

ENGINEERING DESIGN AND FABRICATION OF TAPERED DAMPED X-BAND ACCELERATING STRUCTURES

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Abstract

The accelerating structures (AS) are one of the main components of the Compact Linear Collider (CLIC), under study at CERN. Each accelerating structure contains about 30 copper discs, which form the accelerating cavity. The requirements of different technical systems, such as vacuum and cooling, have to be considered during the engineering design. A fully featured AS is very challenging and requires several technologies. Different damping methods, waveguides, vacuum manifolds, slots and chokes, result in various design configurations. In the CLIC AS each cell is damped by means of four waveguides coupled to the cell. The vacuum manifolds combine a number of functions such as damping, vacuum pumping and cooling. A silicon carbide absorber, fixed inside of each manifold, is required for effective damping of Higher Order Modes (HOMs). This paper describes the engineering design of the X-band AS with damping material, and focuses on few technical solutions.

INTRODUCTION

Several AS have been tested over the past few years in the context of the CLIC study. Based on the test results, the RF design of the structure has been refined [1]. The current basic cell geometry is quite similar to the TD24 geometry [2], but differences are related to the number of regular cells and to the coupler design. Due to the new, so-called compact coupler design, the number of cells in the refined structure changes from 24 to 26 and the overall length is reduced. The coupler cell has two opposite WR90 waveguide connections and other two waveguides which are used for HOM damping as in the regular cells.

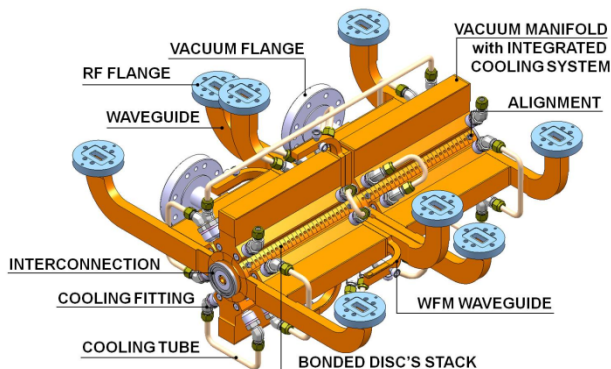


Figure 1: 3D view of a superstructure.

Accordingly, a new engineering design has been developed. The body of an AS is formed by high-precision copper discs joint by diffusion bonding at 1040°C. The structure has four vacuum manifolds and four Wakefield Monitor (WFM) waveguides. Two AS are brazed together to form a superstructure (SAS) (see Fig. 1).

The cooling system is integrated into the vacuum manifolds in order to provide a more compact technical solution. Based on thermal dissipation study, the cooling circuits of two structures are connected in series.

ENGINEERING DESIGN AND ASSEMBLY OF THE ACCELERATING STRUCTURE

Mechanical Design of Copper Discs and Compact Couplers

The design of the AS is based on OFE copper discs bonded together to form a stack. Each disc has an external diameter of 80 mm and includes four waveguides, housing the silicon carbide (SiC) absorbers to provide efficient damping of HOMs. The required geometry, dimensions and tolerances of each disc are based on the RF requirements. The shape tolerance of the RF cells is $\pm 2.5 \mu\text{m}$ and the surface roughness Ra is $0.025 \mu\text{m}$.

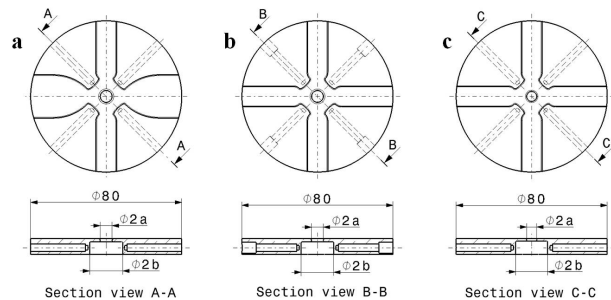


Figure 2: Technical drawings for different types of discs; a) compact coupler cell, b) cell with alignment features, c) regular cell.

The discs comprise four radial holes for the fine tuning of RF frequency. The different types of discs forming the accelerating structure body are shown in Fig. 2.

Mechanical Design of Vacuum Manifolds

Each cell is prolonged by channels machined in external vacuum manifolds (see Fig. 3). The shape tolerance of the waveguides is $\pm 10 \mu\text{m}$ and the surface roughness Ra is $0.1 \mu\text{m}$. A tight contact with the bonded disc stack is provided by brazing. Four vacuum manifolds are brazed directly onto the accelerating structure body by

means of a thin foil of the brazing alloy. The SiC absorbers [1] are fixed to the manifolds in order to efficiently suppress the transverse wakefields (see Fig 4). Two internal cooling channels for the water flow are present in each manifold. The interconnection between them is realized by external copper tubes connected to the manifolds by means of standard fittings. Two of the eight vacuum manifolds are equipped with vacuum flanges for pumping the superstructure.

