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EVELOPMENT OF SPOKE CAVITY FOR MAIN LINAC OF CHINA ADS

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Abstract

During past six years, two kinds of single spoke resonators with beta equal to 0.21 (SSR021) and 0.40 (SSR040) were developed at IHEP CAS, the SSR021 was adopted to accelerate proton from 10 to 36MeV, and 36 to 160MeV for SSR040. Up to now, two kinds of naked spoke cavities have been test in vertical, also the module of SSR021, which equipped with the liquid helium jacket, magnetic shield layer and frequency tuner, has been fulfilled and test, the performance of all of components reach the design requirements. Recently a cryogenic module with six SSR021, six solenoid coil and six BPM, which we call it fourth cryogenic module (CM4) in main linac of ADS, assembled and commissioned with proton beam.

INTRODUCTION

After two injector had commissioned successfully at the Institute of High Energy Physics (IHEP) in Beijing and the Institute of Morden Physics (IMP) in Lanzhou, separately in 2016, all of ADS member were dedicated to fulfil main linac assembly in IMP, the main linac, which connect to injector II, are composed by CM3 and CM4 (see Fig. 1) [1]. On the 5th June 2017, Main linac had successfully accelerated 12.6mA pulse beam from 10 to 26MeV, also accumulated CW 170μA beam to 25MeV, here CM3 is assembled by five 162.5MHz, beta equal to 0.15 half wave resonator (HWR015), and CM4 is assembled by six 325MHz SSR021 [2], all of HWR015 and SSR021 themselves work well during all commissioning period. For future plan, four prototype SSR040 had been fabricated and two of them already had been tested, measuring results shown a good consistency with pioneer cavities.

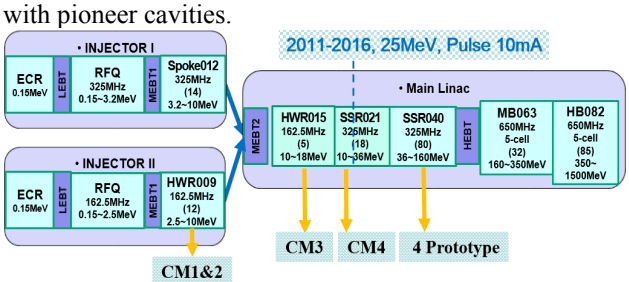

Figure 1: Roadmap of China ADS.

FABRICATION ART OF SPOKE CAVITY

With the efforts to improve the manufacturing technique of spoke cavity through several successive year, we have changed initial design scheme many time, such as the changing of flange from blank hole to through hole, increasing the elliptical blend radius of side plate, especially simplifying the structure of enhance ring, the latest design as shown in Fig. 2, a significant difference comparing to traditional type spoke cavity is that there is a big hole on the side plate, and pasted again by another bowl-like part (green part in Fig.2, we call it nose cone part), the purpose is aimed to welding the seam between cylinder and side plate from inside to avoiding a critical back-forming welding procedure, if we do so, another convenient aspect is that the welding seam can be polished by hand through the big centre hole, the final welding seam between side plate and nose cone is handled by back-forming welding, in this case, this final welding seam can been well-polished by hand with a long handle polishing tools. According the manufacturing process mentioned above, the total welding seam number is reduced dramatically to 25 from traditional one's more than sixties, it benefits by the simple design of enhance ring, another essential benefit is lying on that all of welding seam can be polished by hand with polishing tools, it is verified by the facts that test performance of all of spoke cavities fabricated according this procedure, including prototype ones, reach the design target.

