TECHNOLOGY DEVELOPMENT EFFORTS ON FABRICATION OF SUPERCONDUCTING CAVITIES AT RRCAT

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Abstract

Work has been initiated for the development of Superconducting (SC) cavity manufacturing technology at RRCAT. Initial efforts are focussed on 1.3 GHz SCRF cavity under Indian Institution Fermilab Collaboration (IIFC). Two prototype bulk Niobium (Nb) SC cavities have been developed at RRCAT in collaboration with IUAC. Two prototype copper cavities for thin film deposition R&D at Fermilab have also been developed by RRCAT with industry support. Present efforts are focused on development of multicell cavity consisting of TESLA type end group and dumbbells. In this paper we present the development effort and experience in manufacturing of prototype 1.3 GHz Nb single cell SC cavities. Initial work done on standard end group and plans to make two improved single cell cavities and seven cell cavity will also be presented.

INTRODUCTION

Under XI plan project RRCAT has taken up development of SCRF Cavity and Associated Technology. Efforts have been initiated towards development of Nb SC cavity manufacturing technology with present focus on 1.3 GHz (TESLA shape) cavity. The aim of fabrication of prototype cavity is to gain experience in this highly specialized technology. Initially prototype single cell cavity in aluminum was manufactured as part of process development plan [1]. Two single cell copper cavities have also been developed [2]. Two prototype single cell bulk Nb SC cavities have also been manufactured, processed and tested at 2K. Our current activites are ongoing for making two improved single cell Nb cavities learning from the experienced gained. To work towards multicell cavities, protoype dumbbells have also been developed in aluminum and the development of end group has also been initiated.

PROTOTYPE NIOBIUM SINGLE CELL CAVITY

Manufacturing of SC cavities is an iterative process between press shop, machine shop, metrology, RF measurement, chemical cleaning, electron beam (EB) welding and finally leak testing and RF measurement. In order to satisfy the joining requirement for the desired RF performance, the joining of parts of SC cavity is done by EB welding. Based on the standard DESY recipe [3], in collaboration with Fermilab and our own experience of prototype aluminium cavity, the manufacturing plan was developed consisting of stage wise machining, RF measurement and mechanical inspection. Design for manufacturing was done that included ccertain design modification like welding lip at the backside of flange joint, no recess in the flange bore and square butt joint type weld edge design. Frequency measurements were made at half cell assembly stage and extra equator was timed. RF frequency estimation is also done for various extra lengths at equator. The HF Emag eigen mode analysis of ANSYS is done using 20 noded hexahedral (HF120) element. The equator frequency sensitivity coefficient K_{eq} is estimated to be - 5.1 MHz/mm. The measured K_{eq} matched well with estimated values. Weld shrinkage was accounted during machining of parts to control the final resonating frequency with desired length at operating temperature. Welding fixtures were designed & developed suitable for Nb welding. Half cell forming, machining and testing (mechanical, vacuum & RF) were done at RRCAT. EB welding was done in collaboration with IUAC at their facility.

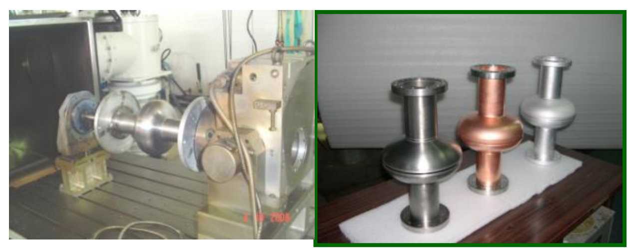

Figure 1(a): Final equator welding setting at IUAC, EBW facility. Figure 1(b): prototype single cell cavities in (r to l) Al, Cu & Nb.

Table-1 shows the measured weld shrinkage & RF measurement data on prototype niobium 1-cell cavities.

