ENGINEERING DESIGN OF A MULTIPURPOSE X-BAND ACCELERATING STRUCTURE

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Abstract

Both FEL projects, SwissFEL and Fermi-Elettra each require an X-band RF accelerating structure for optimal bunch compression at the respective injectors [1]. As the CLIC project is pursuing a program for producing and testing the X-band high-gradient RF structures [2], a collaboration between PSI, Elettra and CERN has been established to build a multipurpose X-band accelerating structure. This paper focuses on its engineering design, which is based on the disked cells jointed together by diffusion bonding. Vacuum brazing and laser beam welding is used for auxiliary components. The accelerating structure consists of two coupler subassemblies, 73 disks and includes a wakefield monitor and diagnostic waveguides. The engineering study includes the external cooling system, consisting of two parallel cooling circuits and an RF tuning system, which allows phase advance tuning of the cell by deforming the outer wall. The engineering solution for the installation and sealing of the wake field monitor feed-through devices that are integrated in the accelerating structure are presented.

INTRODUCTION

The accelerating structure is 965-mm long and its weight is approximately 62 kg. The structure consists of 73 disks of which 19 are specially designed to host the wakefield monitor. The general view of the accelerating structure is shown in Fig. 1.

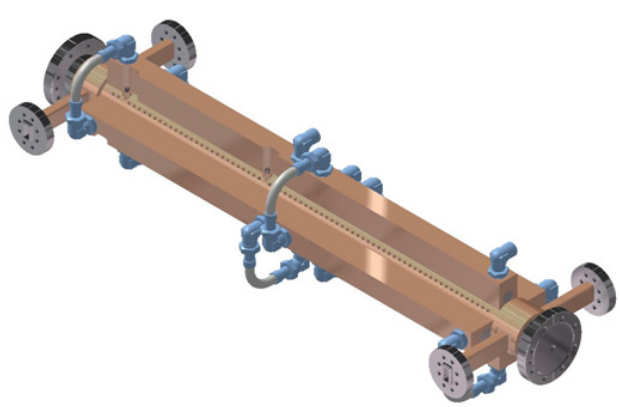

Figure 1: General view of the accelerating structure.

The assembly strategy of the whole structure was developed during the engineering design. The different components are conceived to cope with the alignment and assembly constraints. In the following chapters, the corresponding assembly sequence will be described.

The accelerating structure must be mechanically supported and aligned to the main beam axis of the accelerator within the precision of approximately 5 μm. This will be necessary in order to avoid the beam break-up instability growth due to short range transverse HOMs in the structure.

Two CF63 flanges at the extremities of the structure and four X-band WR90 RF waveguide vacuum flanges on the couplers were used for the vacuum and RF interfaces.

MECHANICAL DESIGN AND ASSEMBLY OF THE ACCELERATING STRUCTURE

Mechanical Design of Copper Disks and Couplers

The accelerating structure body consists of a stack of thick cylindrical copper disks, which are machined following the RF design of the cavity geometry. Two special regions are allocated to be used for monitoring the wakefields in the structure. The RF design for each complete wakefield monitor region was made first. Based on this, the mechanical design for each individual cell followed. The RF design of the special wakefield monitor cavity and its mechanical integration into the complete structure are shown in Fig. 2.

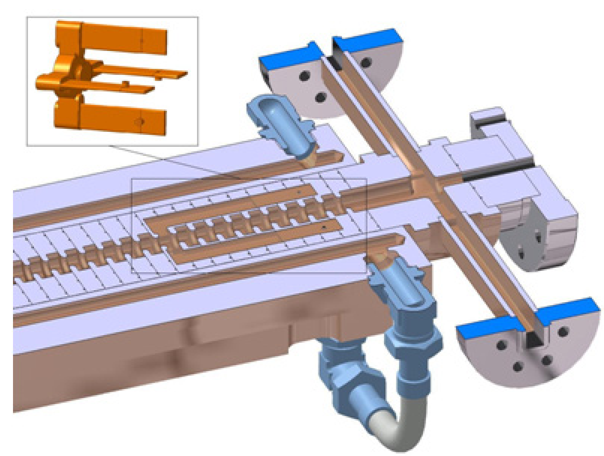

Figure 2: Wakefield monitor details.

The high-precision disks will be machined by single-point diamond turning. For the final RF frequency tuning, the disks are equipped with four radial holes. Each special wakefield monitor disk incorporates four coupling holes and is also equipped with tuning holes. The whole family of discs including the regular cell (A), the special wakefield monitor cell (B), the cells hosting the diagnostic waveguides (C-F) and the RF coupler (G) are shown in Fig. 3. 4-µm fabrication tolerance for the disk interior geometry, for the external disk cylindrical surface and for one of the structure extremity reference surface is requested. This value is relaxed to 10 µm for fabrication of the wakefield monitor part. The surface roughness for the disk's interior is Ra 0.025 and Ra 0.1 for the wakefield monitor.