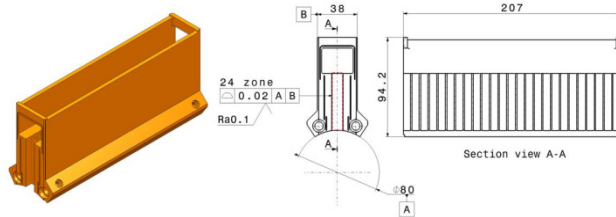


Figure 3: Technical drawing of a typical vacuum manifold.

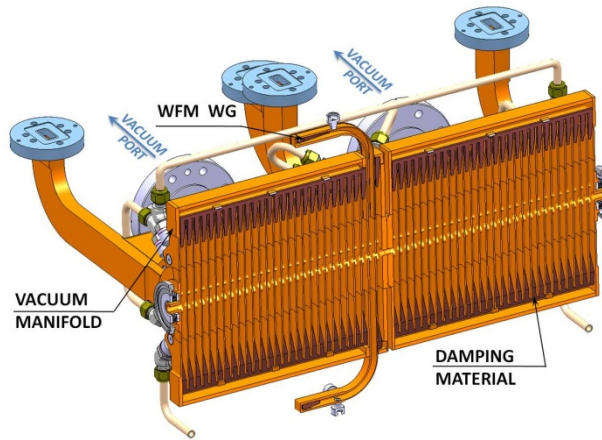


Figure 4: 3D section view of the superstructure.

Wakefield Monitor Design

In order to achieve high luminosity in CLIC, the accelerating structure must be aligned with respect to the main beam axis with an accuracy of $5 \mu\text{m}$. Four position detectors called Wakefield Monitors are integrated in the first regular cell of the second accelerating structure, extending the damping waveguide (WG) by the same section.

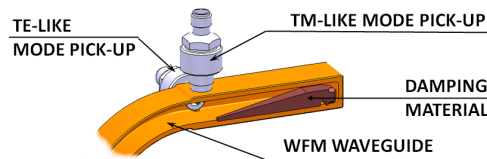


Figure 5: 3D view of the WFM.

Each WFM WG also ends in a SiC absorber. Two RF pick-ups (for TM-like and TE-like modes) [3] are fixed on the WFM waveguide for horizontal and vertical planes correspondingly. The WGs for the WFM are designed in two halves due to their technological complexity (see Fig. 5) and they are brazed together.

Interconnection

Another accomplished challenging task is the design of interconnections between two adjacent SAS. The longitudinal space allocated for one SAS is 502.5 mm, which is $\frac{1}{4}$ of the CLIC Module length [4]. Another requirement is a low pressure level (10^{-9} mbar) needed for beam physics and RF requirements. Both conditions must be taken into account, which complicates the interconnection design. Additionally the interconnections must provide the electrical continuity with low impedance, be flexible and must not restrict the alignment.

The damping material must be used also in the interconnection zone to avoid wakefields. Initially a longitudinal space between two SAS is defined by RF design. After a few iterations of the engineering design it has been decided to use a quick chain clamp connection. Present technologies made them available for the required level of UHV. The flange is fixed to the AS end via bellows in order to give flexibility for thermal elongation. The design of interconnection between two SASs is shown in Fig. 6.

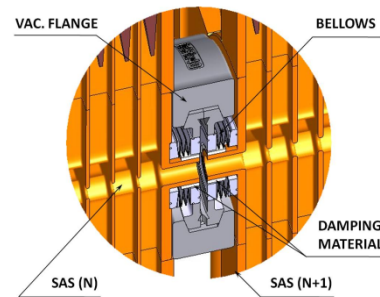


Figure 6: 3D view of the vacuum interconnection.

Alignment

The alignment features are placed on the external reference surface of the structure body, which is the most accurate link to the beam axis. Each AS is equipped with 8 stainless steel inserts brazed directly to the extremity of the tuning hole of the dedicated discs (see Fig. 7).

The insert has a conical bore on the top in order to provide a reference for the arm of the coordinate-measuring machine equipped with a standard probe diameter of 0.5 inches. The recorded coordinates of all points help to determine the AS beam axis and to re-align the AS properly.

Tuning System

The tuning system integrated into AS is based on a push-pull principle. It is possible to increase or decrease the internal volume of each cell by deforming the thin wall. For this reason each disc is equipped with four tuning studs brazed inside the tuning holes.