Table-1

Cavity ID	Length (mm)	weld shrink mm	Frequency (MHz) / Q-factor at 300K
TE1CAT001	393.58	0.46	1296.926 /9076
TE1CAT002	392.96	0.42	1296.675 / 9328

After pre-dispatch inspection qualification including RF & vacuum leak test, the cavities were dispatched to FNAL for processing and performance evaluation. Processing stages involved CBP, EP, HT and HPR followed by clean room assembly. Both the cavities have been tested at 2 K. in VTS at FNAL and have shown E_{acc} of 19.8 and 21 MV/m with Q > 1.5E+10. Fig-2

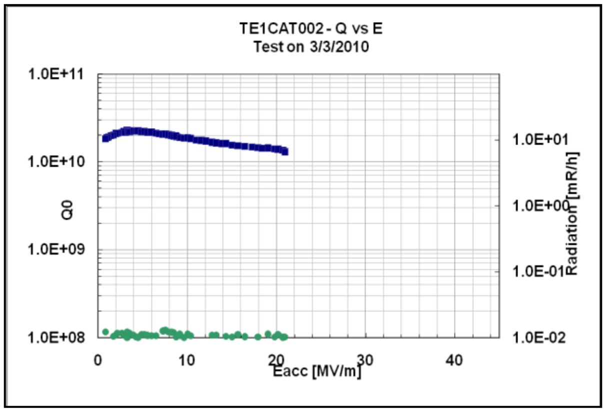

Figure - 2: Q vs Eacc Plot of First prototype 1-cell cavity.

DUMBBELL & END GROUP DEVELOPMENT

Multicell cavity development requires development of dumbbells and end group. It is important to control the length, parallelism and frequency at dumbbell and end group stage to get the desired length, straightness & field flatness in a multicell cavity. Prototype dumbbells in aluminium have been developed. The half cells were machined with only shrinkage allowance at iris and are kept +2 mm at equator.

Figure - 3: Prototype dumbbell under mechanical control and End group fabrication.

Currently we are in the process of learning the frequency measurement and estimation of trimming allowance for the dumbbell. Mechanical measurements were made to monitor the parallelism and weld shrinkage at iris inner/outer and stiffening ring welding.

Dumbbell ID	140/149	141/147	144/146
Parameter	Mechanical measurement (mm)		
Final Height	120.26	119.11	119.84
Concentricity	0.40	0.54	0.15
parallelism	0.68	0.37	0.15
Welding	Dumbbell weld shrinkage (mm)		
Iris outside	0.91	1.28	0.85
Iris Inside	0.71	0.66	0.50
Stiff. ring	0.45	0.80	0.72

Table-2: Weld shrinkage & mechanical measurement

The other critical part of a multicell cavity is end group consisting of RF, pickup and HOM ports with connection to helium vessel. There are numerous small and complex 3-D parts which needs precise machining. While waiting for high RRR Nb, we have initiated the parts manufacturing in dummy aluminium. The welding fixture have also been designed and developed. Initial trial welding is currently going on with at industry. This exercise will help us to develop the manufacturing process & qualify the tooling.

PRESENT ACTIVITIES

A lot of learning experience has been gathered during initial prototype single cell cavity manufacturing & testing. Our present activities are focused to make two more improved single cell 1.3 GHz cavities with IUAC. Important modification being 20µm BCP etching, more careful handling and storing of parts (N_2 backfilled poly bags) and overall improvement in the weld-bead of the equator joint.

FUTURE PLANS

Based on our understanding of prototype dumbbells we plan to work on 1.3 GHz Nb 5-cell cavity. As per the new addendum under IIFC, we have also initiated development of 650 MHz β=0.9 SC single cell cavity. Die design & development has also been initiated at RRCAT [4]. 650 MHz Single cell cavity design for manufacturing has been initiated. Design and fabrication of machining & welding fixtures is in process. We first plan to make single cell cavity in line with 1.3 GHz work in collaboration with IUAC for electron beam welding.

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