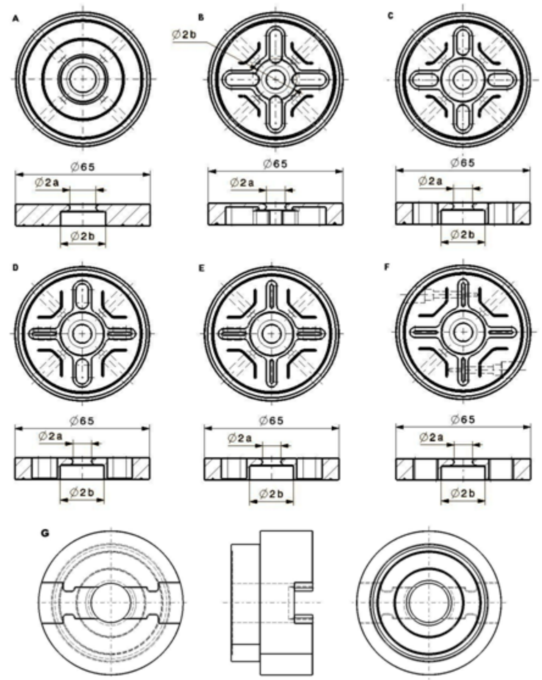

Figure: 3. Technical drawings for a selected number of different disks.

Assembly of the Accelerating Structure Body

The assembly procedure must guarantee a firm and vacuum tight interface between the adjacent copper disks. Various misalignments, such as disk-to-disk transverse misalignment, bowing due to disk slips or bending and book-shelving errors should be avoided or minimized during the assembly. The assembly tolerance is 10 µm. The reference surfaces for assembly are the external disk diameter Ø65±0.002 mm and the flat surfaces of each disk with a flatness accuracy of 2 µm.

The structures will be assembled by diffusion bonding under H_2 at about 1000°C; nevertheless, if following the prototype phase, the vacuum brazing at about 800°C will be required, all the disks are equipped with special slots and cavities for brazing alloy installation and flow (see Fig. 3). In this case the brazing material should be made of wires with diameter from 0.5 mm to 1.0 mm. The brazing alloy could be silver-copper or gold-copper based (for example AuCu or AgCuPd). Each of them has a different brazing temperature. The volumes of the cavities and slots were calculated using the following equation:

$$V_{BM} = 1.5 \cdot V_{BC}$$

V_{BM} – Volume of brazing material

V_{BC} – Volume of brazing material cavity and slots

For each individual disk, the corresponding volumes of the cavities and slots for the brazing material installation were calculated using the Mechanical Design Module and Measurement tool of PLM-system CATIA [3]. In the case of diffusion bonding, these slots and cavities are not used but they do not affect the joining process.

Subassembly of the RF Coupler

The diffusion bonding process is used to join the high-precision parts of the coupler body. The vacuum brazing is used afterwards to join the other components: waveguides, stainless steel adapters and vacuum flanges (see Fig. 4). Finally, the assembled couplers are brazed to the bonded disk stack at a lower (760°C) temperature.

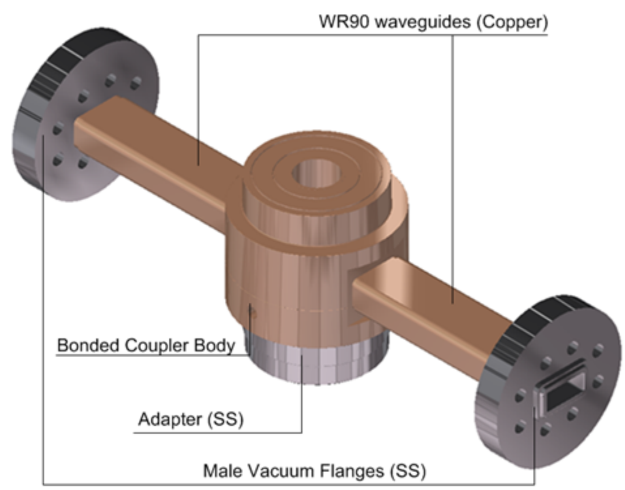

Figure 4: General view of coupler subassembly.

Design and Assembly of the Tuning System

The final RF frequency tuning system is integrated into the accelerating structure. It is based on a push-pull principle (the system was developed in SLAC [5]) and allows an increase or decrease of the equivalent outer diameter of each cell, by deforming the cell's thin wall and thus tuning the cell RF frequency. The system uses the special tuning studs brazed inside each of the four tuning holes. The tuning device linked to the tuning stud is shown in Fig. 5. Two configurations of the tuning studs with internal and external threads have been studied. The tuning operation consists of several steps:

- Screw the threaded tube of the device on the tuning stud in the structure.
- Clamp the slider assembled with hammer on the tube by means of the lock integrated in the device.
- Slide the hammer along the rod by applying pushing or pulling forces, depending on the RF frequency correction which is required.

