MANUFACTURING OF 1.3 GHZ SINGLE CELL COPPER CAVITY

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Abstract

RRCAT has developed 1.3 GHz Single cell copper cavity under Indian Institution Fermi lab Collaboration (IIFC). It is proposed to use this cavity for thin film deposition R&D effort at FNAL, USA.

In this paper the manufacturing and pre-qualification process of single cell cavity are presented. The process consists of rolling of beam pipe, weld edge preparation, chemical cleaning, electron beam (EB) welding of beam pipe, development of copper-stainless steel (SS) joint, EB welding of iris and equator joint for half cells. Development of fixtures, various welding parameters and weld shrinkage estimation is also described. Resonant frequency of half-cell assemblies and the single cavity was measured to know the frequency shift associated with weld shrinkage. The results of the pre-qualification of cavity for mechanical measurement and leak testing of cavity at 300K & 77K are reported.

INTRODUCTION

RRCAT has initiated the development of 1.3 GHz (TESLA shape) single cell cavity under XI plan [1],[2]. Historically niobium coated copper cavities have been proposed, developed & used at many accelerator laboratories around the world. They offer cheap alternative to expensive niobium with added advantage of better thermal stability. A single cell cavity consisting of half cell, simple beam pipe, and flanges is a standard model for R&D activites.

Under IIFC collaboration, Fermi lab along with Argonne Lab is exploring the possibility of R & D efforts on thin film depositions.They plan to deposit 1 micron niobium film and then the multilayer structure on top of it by atomic layer deposition. Single cell 1.3 GHz developed by RRCAT will be used for this R & D.

MANUFACTURING PROCESS

Joining of copper is technically challenging due to its high thermal conductivity & porosity. High beam power density welding (like EB welding) provides a technical solution for this. With our experience of EB welding of aluminium and niobium cavities, the joining of copper cavities were also adopted using EB welding. This also helps to get good RF surface in copper cavity. Various welding & machining fixtures were designed and developed to cover all the manufacturing stages.

***Material*:** Material used for fabrication of half cells & beam pipe is OFE copper. SS 304L is used as flange material for low temperature sealing requirements.

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Weld edge preparation : Proper weld edge prearation is important step to produce correct and uniform wall thickness to avoid local burning during welding. Machining was done keeeping weld shrinakge and frequency correction allowance.

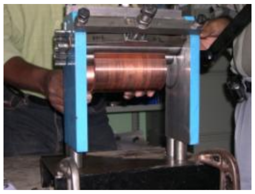
Chemical cleaning : Pre weld cleaning is an improtant pre requisite for good quality welding. As copper gets oxidised in air very fast, the welding of parts is done in a short period after cleaning (<4 Hrs). The chemical recipe consists of following steps:Degreasing in Tri-chloroethylene, pickling in a 50 % HCL solution (30min), rinising in DI water, pickling in Aqua regia solution (42% H_2SO_4, 8% HNO_3,0.2% HCL) (30 s), rinsing in DI water, passivation in a sulpho-chromic solution (2.5% H_2SO_4, 8 g/l CrO_3) (30 s), rinsing in DI water and methyl alcohol and drying in filtered compressed air [3]. Fig-1 shows the chemical cleaning process.

Welding Parameters: The high thermal conductivity of copper necessitates higher power for welding and to counteract this pre-heating was done using defocused beam. Conduction mode of welding was used for present application where joints have 2mm thickness. Beam oscillation is also an important weld parameter in order to reduce the porosity in the weld. A number of welding trials were taken on test coupon to optimise different weld parameters like beam current, voltage, weld speed, defocus current for different gun to work distances. Table-1 shows some typical weld parameters used for few of the weld configurations.

Table-1: EB Welding parameters

	Current (mA)	Feed mm/min	Focus current (A)
For beam pipe seam welding 50 kV (3 mm thk)			
Tack	5	1000	2.040
Seal (3 pass)	20	1000	2.040
Full	53-51	450	1.88
For beam pipe to SS- flange 55 kV (3 mm DOP)			
Tack	5	1000	2.075
Seal (3 pass)	15,17,20	1000	2.075
Full	40-36	450	2.150

Beam pipe manufacturing: Due to unavailability of seamless pipe, beam tube was manufactured by rolling the sheet using dedicated rolling machine for better cylindricity. Fig-2. The rolled tube is longitudinally



Figwelded with full penetration weld from outside. Weld edge preparation of tube is done to match with SS flange and half cell iris at each end.

