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PARAMETERS OF THE NORMAL CONDUCTING ACCELERATING STRUCTURE FOR THE UP TO 1 GeV HADRON LINACS

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Abstract

Compensated bi-periodic accelerating structure Cut Disk Structure (CDS) was developed for accelerating particle beams at β~1. In the papers dedicated to the development of this structure, a significant decrease in Ze was shown for medium energies range, β~0.4-0.5. For high-intensity hadron linacs, this energy range, in which particles are captured to acceleration from the drift tube structure, is of the greatest interest. In this paper, a set of CDS parameters was obtained, which provides a Ze value not lower in the comparison to the proven structures in the medium energy range. By the comparison of the electrodynamic and technological parameters of CDS with these structures, the advantages of its application in multi-section cavities for the up to 1 GeV linacs are shown. The selection of optimal cells manufacturing tolerances, the method of its tuning before brazing and frequency parameters control, and the selection of the method for multipactor discharge suppression are determined. The results of the sketch project of the CDS cavity numerical simulation as a non-uniform coupled system and optimization of the transition part of sections and bridge devices are presented.

INTRODUCTION

Compensated biperiodic structure CDS was proposed for high energy area, β~1 [1,2]. For particle velocities β>0,5 CDS is superior to known analogues in effective shunt impedance Z_e. But in lower energy area, β<0.5, it was difficult to implement internal cooling channels, required for CDS application in hadron linacs with intense beam [3,4]. In recent investigations the cells dimensions were optimized to equalize CDS with analogues in Ze value simultaneously placing internal cooling channels. Also, the techniques for multipacting discharge damping in CDS coupling cells [5], and combining of CDS sections into accelerating cavity [6], were developed. For application in hadron linacs with intense beams and energies up to 1 GeV in the total set of RF and technological parameters CDS surpass [7], known analogues.

CDS STRUCTURE FOR β>0,5

The CDS structure has shown competitive electromagnetic parameters for hadron linacs at comparatively high velocity range 0.4≤ β≤0.8, as it is shown in Fig. 1 [4].

The advantage of CDS in Z_e over proven strictures such as ACS, SCS and DAW decreases with high internal wall thickness at β<0.5. At the same time, it is necessary to place internal cooling channels in them. In high intensity linacs the RF heat load is about 3 kW/m. The RF loss density and temperature distribution is shown in Fig. 2.

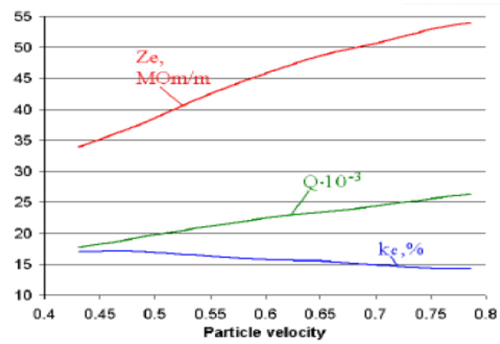

Figure 1: Comparison of the accelerating structures at 991MHz operating frequency.

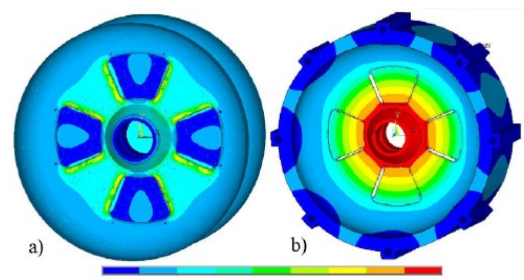

Figure 2: RF loss density (a) and temperature (b) distributions in CDS.

In case of only external cooling channels implemented the drift tube is overheated which causes thermal-stress deformations leading shift of operating frequency.

Calculating a combination of CDS parameters to implement internal cooling channels with maintaining high Z_e value has become the main problem for its application at β<0.5.

CDS OPTIMIZATION FOR β~0,4

To implement internal cooling channels a set of CDS geometrical parameters was calculated, providing both high Z_e value and sufficient internal wall thickness. Comparison of CDS electrodynamic parameters with proven accelerating structures (Fig. 3) at β=0.4313 is shown in Table 1.

