DESIGN OF THE SSR021 CAVITY FOR THE PROTON ACCELERATOR MAIN LINAC OF CHINA ADS*

Z.Q. Li#, Y.L. Chi, H.Y. Lin, Q. Ma, W.M. Pan, P. Sha, Y. Sun, J.Y. Tang,
Q.Y. Wang, B. Xu, X.Y. Zhang, IHEP, Beijing 100049, China
Y. He, C. Zhang, S.H. Zhang, S.X. Zhang, IMP, Lanzhou, 730000, China

Abstract

China ADS is a high intensity proton machine based on CW superconducting technology. It includes two injectors and one main linac. The Institute of High Energy Physics (IHEP) and the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences (CAS), are responsible for developing the main linac together. This paper introduces the physics and mechanical design of the single spoke resonator (SSR021, beta021 cavity), which is used for first section of the main linac.

INTRODUCTION

The China ADS project formally started from Jan. 2011. From physics design point of view, in order to minimize the total cavity quantities, three kinds of spoke cavities are adopted for the accelerator [1]. The design specifications for the spoke cavities are shown in Table 1.

Table 1: Physics Requirements for Spoke Cavities

Parameter	SSR012	SSR021	SSR040
Frequency / MHz	325	325	325
Geometer Beta (β_G)	0.12	0.21	0.40
Cavity No. / Cryomodule No.	12 / 2	32 / 4	80 / 10
Energy Range / MeV	3 ~ 10	10 ~ 36	36 ~ 160
Current (CW) / mA	10	10	10
Cavity Length / mm	≤ 200	≤ 250	≤ 400
Beam Tube Iris / mm	35	40	50

At the end of 2011, we fixed the physics design of SSR021. During the next one and half year, we focused on developing the spoke cavity technology, including mould design and fabrication, parts preparing, EBW and surface treatment. The 325 MHz SSR021 is the first cavity type for the main linac. It covers energy range from 10 to 36 MeV by 32 cavities assembled in 4 cryostat modules. An SSR021 cavity with a pair of round stiffening rings and least welding seams is developed in order to reduce the total price for the future mass production. Up to now, the surface treatment is accomplished. The vertical test will be carried out at the end of Sept. 2013.

*Work supported by CAS "Strategic Priority Research Program"
#lizq@ihep.ac.cn

PHYSICS DESIGN

Structure

By referring to the existing structure of spoke cavities developed by other labs, such as LANL [2], Fermilab [3] etc., we designed our SSR021 cavity. Fig. 1 shows the main dimensions on cross section. Compared to the Fermilab's SSR021, ours is more compact. These are no enhanced wings around the beam tube. The tuner will be attached to the stiffening ring, not the beam tube flange, to keep cavity in tune.

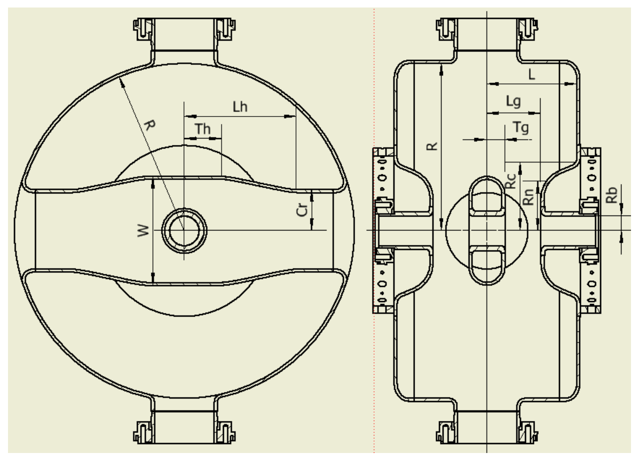

Figure 1: The profile of the SSR021 cavity. L: half cavity length, 120 mm; R: cavity radius, 223 mm; Lg: half gap length, 70 mm; Rc: cone radius, 90 mm; Tg: half spoke thickness, 24 mm; Rn: nose radius, 70 mm; Cr: spoke radius, 55 mm; Rb: beam pipe radius, 20 mm; W: half spoke width, 72.6 mm.

Electromagnetic Performance

By increasing the centre width W of the spoke pole, which can be squeezed from a round tube, the capacitance between both accelerating gaps increased. In order to meet the frequency of 325 MHz, the radius R and Length L of the spoke cavity should be decreased to reduce the equivalent inductance. Compared to the SSR021 of Project X, 35 % of the cavity volume is reduced, at the same time, H_p/E_{acc} increases by 32 %. We tried to find a balance point between the optimized parameter and minimum volume of the SSR021 cavity, and the latter means low fabrication price.

According to the final optimized structure, a set of electromagnetic parameters was calculated by CST (Table 2.) . Here, df / dL is calculated using naked cavity.

ISBN 978-3-95450-143-4

Table 2： Main Parameters of the SSR021

Parameter	Unit	Value
E_p / E_{acc}	(MV/m) / (MV/m)	3.8
B_p / E_{acc}	mT / (MV/m)	8.1
R/Q	Ω	191
G	Ω	71
β_{opt}		0.246
df / dL	kHz / mm	632
Q_e @ 10 mA		7.28E5

Multipacting Simulation

Multipacting (MP) of SSR021 is simulated with CST and Track3P. The results is almost the same for both codes. In Fig. 2, from cavity voltage 0.1 to 0.5 MV, MP occurs around the corner between the side plate and the cylinder. At 0.43 MV, the amplitude is the maximum. From 0.5 to 1.0 MV, MP arises on the bottom of the spoke pole, where it connects with the cylinder. At 0.65 MV, the amplitude reaches the peak. And compared to 300 °C baked surface, the Ar-discharged surface can reduce the amplitude of MP obviously.

