RF DESIGN OF THE CLIC STRUCTURE PROTOTYPE OPTIMIZED FOR MANUFACTURING FROM TWO HALVES

Hao Zha, Alexej Grudiev, CERN, Geneva, Switzerland
Valery Dolgashev, SLAC, Menlo Park, CA 94025, United States

Abstract

We present the RF design of a 12GHz Compact Linear Collider (CLIC) main linac accelerating structure prototype. The structure is made from two longitudinally symmetric halves. The main manufacturing process of each half is precision milling. The structure uses the same iris dimensions as the CLIC-G structure [1] but the cell shape is optimized for milling. The geometry is optimized to reduce the surface electric and magnetic fields and the modified Poynting vector. This design can potentially reduce fabrication cost.

INTRODUCTION

Accelerating structures are usually manufactured by precision turning of individual cells, andcombined with precision milling for complex parts such as rf power couplers. These multiple parts are brazed into a complete structure. An alternative approach is the use of precision milling to cut cells into metal blocks that comprise either halves or quarters of the complete structure [2, 3].

In this paper we describean accelerating structure milled out of two halves and brazedtogether. One of the main motivations for this work is to study the high gradient performance of accelerating structures made with novel manufacturing methods. We found experimentally [4,5] that metal surfaces that are in metal-to-metal contact but not bonded or brazed have poor high power performance. We also have experimental evidence that small gaps (under 1 mm) were damaged even in setups where there were no currents flowing through the gaps (see damage of the disk rim in Fig. 6 of [6]).

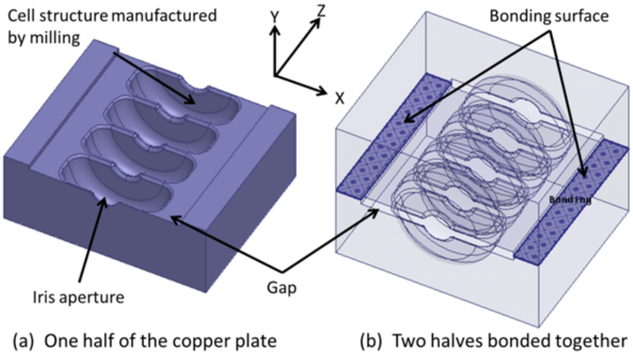


Figure 1: Manufacturing accelerating structure by milling on two halves of copper plate (HFSS model [7]).

Thus we introduced the 1 mm gap between the two halves of the structure to avoid un-brazed metal-to-metal contacts (shown in Fig.1). The gap is in cut-off at the working frequency to minimize fields leaking toward brazed surfaces and it is thus reducing the effect of imperfections of brazing fillets on rf performance. We note that a similar approach could be used to reduce trapping of long-range wakefields in the structure [4].

The full tapered structureincludes 24 regular travelling wave cells and 2 matching cells. It works at 11.994GHz with $2\pi/3$ mode. Each regular cell uses the same iris dimensions as the CLIC-G structure [8]. The structure uses a so called waveguide coupler, with matching transitions to standard WR-90 waveguides. The geometry is optimized to simplify the machining process, as well as to reduce the maximum surface electric and magnetic fields andthe local modified Poynting vector(*Sc*) [9].We used the commercial finite element code HFSS [7]for the simulations.

RF OPTIMIZATION OF SINGLE CELL GEOMETRY

One quarter of the cell prototype of the HFSS model is shown in Fig. 2. The flatbed besides the cell represents the gap between two halves. This single cell model will be used to optimize of the geometry.

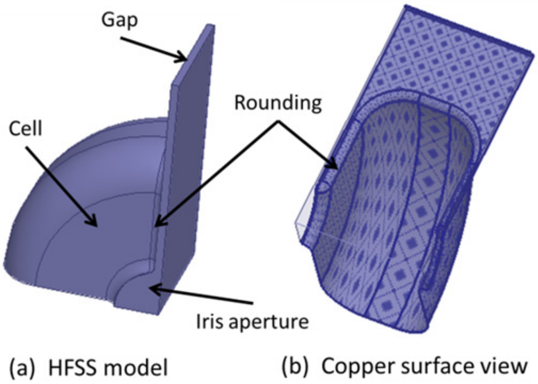


Figure 2: Initial geometry before the optimization.

