RESEARCH OF ELECTRODYNAMIC CHARACTERISTICS CH-BASED ACCELERATING STRUCTURES

A.A. Kalashnikova, M.V. Lalayan, S.E. Toporkov
National Research Nuclear University "Moscow Engineering Physics Institute", Moscow, Russia
E-mail: anastasymf@gmail.com

The CH-based accelerating structure for linear proton accelerator is considered in the paper. The electrodynamic characteristics structures with different geometries are compared. They are the structure with a variable cavity diameter and the structure with pylons. The models have 7 gap CH-based structure with end drift tubes modified geometry. Structure is tuned to the operating frequency 352 MHz and the relative phase beam velocity β = 0.1. The geometric dimensions influence on the overvoltage field factor and electrodynamic characteristics are investigated. The electrodynamic characteristics such as shunt impedance per unit length, Q factor and TOF factor are considered. Field distribution along the axis of the structures is configured to unevenness less than 5%. Also the results of focused beam dynamics simulation are presented in the paper. The structure is proposed to operate at single bunch mode. Bunch current is 10 mA.

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1. DESIGN

1.1. GEOMETRY AND ELECTRODYNAMIC CHARACTERISTICS

The task was to design the most adequate H-based seven gaps structure with the operating frequency 352 MHz and the relative phase beam velocity β = 0.1 for proton linear accelerator. The CH-based structure is one of the most suitable for low beta beams [1] (Fig. 1).

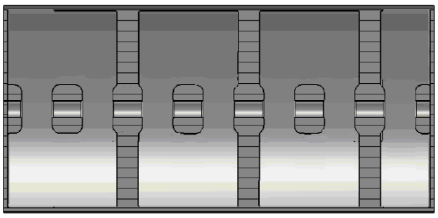

Fig. 1. Conventional CH-based structure

But field distribution along the conventional CH structure axis is not flat enough. Therefore to improve this feature Two models were considered: the structure with a variable cavity diameter and the structure with the pylons.

Both have seven constant periods D that are equal to:

$$D = \frac{\beta\lambda}{2}$$

as for all CH-structures working in π − mode regime.

For improvement of the field amplitude deviation and improvement of the electrodynamic characteristics first structure the end fixing bars were changed. So optimization was performed by tuning resonator diameter, length and rounding end drift tubes length and end fixing bars position. The final structure view is shown at Fig. 2. The field amplitude deviation factor was reduced to less than 5%. The electrodynamic characteristics are presented in Table 1.

For improvement of the field amplitude deviation to less 5% and improvement of the electrodynamic characteristics second structure the undercuts were made in the pylons. The optimization was performed by the pylon geometry and design and end drift tubes length. So the final structure view is shown at Fig. 3. The electrodynamic characteristics are presented in Table 1.

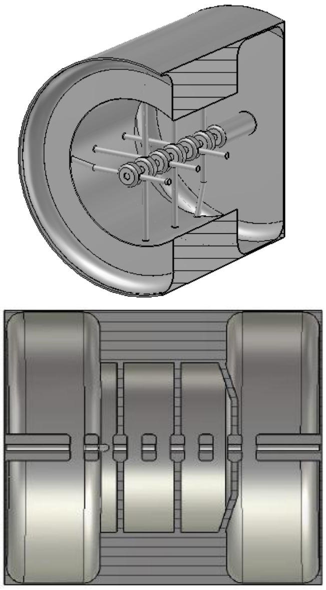

Fig. 2. The structure with a variable diameter cavity

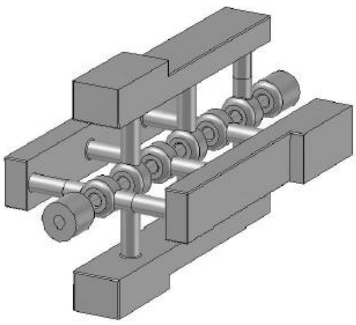

Fig. 3. The structure with pylons

Table 1 shows that the electrodynamic characteristics of the structure with a variable cavity diameter is significantly higher then structure with pylons one. The first uses too long end drift tubes, the total length of which is half the effective structure length (the structure length is without taking into account the end drift tube length). However, 5% field deviation hasn`t been achieved with shorter drift tubes.

Despite the low electrodynamic characteristics of structure with pylons, its size is smaller than the dimensions of the structure with a variable cavity diameter (Table 2). So, its manufacture will be cheaper.

E-field distribution along the structure with a variable cavity diameter axis, and with a variable cavity diameter axis is shown in Figs. 4, 5.

