FABRICATION OF SUPERCONDUCTING NIOBIUM CAVITIES AT NUCLEAR SCIENCE CENTRE

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Abstract

This paper presents the status of the fabrication of niobium superconducting cavities for the heavy ion linear accelerator at Nuclear Science Centre, using the resonator fabrication facility. The facility consists of an electron beam welding machine, surface preparation laboratory, high vacuum annealing furnace, and test cryostat setup. In the first phase a quarter wave resonator has been successfully e-beam welded and tested. Fabrication of two more quarter wave resonators is in an advanced stage. In addition several critical repairs have been successfully performed. Production of resonators for the next linac modules will begin soon.

INTRODUCTION

A Superconducting Resonator Fabrication Facility (SuRFF) for fabricating niobium resonant cavities has been setup at Nuclear Science Centre (NSC). The facility consists of a 15 kW (60 kV, 250 mA) Electron Beam Welding machine having vacuum chamber of size 2.5 m × 1.0 m × 1.0 m, a fully equipped and automated Surface Preparation Laboratory for electropolishing of the cavities, High Vacuum Furnace capable of annealing up to 1300 °C with a hot zone of size ϕ 600 mm × 1000 mm, and a dedicated test cryostat setup. The facility was fully commissioned in August '2002. In the first phase of fabrication a single quarter wave resonator (QWR) [1] for the NSC superconducting linac [2] was successfully constructed. Two more QWRs are presently in advanced stage of completion. In addition several critical repairs on existing resonators have been successfully performed. Production of resonators for the second and third linac modules will begin shortly.

CAVITY FABRICATION

The niobium resonator fabrication work has been taken up in a gradual manner. In what follows, a brief description of the work performed so far, status of the on-going work, and future plans are described.

Fabrication of the First QWR

In order to acquire experience with electron beam welding of niobium, machining and fitting of resonator parts and sub-assemblies, electropolishing and heat treatment, we decided to fabricate the first resonator using extra parts that were made during the NSC resonator construction project (for the first linac module) at Argonne National Laboratory (ANL), USA [3].

This provided us with the opportunity to perform several critical e-beam welds and associated work and laid the road map for the second phase of construction of two completely indigenous resonators. Figure 1 shows the first resonator constructed at NSC. In cold tests this resonator performed at 4.5 MV/m accelerating electric field with 6 W of RF input power (see figure 2). The performance of this resonator is comparable with the ANL produced resonators.

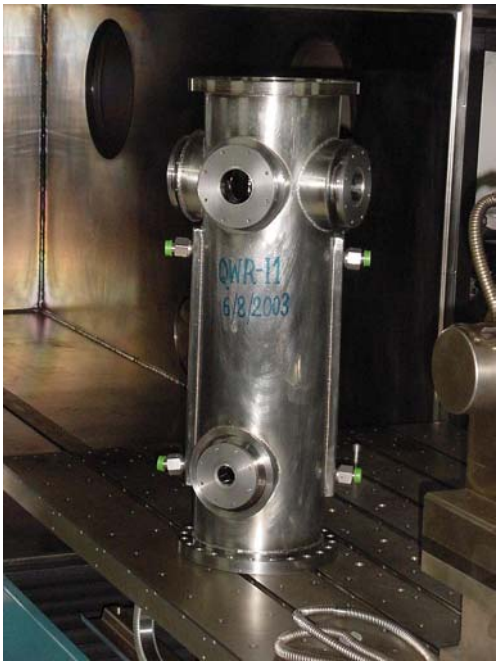

Figure 1: First indigenously built niobium quarter wave resonator

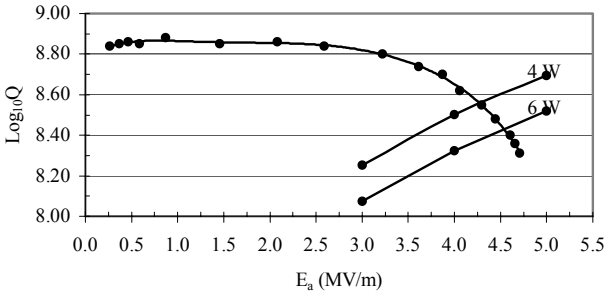

Figure 2: Resonator Q as a function of accelerating electric field E_a at 4.5 K.

Indigenous Fabrication of QWRs

After the successful completion of the first resonator, construction of two more resonators in the second phase has been taken up. Unlike the first QWR, these two resonators are being fabricated completely indigenously. All machining, forming, rolling and fitting is being done at a local vendor's site and the e-beam welding, electropolishing and heat treatment is being done using the facilities setup at NSC. Substantial development work at the vendor's site was undertaken to train the manpower in various machining operations and handling of niobium. Simultaneously e-beam welding parameters of those welds that were not made during the fabrication of the first resonator, were also developed. Figure 3 shows the niobium outer housings and drift tubes of the two resonators after the beam welding and before electropolishing. We expect to complete the fabrication in the next three months. Production of resonators for the second and third modules will begin after that.

Figure 3: Outer niobium housings and drift tubes of the 2nd and 3rd QWR.

Critical Repairs on the QWRs

In addition to fabrication of fresh cavities several critical repairs have also been undertaken. In the NSC resonator design [4] the transition from the inner niobium housing to the outer stainless steel jacket is provided through niobium-stainless steel explosively bonded flange and edge welded stainless steel bellows. On several of the ANL built QWRs the transition flange bellows assemblies have leaked when the resonators were loaded in the cryostat. We had not encountered this problem during the prototype resonator development [4] and it is not entirely clear why it happened on the production resonators. In order to avoid problems on future resonators we have modified the design of the transition flange assembly using formed stainless steel bellows. The wall thickness of the bellows is 0.15 mm and each assembly has four convolutions, enough to provide reasonably large stroke length. This would avoid any stress on the ports due to differential thermal contraction between niobium and stainless steel while cooling down from 300 K to 4.5 K. Several transition flange assemblies have been fabricated, thermally cycled and pressure tested. Figure 4 shows the modified transition flange assembly for the RF power and pickup ports. The leaking assemblies on several cavities have been successfully repaired by machining them out and replacing with the modified design. These resonators are presently under tests and results on the performance of the modified design will be available in the coming months.

Figure 4: Coupling port transition flange assembly.

Two of the resonators developed leak in the niobium central conductor near the top end of the drift tube. This part (called upper cap) had been die formed in two stages and we feel that during the second stage of forming (punching) it thinned down at one end due to its incorrect positioning in the die. The resonators have been cut open and a new upper cap made out of thicker material has been inserted. This repair is more complex since we have to maintain the frequency vis-à-vis the alignment of the beam ports of the central conductor and outer housing. It is by far the most difficult repair work the group has undertaken since the SuRFF facility has been setup. The resonators are expected to be repaired in the next couple of months.

Resonator Production

We plan to undertake production of more than a dozen resonators for the second and third linac modules after the completion and testing of the indigenous resonators. Each of the linac modules in the NSC linac would hold eight resonators and three modules are planned [2]. As mentioned earlier resonators for the first module have already been built [3].

CONCLUSIONS

Superconducting niobium resonator fabrication technology for ion accelerators is new in India. To produce them indigenously a fabrication facility has been setup at Nuclear Science Centre. The setup is fully operational and the first indigenously built resonator has performed well above the design goal. In addition to building cavities, several repairs and associated development work are also being done.

REFERENCES

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