ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-TUPTY055

OPTIMIZATION OF THE RF DESIGN OF THE CLIC MAIN LINAC ACCELERATING STRUCTURE

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Abstract

We present a new optimized design of the accelerating structure for the main linac of CLIC (Compact Linear Collider). The new structure has lower surface magnetic fields and larger wall rounding compared to the baseline design described in the CLIC Concept Design Report (CDR). This new design should reach higher accelerating gradients and has a reduced manufacturing cost. The details of the RF design procedure and the obtained results are presented in this paper.

INTRODUCTION

The baseline design of the Compact Linear Collider main linac is called 'CLIC-G', which was described in the CLIC Conceptual Design Report (CDR) [1]. In recent few years, a lot of work related to this design was carried out. High power tests on the prototype structure with beam loading were made to understand the high-gradient limits [2]. A beam-based wakefield measurement verified the suppression of the long-range transverse wakefield of this design [3]. Mechanical design and manufacturing cost assessment of CLIC-G structures were studied [4]. It resulted that further improvement of the CLIC-G design is possible. RF and wakefield studies were carried out and a new optimized design to CLIC-G with lower pulse temperature rise and reduced manufacturing cost was presented.

RF DESIGN

A single cell of the CLIC-G structure is shown in Fig. 1. Four waveguides terminated with RF loads suppress the transverse wakefields. The waveguide geometry enhances the surface magnetic field and results in a higher surface pulse temperature rise, which is the likely explanation of higher break-down rate of the CLIC-G structure than the corresponding un-damped structure operating at the same gradient [5]. Gaps located between the cavities and waveguides are so-called waveguide openings. The widths of the openings are smaller than the waveguide width, in order to reduce the maximum magnetic field. Smaller opening however reduce the coupling of higher order modes (HOMs) from cavities to the RF loads. Thus the waveguide openings play an important role in balancing high power performance and wakefield suppression. The profile edge of the wall geometry in the cavity contains a straight line plus two quarter elliptical arcs and has been optimized to minimize the surface field. Rounding (0.5 mm) is used along the bottom edge to fit the machining.

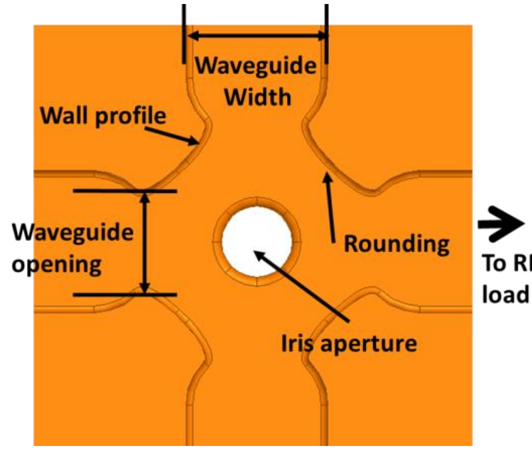

Figure 1: Geometry of a single CLIC-G cell.

The radii of the iris aperture in the CLIC-G design are from 3.15 mm to 2.35 mm. The average value and tapering of the iris aperture was determined by the global optimization considering the performance and the total cost [6]. The iris profiles have been optimized to minimize the surface electric field and the modified Poynting vector *Sc* [7]. This iris geometry is already well designed and will not be changed in this work. The cell geometry optimization is thus concentrated on the wall profile, waveguide geometry and the rounding.

Wall Profile

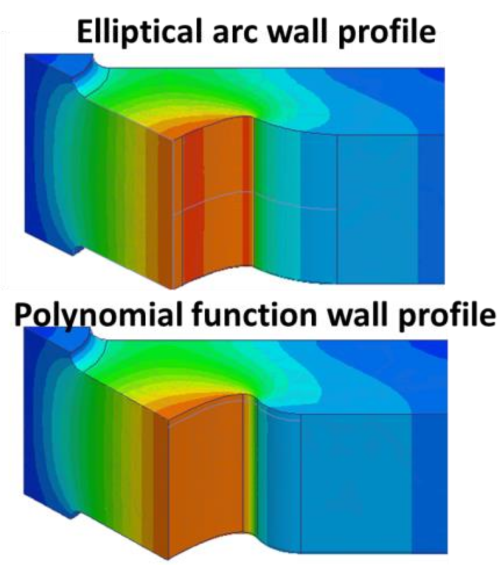

Figure 2: Comparison between elliptical and polynomial wall shape (figures were from HFSS simulations on 1/8 of the middle cell).