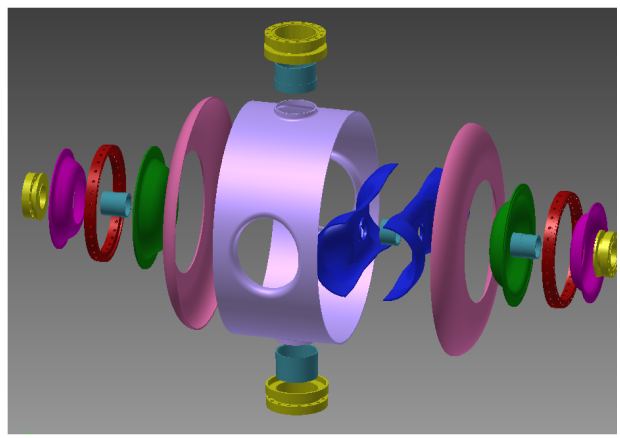

Figure 2: Explosive structure of SSR040.

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Table 1: Structure and RF Parameters of Spoke Cavities

parameter	SSR021	SSR040
Beam tube iris radius [mm]	20	25
Spoke radius [mm]	55	90
Cylinder radius[mm]	223	265
Cylinder width [mm]	240	370
Enhance ring centre radius [mm]	200	250
R/Q [Ω]	191	246
RF voltage @B_{peak}=65 mT [MV]	1.58	2.70
Optimal beta, β_{opt}	0.243	0.40
RF frequency [MHz]	325	325
Naked Weight [kg]	35	58

Some key parameter of both spoke cavities are list in Table1, in consideration of simplest enhance ring design, those spoke cavities are of weak mechanic performance, spoke cavity itself is not strong to against air pressure after evacuation, a set of jig is needed to pulling both sides enhance ring in condition of any evacuation case, as shown in Fig. 3, otherwise, a permanent deforming will be made.

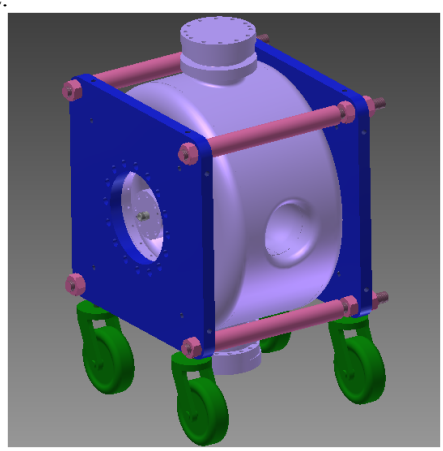

Figure 3: SSR021 with supporting jig.

BELLOWLESS HELIUM VESSEL

As mentioned above, given that the poor mechanic performance of spoke cavity, by optimizing the radius of enhance ring (in Table 1.), we have a strategy to balance the force coming from inner surface of helium vessel and outer surface of niobium cavity (refer to Fig. 4.) [3], we expect that the frequency shift divided by the pressure of helium vessel, df/dp is as possible as low. We use the tool of COMSOL [5] to simulate the above situation with the pressure of 1bar, and then calculate frequency shift of the deformed cavity shape (see Fig. 5.) [4], simulation result show that df/dp is about -15Hz/mbar at condition of tuner free, we also measure df /dp of those from SSR021 No.5 to 10 (see Table 2.) [5], which installed into CM4, the fluctuation come from uncontrollable issues, such as material, welding condition and etc.

Comparing with normal spoke or HWR cavities' design, a noteworthy feature is that no bellow adopted to connect helium vessel with niobium cavity body, the purpose is to enhance the weak niobium cavity to against the outer air pressure, most important issue is to reduce the df/dp.

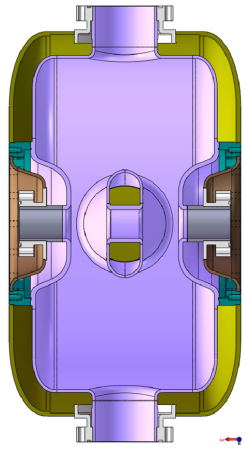

Figure 4: Bellowless helium vessel jacket.