Development of Copper–SS joint: The large variation in chemical, physical and mechanical properties across the joint, make dissimilar metal joining more complex. The EB welding can solve the problem, due to the high energy density process. The large difference in thermal conductivity problem is solved by offsetting the electron beam toward the copper side & pre-heating [4].

Samples were prepared, welded and metallographic section was examined for weld parameter optimisation before the actual joint. Fig-3 shows the copper – SS joints section and Fig-4shows the welded copper pipe-SS flange.

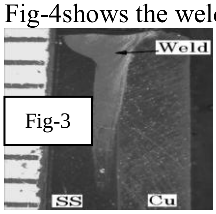


Fig-3


Fig-4

Iris Joint: The copper tube with SS flange assembly is joined to the formed & machined half cells at iris, firstly from out side & then from inside to get smooth under bead. Fig-5 shows setup for inside welding of iris. The weld shrinkage at iris of half cell assemblies are measured to be 0.35 to 0.45 mm. Machining for length correction at equator to correct the frequency keeping equator welding shrinkage allowance is done at this stage.

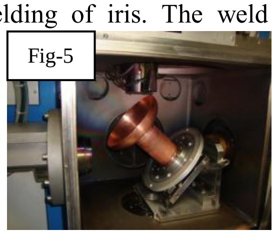


Fig-5

Equator joint: The equator is most critical joint in which smooth under -bead is to be obtained form a full penetration from outside. Fig-6 shows equator welding setup. The weld shrinkage at equator was measured to be 0.90 mm. The EB welding was carried out at M/s LTE Industries, Coimbatore using 60 KV, 100 mA EBW machine.

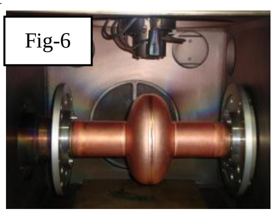


Fig-6

MEASUREMENT OF RESONANT FREQUENCY

The frequency measurement gives the information about accuracy of the contour of half cell & the reproducibility of formed half cells. It also determines the amount of trimming required at equator to achieve correct length and frequency of the finished cavity. The resonant frequency was measured at component, sub assembly stage and final stage and change in frequency due to weld shrinkage was also monitored.

1.3GHz Cavity	length (mm)	Frequency (MHz) 300K	Q Factor 300 K
Copper-01	393.34	1296.74375	28505
Copper-02	394.58	1296.883125	27146

Table-2: shows the measured frequency and quality factor.

PRE-QUALIFICATION

Mechanical Measurement: Mechanical dimensional inspection, as per quality control procedure developed, was incorporated at components, sub assembly and final stage. It gives information of dimensions, geometry and form during fabrication process.

Leak testing at 300K and 77K:

Since niobium–coated copper cavity has to work at super fluid helium temperature at 2K.Therefore leak tightness is very important for all joints. The final cavity was given thermal shocks between 300K and 77K. The cavities I in our case qualified for leak rate of 1 x 10^{-12} mbar.l/sec.

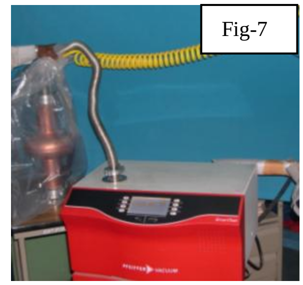


Fig-7

Figure 7-shows the leak testing set-up.

CONCLUSION

Two nos. of 1.3 GHz Single cell copper cavities have been fabricated under IIFC collaboration. Selection of material, proper pre weld cleaning, weld edge preparation, optimized weld parameter are key elements to fabricate good RF copper cavities. These cavities have been used in commissioning of centrifugal barrel polishing (CBP) being developed as part of SCRF infrastructure. These cavities are now ready for dispatch to FNAL for thin film deposition R&D.

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