To braze the tuning studs inside the disks, the brazing alloy is used. The location of the wire-type brazing alloy is shown in Fig. 5.

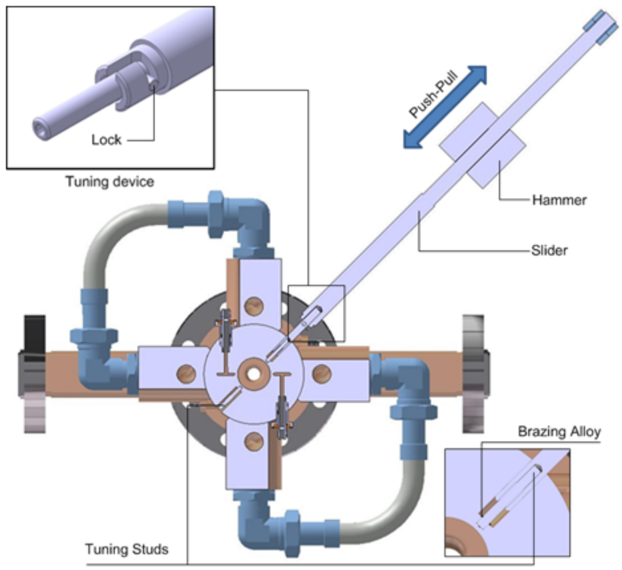

Figure 5: Tuning system of the accelerating structure.

Design and Assembly of the Cooling Circuit

The water cooling system was designed to cope with the average power dissipation in the structure of about 0.3 kW. The cooling system itself consists of eight cooling blocks each of 394 mm long. They are brazed directly onto the accelerating structure body with a thin foil of the brazing alloy. After the brazing operation, a good thermal contact between the cooling blocks and the structure body is provided, insuring the required heat extraction. Water is supplied at two points: at the end and at the middle of the structure. The two cooling circuits give a uniform temperature distribution along the structure. The temperature difference between inlet and outlet is about 10°C. Cooling hoses are attached to the cooling blocks by means of standard water connectors. The cooling fittings are connected to the accelerating structure at the very end of the assembly procedure.

Installation and Sealing of the Wakefield Monitor Feed-through Connectors

The design of the wakefield monitor feed-through is based on the standard commercial product by Orient Microwave Corp. [4] and cannot be heat treated over 125°C due to the presence of internal ceramic insulators. During the engineering phase, a dedicated adapter from the standard feed-through to the accelerating structure body was designed. The adapter (see Fig. 6) consists of two parts: the copper flange (coloured in orange) and the stainless steel tube jointed together by vacuum brazing. The subassembly is then laser welded to the standard feed-through. This technology guarantees the local heat load and does not affect the ceramic insert. The final, vacuum tight connection of the feed-through assembly is made by electron beam welding, as shown in Fig. 6.

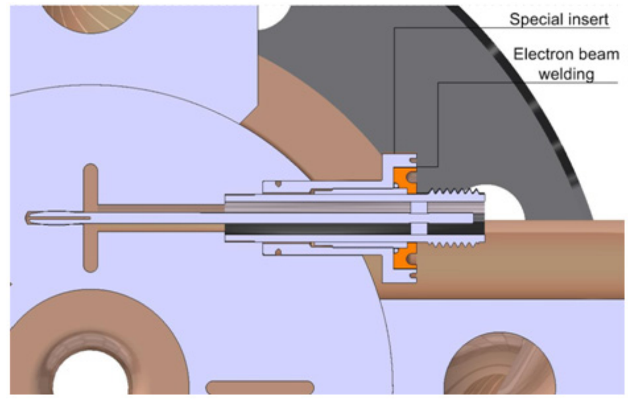

Figure 6: The RF feed-through installation.

A good electrical contact is necessary between the accelerating structure body and the wakefield monitor pick-ups. As a standard solution is not available on the market, a special design of the antenna was developed (see Fig. 7). Here, after installation of the antenna, the four petals will be deformed enough to provide good electrical contact between the antenna and the rest of the surface in the special pick-up hole.

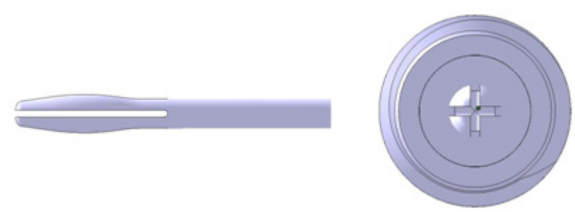

Figure 7: The custom design of the feedthrough antenna.

Connecting the Vacuum Flanges

The connection of the beam pipe vacuum flanges is one of the last operations. It is done using the TIG (tungsten inert gas) welding. This is necessary to avoid the dulling of the knife-sharp edge of the stainless steel CF63 vacuum flange, which can occur during bonding or brazing process.

REFERENCES

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