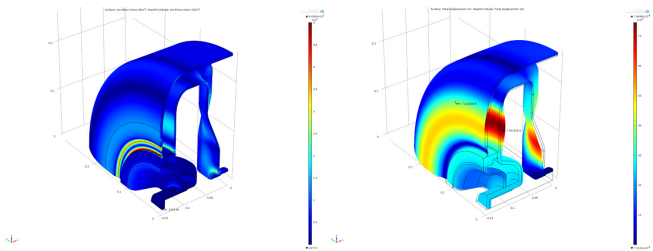

Figure 5: Distribution of stress and displacement with 1bar helium vessel pressure.

Table 2: Measured Frequency Sensitivity to the Helium Vessel Pressure

Cavity No.	df/dp @RT with tuner [Hz/mbar]
SSR021 #5	~0
SSR021 #6	-13
SSR021 #7	-12
SSR021 #8	-9
SSR021 #9	not measured
SSR021 #10	-4

REALIZING A DOUBLE SCISSORS TYPE TUNER

Refer to existed various design, a new type frequency tuner is developed for spoke cavity, the tuner arm connect with enhance ring by those blank hole on the surface of enhance ring (see Fig. 6.), both tuner arm concatenate by rotatable joint at back side, and a double scissors structure is adopted at front side, by rotating the axis, we can adjust

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the distance between both tuner arm to shift frequency, it seems that all of structure is simple and reliable. The test characteristic shown in Fig. 7, tuning range is more than ± 350kHz, tuning sensitivity is 1.15kg/1kHz, it is a reasonable value, the tuning backlash is almost negligible during test.

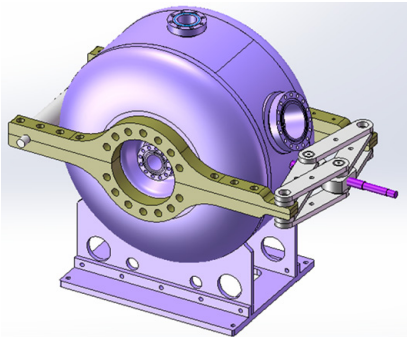

Figure 6: Double scissors type tuner.

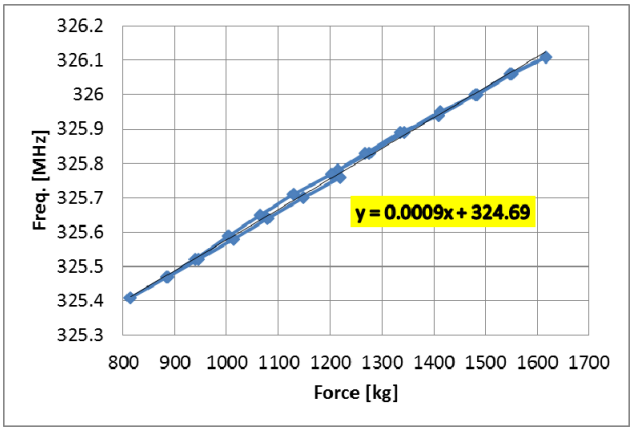

Figure 7: Frequency response vs. tuning force @cooling by liquid nitrogen.

CONCLUSIONS

In this paper, we introduce the progress of ADS in China, during construction ADS, many kinds of SRF cavities have been developed such as HWR, SSR and low beta multicell ellipse cavity [5], those technology about how to fabrication, welding and assembling cavities already realized and can be used to future CiADS project.

During cavity design stage, we already consider how to integrated helium vessel with niobium cavity together to uniform a whole part, as we do so, the df/dp can be reduce to within ±15Hz/mbar.

A new type double scissors tuner is been design, this tuner joint with niobium cavity directly through blank hole on the enhance ring, it can pull or push cavity through both side enhance ring.

ACKNOLOGYMENT

During developing of spoke cavities, we have gotten change to visit Fermilab, KEK, SLAC and others, collaboration to us is essentially important to fulfil our target in a short period. Here I would like to express my appreciation to Prof. L. Ristori, V. Yakovlev and C. Grimm from Fermilab, Prof. T.Furuya from KEK and Prof. T. Tajima from LANL for their useful discussion.

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