DEVELOPMENT OF A NEW SUPPORT-STAND WITH HIGH THERMAL-STABILITY FOR THE SCSS PROJECT

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Abstract

A new support-stand with high thermal-stability was developed for the Spring-8 Compact SASE [1] Source (SCSS) project [2]. The support-stand is composed of cordierite (2MgO $2Al_2O_3$ $5SiO_2$) body attached with two flanges at top and bottom. Because the cordierite material has the low thermal expansion rate of about 10^{-6} (1/ ^{0}C), the newly developed support-stand has a comparable thermal-stability. Seven new support-stands were successfully produced. The design of the support-stand as well as the measurements of the thermal expansion rate, weight-load and impact tolerance for the support-stand would be presented.

INTRODUCTION

In order to obtain necessary intensity of soft X-ray Free Electron Laser (FEL) light in the SCSS project, the alignment precision of Beam Position Monitors (BPM) is critical. The intensity of light would degrade to half of the ideal light intensity at the beam-energy of 1 GeV if the alignment error becomes 40 μm in x and y coordinates [3]. Therefore, the alignment precision should be controlled as accurately as possible. One of the major sources of the BPM alignment error is the fluctuation of air-temperature which ranges from 1 to 2 ^{0}C in the hall.

In this situation, we found that the cordierite material has low thermal expansion rate and some products of the material are made by Daito and Kinden Corporations. Then we made a collaboration to produce new support-stands for the SCSS project.

CHARACTERISTICS OF CORDIERITE MATERIAL AND PRODUCTS

The cordierite material has the components of (2MgO $2Al_2O_3$ $5SiO_2$). The thermal expansion rate of pure cordierite material is about 0.15 (10^{-6} 1/^{0}C). This value is lower by about one-order of magnitude than usual materials, e.g. iron: 15, ceramics: 7, granite: 5-15, marble: 8-26, concrete: 7-13.

In the first process of making cordierite products, appropriately mixed ingredients, mainly of talc and clay, are used to make body shapes. Then they are burned in a furnace at the temperature of 1,300 ^{0}C to yield the cordierite component in the body. The components of final product are not pure cordierite, and the expansion rate is ranging from 1 to 4 (10^{-6} 1/ ^{0}C) product by product, although rather uniform rate is kept in the same burning lot. Owing to the water absorption rate of 0 % for cordierite products, the long-term stability of dimension is excellent. Usual cordierite products are high-voltage insulators for transmission line. Main parameters for cordierite products are shown in Table 1.

Table 1: Characteristics of cordierite products.

Parameter		Unit
Density	2.2	g/cm^2
Water absorption rate	0.0	%
Elastic coefficient	7	10^6 N/cm^2
Thermal expansion rate	1 – 4	10^{-6} (1/ ^{0}C)

DESIGN OF CORDIERITE SUPPORT-STAND AND PRODUCTION

Beam-line height from floor in conventional linac-accelerators is usually more than one meter. In the SCSS project, we considered BPM alignment error from the thermal expansion fluctuation of support-stands, and then we set the beam-line height to a lower value, i.e. 800 mm from the floor. Consequently, the height-dimension of the cordierite support-stand is designed as 575 mm. A picture of a completed product of the cordierite support-stand is shown in figure 1.

Figure 1: Completed product of cordierite support-stand.

Two flanges are attached at the top and bottom of the cordierite body with appropriate adhesive mortar-cement, which is used usually for cordierite high-voltage insulator products. The upper surface of the top flange is set higher by 5 mm than the top edge of the cordierite body. A pair of clamps is included to hold the support-stand onto floor. A special material is painted on the side-surface of the cordierite body for protection from impact. Sand is stuffed in the cordierite body to increase the heat capacity and insensitivity to noise vibration. The dimension of the cordierite support-stand is shown in Table 2. Nine cordierite support-stands were produced successfully in the same burning lot and two of them were broken in breakdown tolerance tests.

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Table 2: Dimension of cordierite support-stand.