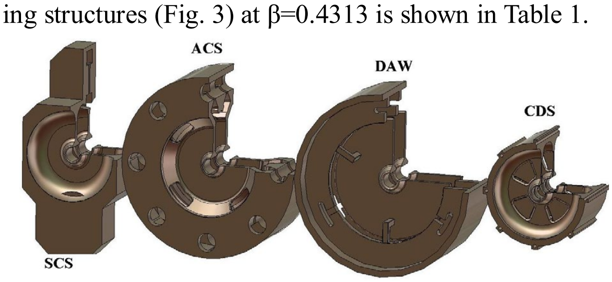

Figure 3: Comparison of the accelerating structures at 991MHz operating frequency.

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Table 1: Parameters of Accelerating Structures, β=0,4313

Parameter	DAW	ACS	SCS	CDS
Length, mm	65,24			
Width, mm	425.67	405.35	211.79	211.54
Height, mm	425.67	405.35	465.74	211.54
k_c	0.56	0.054	0.042	0.164
Q	23407	15834	16998	14738
Z_e, Mom/m	30.76	28.66	30.04	31.16

The structures have a similar efficiency of using RF power, determined by the value of Z_e. At the same time, the CDS structure has twice smaller transverse dimensions.

In terms of the coupling coefficient value, the DAW structure has an overwhelming advantage, for which it is more than 0.5. But in the vicinity of the operating mode of the DAW, there are parasitic oscillations with variations of the field along the azimuth, taking into account the splitting from the stems. The suppression of the influence of these oscillations requires the introduction of additional elements into the structure, such as slots, which complicate the manufacturing and tuning of the cavity. At the same time, the CDS structure has a coupling coefficient reaching 0.16, three times higher than that of the ACS and SCS structures, which is an intermediate value [7].

Based on the optimization and of the geometrical parameters of the cells of the sections, a design technical drawing of the CDS structure for the 991 MHz operating frequency and β=0.4313, taking into account the wall thickness for the internal cooling channels, shown in Fig. 4.

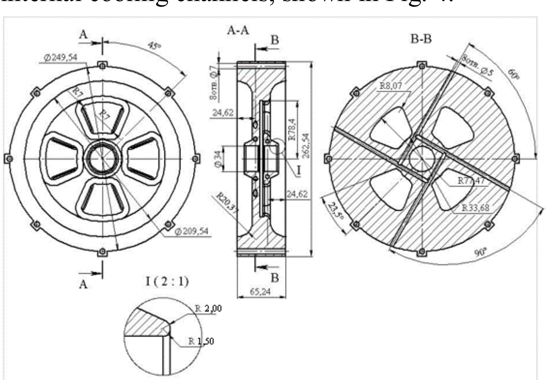

Figure 4: CDS structure design drawing at 991MHz operating frequency, β=0.4313.

The figure shows both external and internal cooling channels. Taking into account the results of comparing the efficiency of the cooling system options used in the CDS cavity, external channels can be excluded from the project to simplify the manufacturing of the structure.

The twice smaller transverse dimensions although allows application of CDS for relatively small operating frequencies ~300 MHz in comparison with widely used π-mode structures (PiMS) CDS shows higher Z_e value as a compensated structure (Fig. 5) [8].

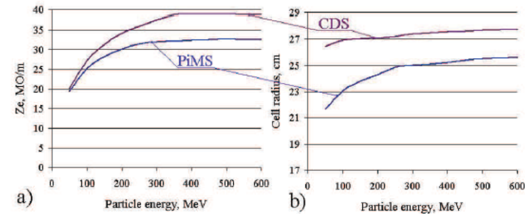

Figure 5: The plots of shunt impedance Ze, (a), and cell radius R_c, (b), for PiMS and CDS.

MULTIPACTING SUPPRESION

Using the example of a CDS structure tuned to a frequency of 991 MHz, acceleration rate of 2.5 MV/m, β=0.4313, the probability of the of a multipactor discharge near the operating field level in the gaps of the coupling cells was shown [9].

To suppress the discharge at the operating field level, a proven method of multipactor suppressing in the structure can be used by introducing alternating detuning of neighboring accelerating cells to create an electric field voltage in the coupling cell that exceeds the upper threshold for the multipactor occurrence. In the CDS structure at frequency of 991 MHz, acceleration rate of 2.5 MV/m, β=0.4313, the value of neighboring accelerating cells detuning is ±1.2 MHz

To preserve the uniformity of the geometric parameters of the structure in the sections and simplify the tuning of the cavity before brazing, a technique of multipactor suppressing is considered, which allows violating the condition of resonant electron motion by changing the geometry of the plane gap of the coupling cell– the distance δl between the lower faces of the planes forming the gap increases, as shown in Fig. 6. The maximum value δl is limited by the conditions of inner cooling channels placement in the drift tubes.