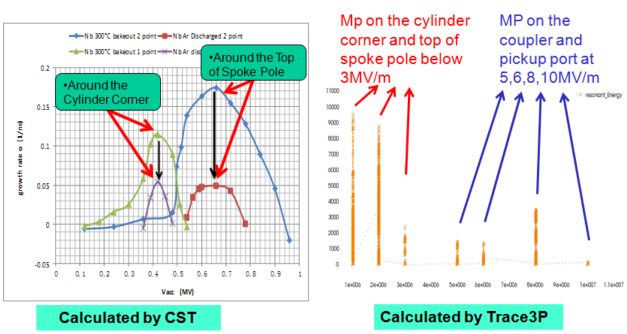

Figure 2: Results of multipacting simulation for SSR021.

Mechanical Performance

Compared with HWRs, the mechanical behavior of spoke cavities should be considered more carefully because their rotation axis is different. The rotation radius of SSRs is usually larger than HWRs for the same geometry beta cavity. So how to enhance the spoke cavity is a challenge to its designer.

We conceived several kinds of schemes to enhance the cavity structure. The results are shown in Fig. 3. Finally we chose the c scheme, which has the simplest stiffen ring. The maximum stress reaches to 38 MPa at the pressure of 1 atm with 800 kg preload force on stiffen rings. Even the pressure increases to 2 atm, the preload force will increase automatically to compensate the displacement of side plate.

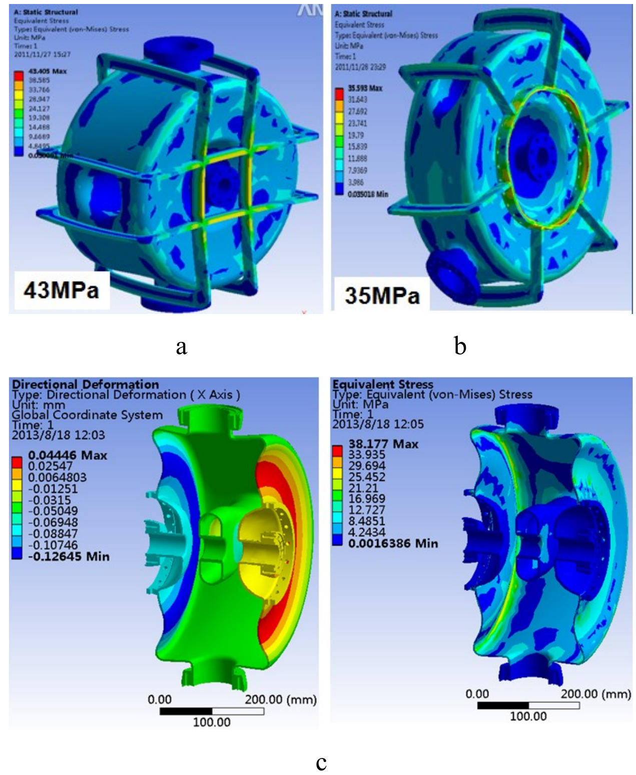

Figure 3: Schemes of enhance structure for SSR021.

Pretuning

During the past one and a half years, two SSR021 prototypes are fabricated. The EBW of another three are going on. At the same time, the surface treatment facilities including BP, BCP and HPR, are built and used to process these SSR021 cavities.

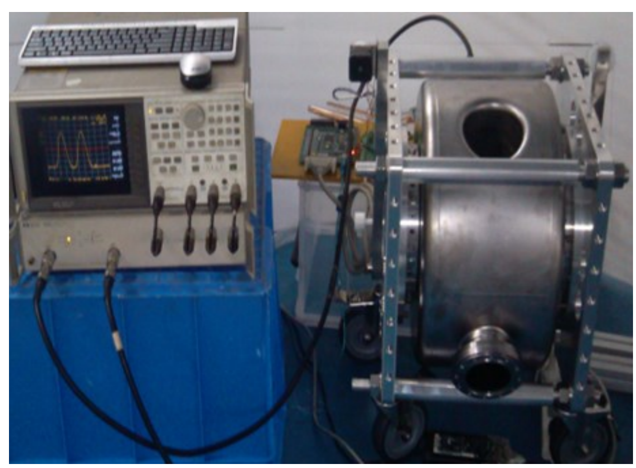

Figure 4: Field measurement and pretuning device.

After annealing at 700 °C for 3 hours, we measured the frequency and the field distribution along the axis. After pretuning (Fig. 4), the frequency reaches the target value of 324.2 MHz and the field flatness is better than 95 %.

ACKNOWLEDGMENT

Thanks to my colleagues J.Y. Zhai and T.X. Zhao for their support to our work. Special thanks to T. Furuya of KEK, T. Tajima of LANL, V. Yakovlev and C. Grimm of Fermilab for their useful discussion.

REFERENCES

[1] Z.H. Li, et al., "Physical design of the proton accelerator for China ADS," Progress Report on China Nuclear Science & Technology (Vol.2), October 2011.

[2] T. Tajima, et al., "Results of two LANL β = 0.175, 350 MHZ, 2 gap spoke cavities", Proceedings of the 2003 Particle Accelerator Conference.

[3] L. Ristori, et al., "Design of Single Spoke Resonators for Project X", SRF'11, Chicago, July 2011

ISBN 978-3-95450-143-4