Item	Part	(mm)
Support-stand	Height	575
Top flange	Outer diameter	480
Bottom flange	Outer diameter	625
Cordierite body (top)	Outer diameter	350
	Inner diameter	290
Cordierite body (bottom)	Outer diameter	500
	Inner diameter	440

MEASUREMENT OF THERMAL EXPANSION RATE

Because the expansion rate of the cordierite products have never been measured within the error of a few tens of percent and the rate would fluctuate lot by lot, we tried to measure the thermal expansion rate of the cordierite body of the support-stand. However, the measurement is not easy, because direct measurements of length would be usually done by instruments which themselves have much larger expansion rates than cordierite material. For this reason, we chose a relative measurement method by using two cordierite bodies without flanges.

Setup of the measurement

The setup of the measurement of the thermal expansion rate is shown in figure 2.

Figure 2: Setup of expansion rate measurement.

Two cordierite bodies without flanges were put on a precision granite table, where three small ceramic blocks were inserted between each body and the table in order to cut thermal contact. A massive brass bridge (length: 400, width: 80, height: 60 mm) was put between each top-edge of cordierite bodies, where two small ceramic blocks were also employed for thermal disconnection. The distance of the bridge girder is 210 mm. Each body is wrapped with aluminium foil and only one body (left one in figure 2) was heated using water which is kept at the temperature of 80 ^{0}C by a temperature-control instrument. A few meters of copper pipe was rolled onto the cordierite body to provide heated water and then sheets of thermal insulator were wrapped threefold. Each body was stuffed with thermal-insulation material. A simple chimney was set for the Heated Body (called HB hereafter) to make warmed air to escape upward.

Three level-meters with the accuracy of one micro-radian were put on the brass bridge to measure changes of flatness caused by the expansion of HB.

Eight Temperature-Sensors (called TS's hereafter) were set on the inner-side of HB and one TS was set for Room-temperature Body (called RB hereafter). Eight TS's were set onto the brass bridge because the bridge itself would have a non-uniform thermal distribution and might bend. This possibility was checked by the redundant measurements of flatness by three level-meters. The temperature of air and the granite table were also monitored.

Measurement

Measured temperature for the HB is shown in figure 3.

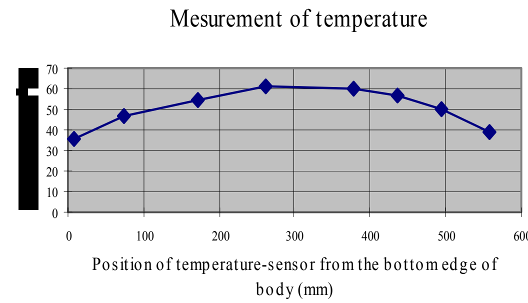

Figure 3: Temperature versus position of temperature-sensor from the bottom edge of the heated body.

Both the top and bottom edges of the body had about by 20 ^{0}C lower temperature than the centre position. This means that the heat escaped from both edges. The temperature of RB was 22.6 ^{0}C. There were differences of temperature between left and right, and also upper and lower parts of the bridge, i.e. 0.9 and 1.0 ^{0}C, respectively. However, the three level-meters gave the same change of flatness i.e. 148 μ radian. This means that the bridge did not bend and gave no distortion to this measurement. The temperature of air fluctuated by 1 ^{0}C during the measurement.

Estimate of the thermal expansion rate.

The changed flatness of 148 μ radian corresponds to the changed height of 31 μm for the arm of 210 mm. Among this, the thermal expansion of brass bridge contributes to 0.9 μm. The graph in figure 3 is used as the thermal distribution of HB. Assuming a uniform expansion rate over HB, the expansion rate of the cordierite body is calculated to be 1.9×10^{-6} (1/^{0}C).

BREAKDOWN TOLERANCE TEST

Weight-load and impact tolerance tests of the cordierite support-stand were performed. Setups and results of tests are described in this section.

Setup of the weigh-load tolerance test.

The setup of the weight-load test is shown in figure 4. The cubic metal-block of about 10 cm was put on the top flange and weight-load was applied to the block. Thus the weight-load was applied not in balance to the top flange. The displacement of the top flange was measured by a displacement micro-meter with putting the stylus of micro-meter onto the back-side of the top flange.

Figure 4: Setup of weight-load test.