Table 1

Electrodynamic characteristics

	The structure with a variable diameter cavity	The structure with pylons
Frequency f, MHz	345.7	348.3
Total Loss P	2.8e5	6.7e5
Q-factor	7678	3278
Shunt impedance per length, MOhm/m	21	12
Effective shunt impedance per length, MOhm/m	46	16
TOF factor T	0.67	0.87
The maximum E-field Emax, MV/m	38.1	42.5
Field amplitude deviation factor k, %	5	4.5

Table 2

Structures dimentions

	The structure with a variable diameter cavity	The structure with pylons
Aperture, mm	5	5
Structure length L, mm	472.2	346.2
Diameter, mm	127	91.5
End drift tubes length, mm	84	21

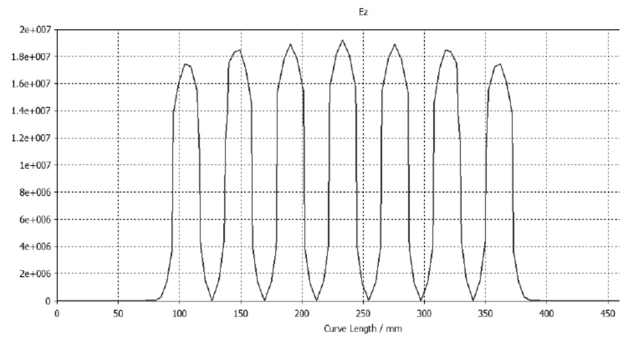

Fig. 4. E-field distribution along the structure with a variable cavity diameter axis

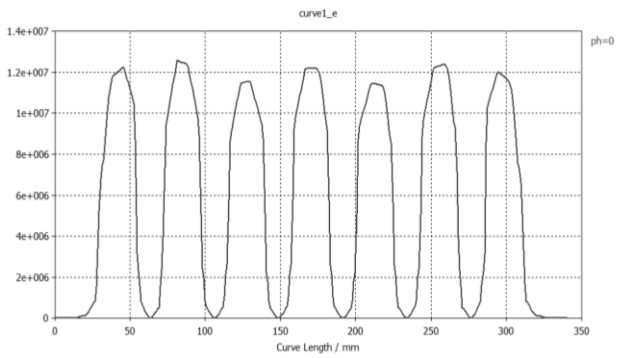

Fig. 5. E-field distribution along the structure with pylons axis

1.2. DYNAMICS

Also the paper presents the results of beam dynamics simulation in structures. The fields in the structures are similar, so the dynamics simulation has been performed only for one structure. A single pulse current of 10 mA is considered. The proton source diameter is 5 mm. The kinetic energy spread is 2%. The angle spread is 0.3°. The results of beam dynamics simulation are presented in Table 3 and Figs. 6-10.

Table 3

The result of beam dynamics simulation

Beam energy, MeV	Particle amount with energy 6.2 MeV	Energy range, MeV
6.20	1081	6.09…6.25

