Design of a Pre Slit for the SPring-8 Undulator Beamlines (3)

Sunao TAKAHASHI, Yoshiharu SAKURAI and Hideo KITAMURA

SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan

1. Introduction

We have been continuing Research and Development for the volumetric heating technique, which is applied to the pre slit on the front ends of the standard undulator beamlines to handle the very intensive photon beam[1,2]. To enhance strength of the brazed joint and besides vacuum properties, we have started to investigate the application of a beryllium (BH-2; manufactured by NGK INSULATORS, LTD.) to the irradiated body of the pre slit in place of graphite. Here, we describe;

(1) thermal and thermo-mechanical analysis for the beryllium type pre slit,

(2) strength evaluation tests for the joint between beryllium and oxygen-free high-conductivity copper (OFHC),

(3) vacuum performance test for the beryllium.

2. Analysis

For the preliminary estimation, the ANSYS finite element analysis for the beryllium type pre slit was performed at a deflection parameter of the undulator (K) of 2.3 for the same configuration and on the same boundary conditions as that for the present graphite type pre slit[3]. Although there is no problem regarding the calculated maximum temperatures of the irradiated body, the brazed joint and the cooling surface, the calculated maximum thermal stress on the irradiated body represented by Mises's equivalent stress is 31.51 kgf/mm^2, which exceeds the tensile strength of beryllium of 28.0 kgf/mm^2. This problem is occurred because the modules of longitudinal elasticity for beryllium is comparatively high, namely about 30 times as much as that for graphite. Therefore, we try to modify the shape of fixed mask portion by way of the following parameters, that is tapered angle of irradiated body (Ai), tapered angle of brazed joint (Aj), size of irradiated body (Si) and location of cooling channel (Lc), as shown in Fig.1. Table 1 shows the parameters and the results of thermal and thermo-mechanical analysis for each cases. Summing up the component forces in the shearing direction throughout the beryllium side area of the joint using the component stress on each node, the total static forces of the area generated by the thermal stress in the shearing direction are also calculated, whose estimation will be discussed in the next paragraph[4].

Except the original design configuration (Case 1-1), the maximum thermal stresses on the irradiated body could be less than 28.0 kgf/mm^2. The reduction of Si (Case 3-1, Case 3-2) can decrease the thermal stress on the irradiated body fairly, but the total static force cannot be decreased significantly. The modification of Lc (Case 4-1) hardly influence on the analysis results.

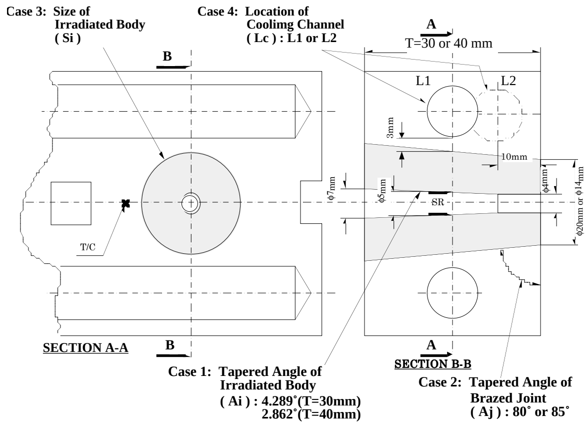

Fig.1. Parameters for the modification of fixed mask portion.