Results of the weight-load tolerance test.

The results of the weight-load test are shown in figure 5

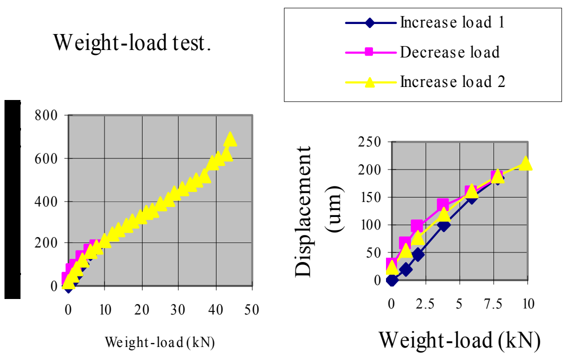

Figure 5: Results of the weight-load test. Left-hand-side: Displacement of the flange versus weight-load. Right-hand side: A zoom of the left-hand side plot.

Firstly, the weight-load was increased step by step up to 7.8 kN. This is shown in the figure 5 as blue points, where the top flange slipped at the mortar-cement part, which attaches the top flange and body. Then the weight was decreased inversely to zero, as shown by magenta points. At this step, the displacement of 25 µm was observed as a hysteresis. The weight was again increased as is denoted by yellow points. The cement part broke down at the weight-load of 44.7 kN (4.6 ton f), where the displacement of the top flange reached to 689 µm.

Setup of the impact tolerance test.

The setup of the impact tolerance test is shown by the left-hand side picture of figure 6. A stainless-steel plate was attached on the top flange of the support-stand and a guide-pipe was set on the plate. The plummet of 50 kg binding with a rope was put inside the guide-pipe. The rope was pulled up from the top-end of the guide-pipe to lift the plummet. If the plummet is released, it gives an impact on the stainless-steel plate, and thus the top flange. The displacement of the stainless-steel plate was measured by a displacement micro-meter by putting the stylus onto the surface of the plate.

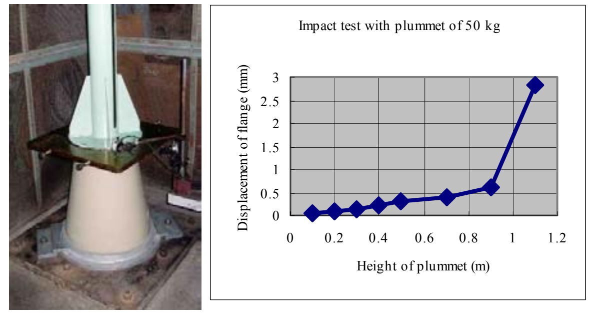

Figure 6: Setup and results of the impact test.

Results of the impact tolerance test.

The results of the impact tolerance test are shown in the right-hand side plot of figure 6. The releasing height of the plummet was increased step by step. A tip of mortar-cement dropped out at the plummet height of 0.9 m. Then in the next trial, i.e. the height of 1.1 m, the adhesive mortar-cement broke down. The displacement of the stainless board reached to 2.83 mm.

SUMMARY AND FURTHER STUDY

Nine cordierite support-stands were produced and two of them were used in breakdown tolerance tests. The thermal expansion rate of the cordierite body was measured as 1.9×10^{-6} ($1/^{0}C$). The mortar-cement part broke down at the unbalanced weight-load of 44.7 kN and the impact of 50 kg plummet at the releasing height of 1.1 m, respectively. The cordierite body was perfectly intact.

It was found that the adhesive mortar-cement is the weakest part of the support-stand. If the top flange is attached to the body so as the flange-surface is lowered by a few mm from the top-edge of the body, the weight can be loaded directly onto the cordierite body and the breakdown tolerance might be upgraded.

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REFERENCES

[1] Self-Amplified Spontaneous Emission.
[2] T. Shintake, "Status of spring-8 compact SASE source FEL project", NIMA21188, Nucl. Instr. Meth. A, 507 (2003) 382-397.
[3] T. Tanaka, H. Kimura, and T. Shintake, "Consideration on the BPM alignment tolerance in x-ray FELs.", Nucl. Instr. Meth. A, in press.