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The magnetic field along the wall profile for the middle cell of the CLIC-G design is simulated in HFSS [8] and shown in Fig. 2. Although the elliptical profile was optimized to have a flat field distribution, two bumps were still seen in the wall. We proposed a new profile based on 4-th order polynomial function, which has a more flat magnetic field distribution. The maximum magnetic field decreases by 3%, which is nearly 2 K in terms of surface temperature rise.

Waveguide Geometry

The waveguide width in the CLIC-G design is 11 mm and the opening width is 8 mm. By HFSS simulation and by calculating the transverse wakefield using the Gdfidl code [9], it is observed that reducing the waveguide width from 11 mm will increase the wakefield suppression as well as decrease the maximum magnetic field. A smaller waveguide width also leads to a shorter penetration depth of the fundamental mode into the damping loads and allows smaller transverse diameters of the disks. The width of the waveguide openings, as introduced formerly, will be set to the minimum value at which the wakefield suppression is still maintained as for the CLIC-G design. The waveguide geometry also includes the dimension of the rounding, thus the comprehensive optimization should integrate waveguide width, opening and the rounding.

Rounding

According to the machining cost assessment studies on the CLIC-G structures [4], larger rounding decreases the cost. Larger rounding however demands a larger waveguide opening to maintain the wakefield suppression and it increases the surface magnetic field. Gdfidl calculations of wakefields in the tapered structure on different rounding and waveguide widths gave the minimum waveguide opening width for each case. With these opening widths, roundings and waveguide widths, the maximum surface magnetic field could be solved by HFSS simulations (see Fig. 3). The optimum waveguide widths are near 10.1 mm for all roundings.

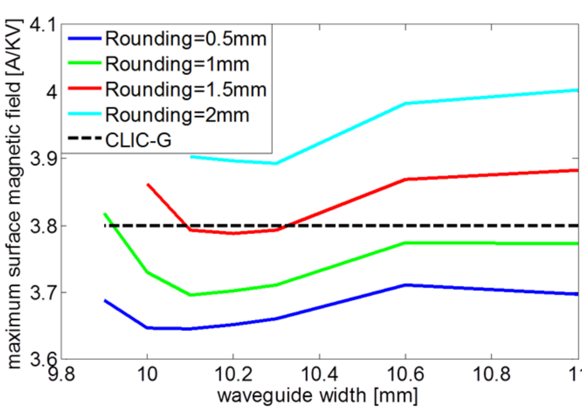

Figure 3: maximum magnetic field versus different roundings and waveguide widths (waveguide opening width in each case fits the requirement of wakefield suppression).

A plot of machining cost reduction and reduction of the pulsed surface heating temperature rise versus rounding is shown in Fig. 4. The temperature rise is calculated from the solutions with optimum waveguide width. Due to the optimization of the wall profile and waveguide width, the temperature rise of the solution with 0.5 mm rounding is lower than that of CLIC-G, leaving space to increase the rounding. We chose the 1 mm rounding design for its significant reduction both on cost and temperature rise. A larger rounding was not considered because the further improvement on cost is small and the temperature increase is higher.

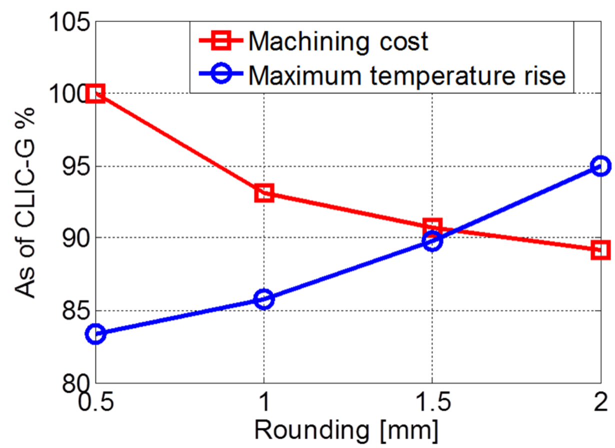

Figure 4: Selection of rounding.