The gap design changes the boundary condition in the cell and consequently affectsthe surface field. Figure 3 shows the comparison of our new structure with the regular un-damped middle cell of CLIC-G (T24). Wenote that the larger gap will significantly increase the maximum surface field and *Sc*.We use 1mm gap as compromise between increasing surface fields and degrading high power performance due to small gap (Fig. 6 in [6]).

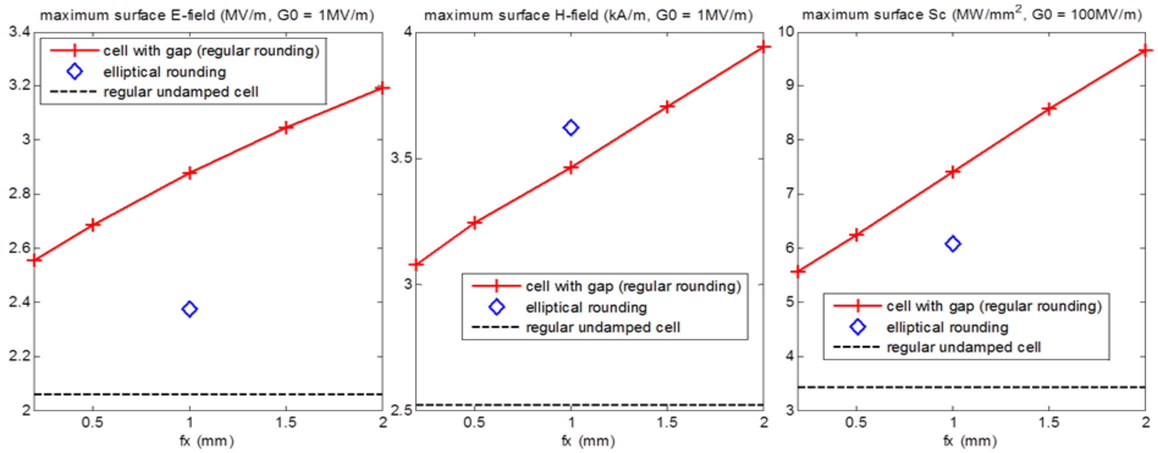
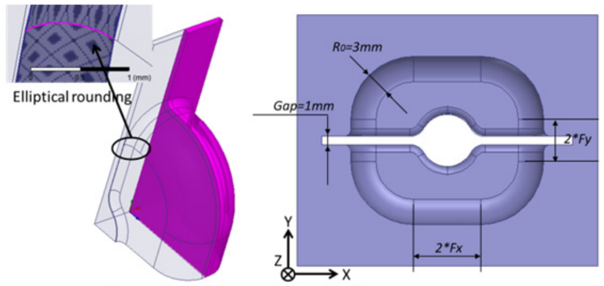


Figure3: Surface fields versus the gap (dash lines are for reference).

As shown in Fig. 2, there isa rounding along the edge between the gap and the cell geometry to reduce the surface field on the edges. An elliptical-arc rounding is proposed and usesthe same dimensions as the iris (shown in Fig. 4(a)). This design allows using only one rounding profile in one cell to make manufacturing easier. In Fig. 3, the diamond dots are the simulationresults for elliptical-arc rounding. Compared to the regular-arc rounding with the same gap (1mm), this design has a lower surface electrical field and Sc. Despite of thesomewhat higher magnetic field, we chose the elliptical-arc rounding for our final design.



(a) A quarter cell model (b) Geometry Parameters

Figure 4: Race track cell design.

For the cell geometry we proposed a race-track profile shown in Fig.4. This design provides more freedom in manipulating multipole fields in the cell than the regular round shape. We defined dimensions of the flat section in Fx and Fy.

The effects of Fx and Fy on the maximum surface field are shown in Fig. 5. The plot shows that the maximum Scwill be significantly reduced after increasing Fx and Fy. This race-track design distorts the distribution of the magnetic field and will therefore reduce the maximum Scwhich is the product of both,the electric field and the magnetic field. Increasing Fx and Fy will also reduce the magnetic field. We choseFy = 1.2mm as both the magnetic field and the Scwill be minimized. The dimension of 1.2mm for Fy already reachesits minimumfor the middle cell since there should be some space for the gap and the elliptical rounding. We choseFx = 4mm in order to compromise minimizing the magnetic field and the Sc. The electric field will increase about 4% compared to the cell not using a race-track design.

The race-track cell with 1mm gap and the elliptical rounding is selected as the final geometry of the single cell.