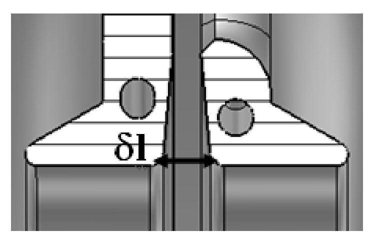

Figure 6: The change of geometry of coupling cells for multipactor suppression in CDS.

With an increase in the δl to 2 mm, the electron flight time decreases to a value below 0.5 of the RF field period and the number of secondary electrons decreases [5].

CDS CAVITY TUNING

Cavities based on normally conducting structures in the main parts of high intensity hadron linacs consist of sections connected by bridge devices. In particular, the first cavity of the main part of the INR linac consists of four sections (18, 20, 21, 19 structure periods, respectively) and three bridge devices made of a standard 220x104 mm waveguide. The total length of the cavity is more than 13.5 meters, as shown in Fig. 7.

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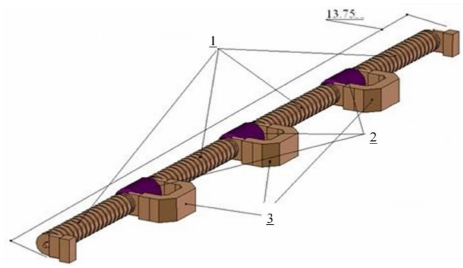

Figure 7: CDS based accelerating cavity. 1 – CDS accelerating sections, 2- focusing elements, 3- coupling bridge devices.

Numerical simulation of a complete cavity by modern software tools with the use of reasonable computing resources will not provide the necessary calculation accuracy. At the same time, individual configuration of sections and bridge devices as a non-uniform system will require multiple iterations of simulation that take a long time.

To simulate the cavity as a system of sections and bridge devices, a technique based on a multimode approximation was used, operating with the integral parameters of the system elements – the eigenfrequencies and the values of the magnetic field of sections and bridge devices on the coupling gap [10]. This technique is a generalization of the single-mode approximation technique. A special feature of the technique is the possibility of using the parameters of the elements of a non-uniform coupled system obtained by direct numerical simulation, which allows to fully take into account the details of their design.

With connection of the CDS section and the bridge device in the form of a rectangular waveguide segment with a transition part, it is necessary to achieve the optimal separation of the operating and two neighbouring modes while maintaining sufficient sensitivity of the frequency of the operating mode to the frequency tuning elements. The presence of sufficient mode separation near the operating frequency is necessary to increase the stability of the field distribution in the cavity sections. Figure 8 shows the dependence of the frequency of the resulting modes of the system depending on the position of the tuning plunger for the case of a CDS section and a bridge device near the operating frequency of 991 MHz

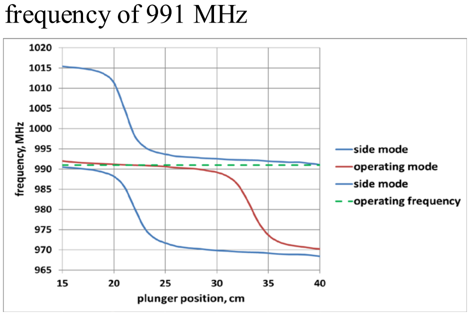

Figure 8: The tuning of CDS cavity sections connected by bridge devices at 991 MHz frequency.

In this case, the distance between the operating mode and neighbouring modes is determined by the value of the coupling coefficient, which depends on the length of the gap.

The presence of a coupling gap between the section and the bridge device leads to a decrease in the frequency of the operating mode of the section, in full accordance with the multi-mode technique. In this regard, it is necessary to adjust the frequency of the ending half cells before brazing the sections.

This ensures both the tuning of the operating frequency and the equal separation of neighbouring oscillations in frequency.

The results obtained show that using a model based on a multi-mode technique, it is possible to analyse and simulate a non-uniform coupled system of four unequal CDS sections connected by three bridge devices with RF power input to the central bridge [6].

CONCLUSION

The problem of implementing the CDS structure for hadron linacs in the area of $0.4<\beta<0.8$ and optimizing its parameters has been completely solved. According to its results, it is not inferior to proven structures in terms of electrodynamic parameters, having twice smaller transverse dimensions and can be used both at frequencies of ~ 1000 MHz and at a lower frequency of ~300 MHz

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