sci. Technol.6 (1969) 398.

[5] S.Takahashi et al., SPring-8 Engineering Note, FE-007-96 (1996.7.23).