	Case 1-1	Case 1-2	Case 2-1	Case 3-1	Case 3-2	Case 4-1
1. Parameters						
Ai :	4.289 (T=30mm)	2.862 (T=40mm)	2.862 (T=40mm)	2.862 (T=40mm)	2.862 (T=40mm)	2.862 (T=40mm)
Aj : Brazed Joint	80	80	85	80	85	85
Si :	φ20／80	φ20／80	φ20／85	φ14／80	φ14／85	φ20／85
Lc : Cooling Channel	L1	L1	L1	L1	L1	L2
2. Resultes of Analysis						
Max. Temperature ( )						
Irradiated Body	194.8	177.54	175.68	170.74	167.94	174.25
Brazed Joint	81.17	79.09	77.90	83.62	82.37	75.65
Cooling Surface	64.22	61.00	61.26	62.12	63.32	65.09
Max. Thermal Stress (kgf/mm2)						
Irradiated Body (Be)	***31.51***	27.13	26.52	24.05	23.00	26.20
Brazed Joint (Be/Ag/OFHC)	6.03	5.30	4.90	5.80	6.11	5.28
Cooling Holder(OFHC)	4.99	4.46	4.56	4.67	4.64	4.46
Brazed Joint in the shearing direction						
Min.component stress (kgf/mm2)	-3.28	-2.98	-2.99	-3.62	-3.85	-2.88
Total static force throught Be side area (kgf)	***-5266***	***-6257***	***-5366***	***-5486***	***-4631***	***5266***

Table1. Results of thermal and thermo-mechanical analysis according to each parameters.

3. Strength Evaluation Tests

We manufactured two types of test pieces for static strength evaluation tests, whose shapes are corresponded to Case 2-1 and Case 3-2 indicated in Table 1, respectively. From a viewpoint of a reliability of a joint, we applied the brazing method to the combination between beryllium and oxygen-free high-conductivity copper (OFHC) with silver base braze alloy (InCusil-ABa).

Applying load in the axial direction on beryllium by a loading bar, while fixing OFHC, we measured the necessary load to exfoliate the brazed joint (separate beryllium from OFHC)[4]. Because the joint strength is much stronger than we expected, the loading bar is buckled before the exfoliation is occurred in some cases. So, as we regard a necessary force to exfoliate the joint as a force obtained when an exfoliation was started, they are more than 13000 kgf and 6600 kgf for Case 2-1 and Case 3-2, respectively.

Comparing the above forces with the calculated total static forces of 5366 kgf for Case 2-1 and 4631 kgf for Case 3-2, indicated in Table 1, it can be said that a fracture of the brazed joint in the shearing direction by the thermal stress would never even started. And, also, we can say that the strength of the joint for the beryllium type pre slit is much stronger than that for the graphite type pre slit[4].

Furthermore, the fatigue strength evaluation test is now prepared.

4. Vacuum Properties of the Beryllium

We made a vacuum performance test of the beryllium by the same method as the case for graphite, namely using the same ultra-high vacuum test stand, the same sample geometry, the same number of samples and the same manufacturing process[2,5].

Figure 2 shows that the states of pressure descent monitored by Bayard-Alpert nude gauge (GAG) after 250˚C x 48 hrs bakeout with samples made of beryllium, and also shows that in case of with samples made of graphite for comparison. Considering the effect of dark current, the value of BAG was revised to be the gauge indicated value minus 2.6 x 10^{-9} Pa. The pressure in case of beryllium is decreased to 1.0 x 10^{-9} Pa in about 50 hrs after the bakeout, which is less than the ultimate pressure in case of without samples (=2.7 x 10^{-9} Pa). We assume that this reversed phenomenon is caused by exchanging a titanium getter pump head to new one before the test for beryllium. Anyway, from the both viewpoints of the states of pressure descent and the ultimate pressure, we can concluded that the vacuum properties of beryllium is much superior to that of graphite.

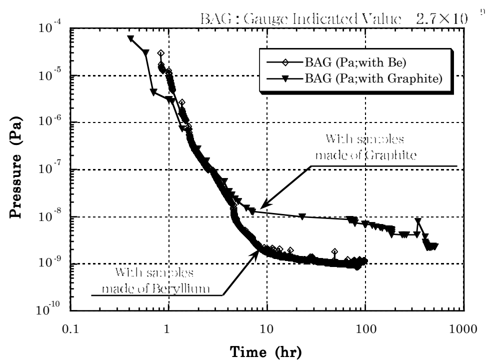

Fig.2. Pumping curves measured by BAG after 300 ˚C × 48 hours bakeout in both cases of with samples made of beryllium and with samples made of graphite.

References

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

[2] S.Takahashi et al., SPring-8 Annual Report 1996, P191

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

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

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