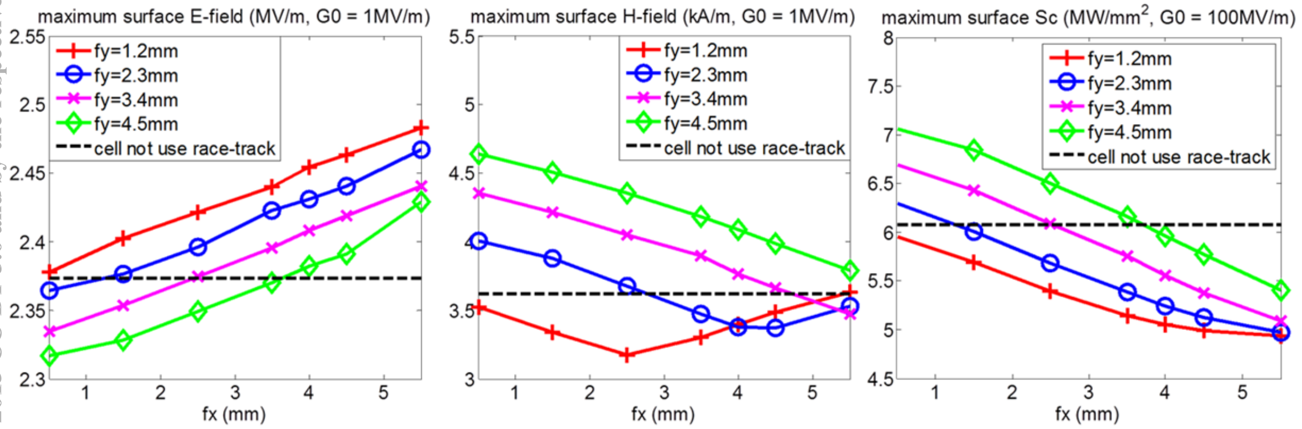


Figure 5: Surface fields versus Fx and Fy (dash lines are for reference).

RF DESIGN FOR FULL PROTOTYPE STRUCTURE

A full tapered prototype structure will include 24 regular cells, 2 matching cells and waveguide couplers. The waveguide couplers are on-axis double-feed and can be manufactured by millingonly. Due to the size of milling cutter, the rectangular waveguides will have 3mm rounding in their side edges. The matching cell uses same geometry parameters as its neighbour regular cell except for the matching iris aperture.

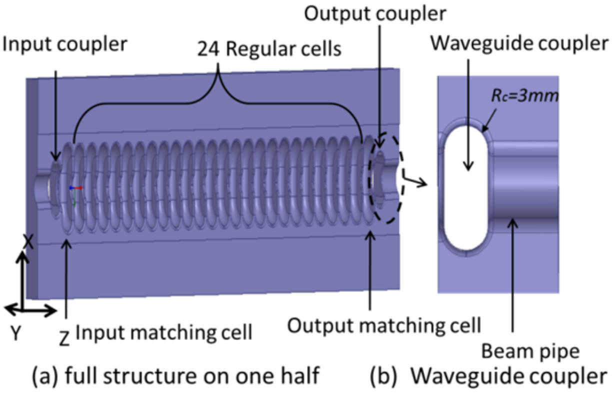


Figure 6: Model of the full tapered structure.

The full tapered structure is designed with optimizations on each cell andon the couplers. Dimensions are well tuned to minimize the reflection among cells. The reflection at the input coupler is -52dB. RF parameters of the full tapered structure are listed in Table 1 together with the RF parameters of the CLIC-G undamped T24 structure.

Table 1: RF Parameters of Full Tapered Structure

	Our structures	CLIC-G T24
Unloaded gradient[MV/m]	100	100
Input/output radii [mm]	3.15/2.35	3.15/2.35
Group velocity [%c]	1.99/1.06	1.79/0.91
Shunt impendence [MΩ/m]	107/137	116/150
Peak input power [MW]	44.5	37.5
Filling time [ns]	49	57
Maximum E-field [MV/m]	268	222
Maximum modified Poynting vector[MW/mm^2]	5.16	3.51
Maximum pulse heating temperature rise [K]	25	14

CONCLUSION

A prototype 12GHz structure manufactured by milling of two longitudinal halves is designed. This structure contains 24 regular and 2 matching cells;each regular cell uses the same dimensions of irises as CLIC-G. The race-track profile with 1mm gap and the elliptical rounding is selected for the geometry of single cells in order to have lower surface field and easier manufacturing. The structure will be manufactured at SLAC and will be high power tested at CERN.

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