Tapering on Waveguide Openings

A tapered CLIC-G structure includes 26 regular cells. The waveguide width and opening are constant along all cells. The upstream cells are the highest point for the pulse temperature rises, as seen in [6]. Due to the dependency of waveguide opening width on the surface magnetic field, the temperature rise of upstream cells could be decreased by reducing the waveguide openings. Meanwhile, the waveguide openings of downstream cells were increased to compensate the wakefield suppression. Figure 5 shows the tapering on the waveguide openings versus the change of temperature rises. A quadratic function based tapering on the waveguide openings is selected and the maximum temperature rise decreases by 2 K.

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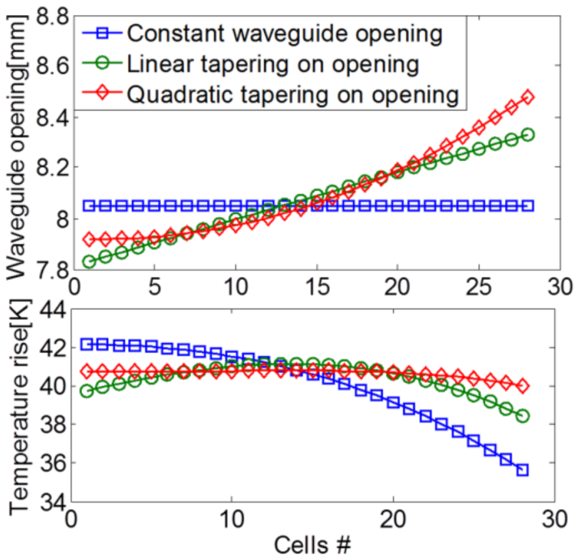

Figure 5: Tapering on the waveguide openings and corresponding temperature distributions.

New Optimized Design

The new optimized design integrates all features introduced above. Since the new design doesn't change the iris parameters, it was named 'CLIC-G*'. The detailed parameters are listed in Table 1. Compared to CLIC-G, this new design reduces the temperature rise by 20% from 52 K to 41 K. The estimated cost is reduced by 7% and the power consumption is 1MW lower.

Table 1: Structure Parameters of CLIC-G* design. The parameters of CLIC-G inside the braces are given in [1, 6], outside are recalculated in latest HFSS version.

	CLIC-G	CLIC-G*
Rounding [mm]	0.5	1.0
Manufacturing cost reduction	--	7%
Shunt impedance [MΩ/m]	92.0	95.4
Peak input power [MW]	63.4	62.4
RF to beam efficiency	27.9%	28.4%
Filling time [ns]	67	66
Maximum electric field [MV/m]	248(230)	250
Maximum *Sc* [MW/mm^2]	5.70	5.65
Maximum temperature rise [K]	52(47)	41

The simulated wakefield of the new design is shown in Fig. 6 and compared to the CLIC-G design in the CDR. The attenuation of two curves are similar. The wakefield potential of the new design at the positon of the second bunch (0.15 m) is 2 V/pC/m/mm, as required by beam dynamics.

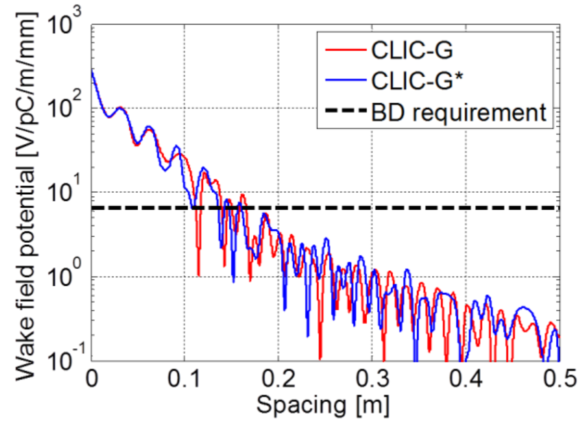

Figure 6: Simulated results of transverse wakefield envelope in CLIC-G structure and the new design.

The design of coupler and RF loads for the CLIC-G* are still ongoing. Prototype structures of the new design will be built and high power tests are foreseen.

CONCLUSION

A new optimized design of the accelerating structure for the main linac of CLIC was presented. A 1 mm rounding was selected, which reduces machining cost by 7%. By optimizing the wall profile in the cavity, the waveguide geometry and the tapering waveguide openings, the maximum temperature rise is reduced by 20%. This design will be further studied in future high power tests.

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