Assembly of the Accelerating Structure Body

The assembly of the superstructure components consists of several steps (see Fig. 8):

- Alignment of the cells in a dedicated V-shaped support. Based on the previous experience, a total accuracy better than 5 μm can be achieved.

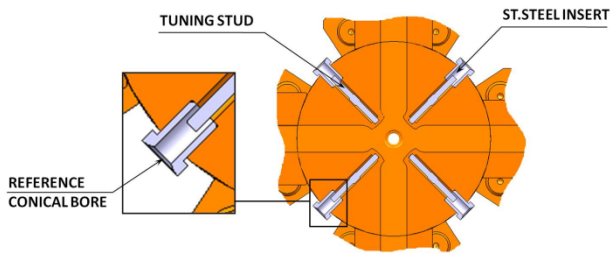


Figure 7: Alignment features of superstructure.

- Diffusion bonding of the discs under hydrogen at 1040°C.
- Pre-assembly and brazing of vacuum manifolds and waveguides at about 1000°C.

- Brazing of pre-assemblies (waveguides, WFM) to the vacuum manifolds at about 1000°C.
- Brazing of pre-assembled vacuum manifolds and interconnection bellows to the bonded disc stack at about 950°C.
- Brazing of the two equipped stacks to form a superstructure at about 900°C.
- Installation and fixation of the SiC damping loads.
- Electron beam welding of the interconnection vacuum flanges and vacuum manifold covers.
- Installation of the cooling tubes.
- Baking of the SAS. The SAS is then installed into a dedicated stainless container with separate high vacuum and baked in a vacuum furnace at 650°C for at least 10 days.

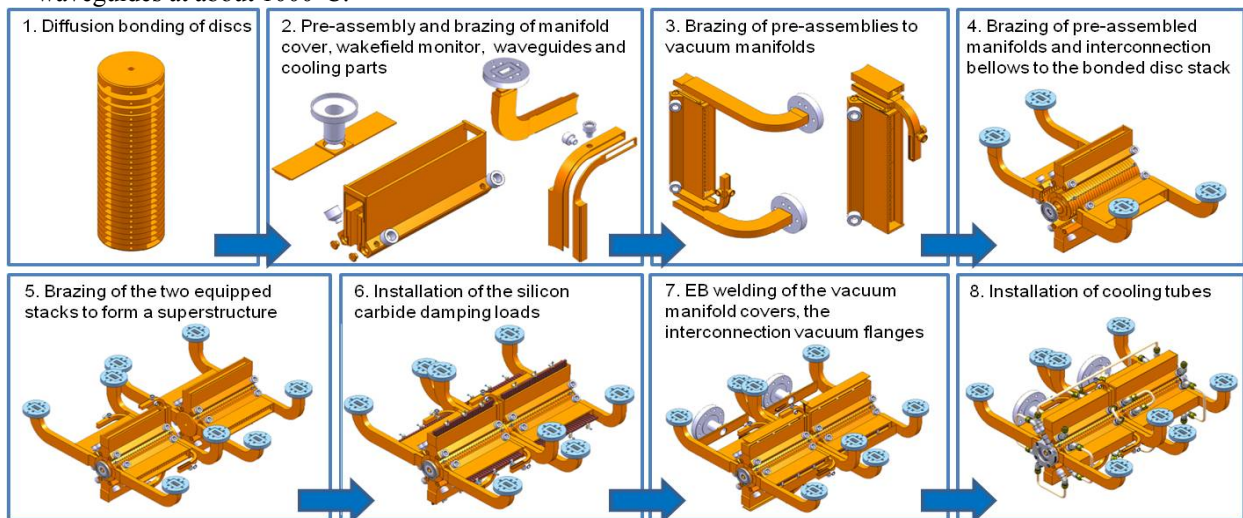


Figure 8: Main assembly steps of superstructure.

FABRICATION STATUS

The manufacturing process of the fully featured accelerating structure includes the following main steps: ultra-precision diamond machining in order to fulfil the RF requirements; surface treatment and all the assembly steps previously described. Diffusion bonding and several brazing cycles are needed under hydrogen atmosphere and at temperatures of about 1000°C. Different Au/Cu brazing alloys are required.

Before starting the machining of the discs, many qualification tests are being performed, i.e. the diffusion bonding for the compact coupler cells and vacuum brazing tests for joining the vacuum manifolds and the bonded disc stack. The contract for the machining of the discs has been adjudicated to an European company and the corresponding production will start upon the successful validation of the previous tests.

CONCLUSIONS

The design of the fully featured X-band accelerating structure has been developed. The engineering design has

been made considering the RF requirements and manufacturing constraints. Additionally all integration issues in the CLIC two-beam module are taken into account. The first structure is under fabrication and it is expected to be ready for high-power tests in the first quarter of 2012.

REFERENCES

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