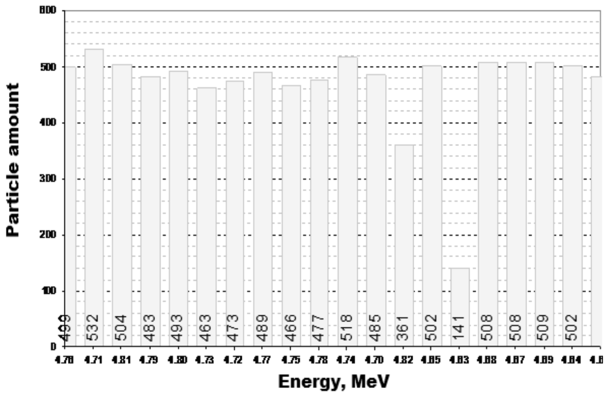

Fig. 6. The initial energy spread of the beam

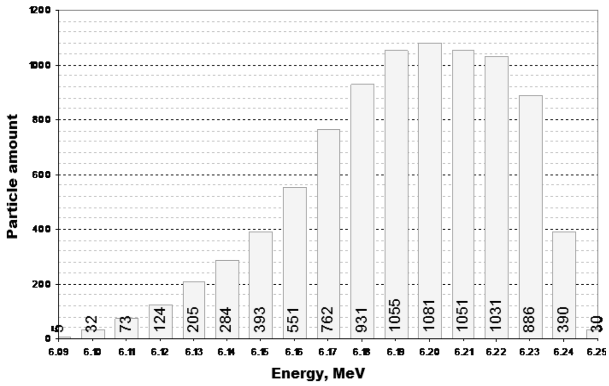

Fig. 7. The final energy spread of the beam

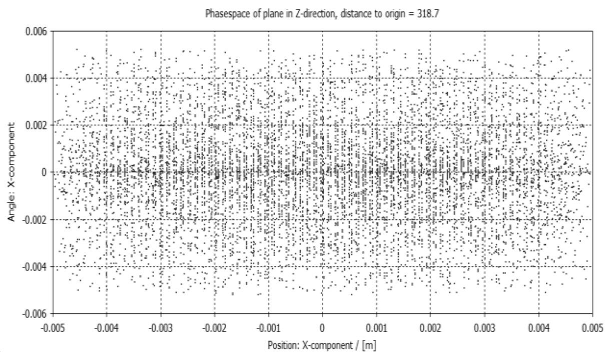

Fig. 8. The initial space phase plot of the structure with the pylons

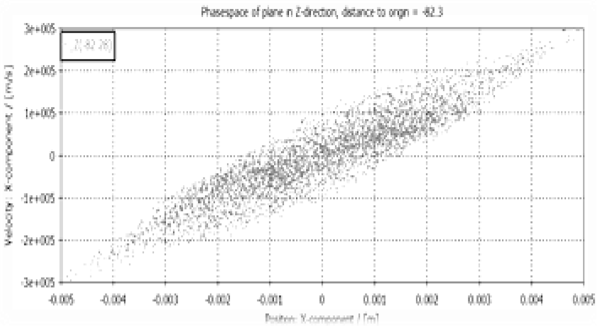

Fig. 9. The final space phase plot of the structure with the pylons

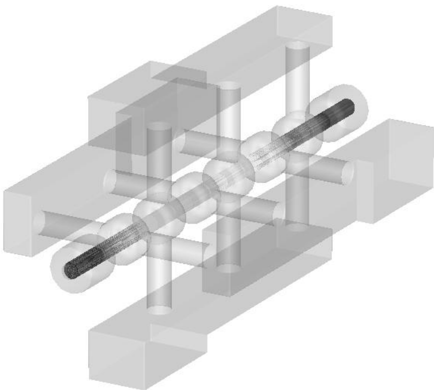
Fig. 10. The particle trajectories in the structure with the pylons

CONCLUSIONS

The comparison of structure with a variable diameter cavity and the structure with the pylons is presented. the electrodynamic characteristics of the structure with a variable cavity diameter is significantly higher then structure with pylons one. Therefore, it is more appropriate structures for linear proton accelerator at low beta then the structure with the pylons.

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ИССЛЕДОВАНИЕ ЭЛЕКТРОДИНАМИЧЕСКИХ ХАРАКТЕРИСТИК УСКОРЯЮЩИХ СТРУКТУР НА ОСНОВЕ CH-РЕЗОНАТОРА

А.А. Калашникова, М.В. Лалаян, С.Е. Топорков

Представлены результаты научной исследовательской работы по выбору оптимальной геометрии ускоряющей структуры на основе CH-резонатора для линейного сильноточного ускорителя протонов. Проведено сравнение электродинамических характеристик структур с разной геометрией: структуры с переменным диаметром резонатора и структуры с пилонами. Модели представляют собой 7 периодов CH-структуры с измененной геометрией торцевых трубок дрейфа. Настройка структур проводилась на рабочую частоту, равную 352 МГц, при относительной фазовой скорости пучка 0,1 скорости света. Изучено влияние геометрических размеров на коэффициент перенапряженности поля и основные электродинамические характеристики структуры: погонные шунтовые сопротивления, добротность и времяпролетный фактор. Проведена работа по настройке распределения поля вдоль оси структур, при котором коэффициент неравномерности поля не превышает 5%. Также в работе представлены результаты численного моделирования динамики пучка в рассматриваемых структурах. При анализе динамики в структурах рассматривался единичный импульс тока, равный 10 мА.

ДОСЛІДЖЕННЯ ЕЛЕКТРОДИНАМІЧНИХ ХАРАКТЕРИСТИК СТРУКТУР, ЩО ПРИСКОРЮЮТЬСЯ, НА ОСНОВІ CH-РЕЗОНАТОРА

А.А. Калашнікова, М.В. Лалаян, С.Є. Топорков

Представлено результати наукової дослідницької роботи з вибору оптимальної геометрії прискорюючої структури на основі CH-резонатора для лінійного потужнострумового прискорювача протонів. Проведено порівняння електродинамічних характеристик структур з різною геометрією: структури з перемінним діаметром резонатора і структури з пілонами. Моделі являють собою 7 періодів CH-структури зі зміненою геометрією торцевих трубок дрейфу. Налаштування структур проводилося на робочу частоту, рівну 352 МГц, при відносній фазової швидкості пучка 0,1 швидкості світла. Вивчено вплив геометричних розмірів на коефіцієнт перенапруженості поля і основні електродинамічні характеристики структури: погонні шунтові опори, добротність і часопрольотний фактор. Проведено роботу з налаштування розподілу поля уздовж осі структур, при якому коефіцієнт нерівномірності поля не перевищує 5%. Також у роботі представлено результати чисельного моделювання динаміки пучка в розглянутих структурах. При аналізі динаміки в структурах розглядався одиничний імпульс струму, рівний 10 мА.