TESTS OF INDIGENOUSLY FABRICATED CAVITIES AT IUAC: LESSONS LEARNT AND SUBSEQUENT IMPROVEMENTS

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Abstract

With the first module of the superconducting booster Linac[1] at IUAC fully operational[2], much of the focus has now shifted towards the installation and commissioning of the remaining two modules. A total of seventeen indigenously fabricated Quarter Wave Resonators (QWR) are available for installation in the second and third modules. Several offline cold tests of many of the QWRs were carried out over the past year. The basic objective of the tests was to validate the performance of the cavities prior to their installation in the Linac modules. Initial tests yielded poor results. Subsequently corrective measures were taken based on the possible reasons for the poor performance. Some improvements were also made in the cavity preparation techniques followed at IUAC. These have resulted in a substantial improvement in the cavity performance.

INTRODUCTION

The cold tests of the indigenously fabricated QWRs [3] have been going on for over a year and more than a dozen tests have been conducted with cavities randomly selected from the lot. The initial results were not very promising, which was a cause of major concern as no concrete reason could be attributed to the poor performances. Several possible causes were thought of which included inadequate Electro Polishing (EP) in the final cavity preparation, increased surface resistance due to trapped magnetic flux in the high current region of the cavity and Q degradation due to hydrogen precipitation on the RF surface resulting from a slow cool down rate. A series of corrective actions were taken based on these assumptions each of which was followed by a cold test to check out its validity. Simultaneously, the EP process was modified by constantly churning the acid during the cycle and altering the composition of the acid mixture. This was done to have greater current oscillations during the cycle, which have been reported [4] to produce the actual polishing effect. An additional step of post EP ultrasonic cleaning with 2% Liquinox solution was also introduced.

THE INITIAL TEST RESULTS AND SUBSEQUENT MEASURES

Initial tests were done with two indigenous cavities I-06 and I-15. I-06 had a low field Q_0 of 9.2 x10^7 @ 0.4 MV/m and achieved a field level of 2.1 MV/m @ 5.5 W of power beyond which it became thermally unstable. I-15 on the other hand had a low field Q_0 9.8x 10^7 @ 0.4 MV/m and could only take 3.3W of power at which it achieved a field of 2.1 MV/m. Magnetic field measurements near the top dome structure of the SS jacket of both the cavities indicated a high level of residual magnetization of the SS material. It was thought that the poor results were probably due to the trapping of magnetic flux in the high current region of the cavity during cool down leading to an increased surface resistance [5]. The SS dome structure of I-15 was subsequently demagnetized (the residual magnetic field levels were brought down to ~0.5G from earlier value of ~6G) and the cavity was tested again. However, its performance did not improve and it achieved a field of 1.6 MV/m @ 6 W of power with a low field Q_0 of 6.1 x10^7 @ 0.2 MV/m. This ruled out the possibility of performance deterioration due to magnetic flux trapping. In a parallel effort the other resonator I-06 which was earlier electro polished to remove ~40µm of Nb from the surface was given more EP to remove another ~60 µm of material followed by a post EP ultrasonic rinse in ultra pure water.

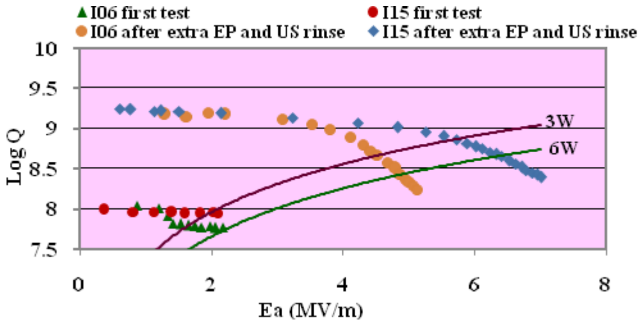


Figure 1: Comparative Q curves for QWR I-06 and I-15

This was done with the assumption that the poor performance of the cavities was due to inadequate cleaning of the RF surface and that more chemical treatment was required to etch out the damaged layers from the niobium surface. In subsequent cold test there was dramatic improvement in the cavity performance. Its low field Q_0 improved to 1.5x10^9 @ 1.3 MV/m and it could achieve a field level of 4.9 MV/m @ 6W of input power. The same recipe was followed with I-15 with only one minor difference, that this cavity was given a more thorough post EP ultrasonic rinse (for ~1¼hrs) with ultrapure water heated to ~55°C. Its low field Q_0 improved to 1.7 x10^9 @ 1.6 MV/m and it could attain a field level of 6.4 MV/m @ 6W of power. Figure 1 shows the Q curves of I-06 and I-15 before and after the extra surface treatment steps given to the cavities.

Investigation of a possible Q disease:

During the cold tests in the test cryostat as well as in the Linac operation the cavities are first pre-cooled with LN_2 to 170K before the final cool down with LHe. Doubts were raised as to whether holding the cavity temperature at 170K [6] was resulting in Q disease due to higher hydrogen concentration in the bulk material owing to the heavy EP given to the cavity. The test was done with the Indigenously fabricated resonator I-18 which was first electro polished to remove ~100µm of material and then tested twice, once after holding it at ~170K overnight before a final cool down to 4.2K (cool down rate ~40 K/hr) and the second time with a direct cool down from 200 K to 4.2 K at a rate of ~50 K/hr. Though the cavity performance was not very promising in both the tests, a marked improvement was observed in the second test. The low field Q_0 @ 0.4 MV/m improved to 1.5 $x10^8$ from 1.1 x 10^8 achieved in the first test. The high field performance of the cavity also showed a similar improvement. A field level of 2.5 MV/m@ 6W of power was achieved as against 1.7 MV/m @ 6W achieved in the first test. This study pointed towards the possibility of Q disease occurring in the IUAC cavities. However, another cavity I-04 when tested under similar conditions (cool down from 170K) did not show any signs of Q degradation. More statistics are therefore required to confirm the presence or absence of Q disease.

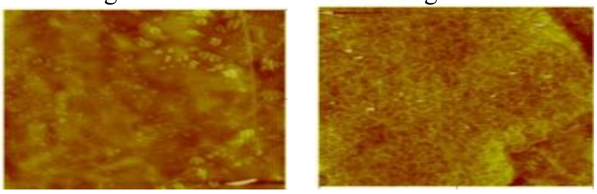
IMPROVEMENTS IN CAVITY PREPARATION TECHNIQUES

The major changes are described in the following subsections:

Modification in the EP procedure:

The EP process at IUAC consists of discrete cycles, each of which is of ~150seconds duration. During one cycle the current flows through the electrolyte for ~30 seconds (known as ON time) and for the remaining 120 seconds (known as OFF time) the acid mixture is churned by means of a pump. This is done to remove the hydrogen evolved at the cathode and to dissolve any insoluble niobium oxide formed during the passage of current. This process has now been modified and the acid mixture is now continuously churned both during the ON time as well as the OFF time in a cycle. The composition of the acid mixture has also been changed to 9:1(H_2SO_4: HF) from earlier value of 7:1. These changes have resulted in greater current oscillations during the ON time producing a better polishing effect, a more uniform temperature distribution in the acid mixture and an efficient removal of the evolved hydrogen gas. Roughness measurements using Atomic Force Microscopy(AFM), shown in figure 2, were done on two niobium samples. One of these was electro polished with acid churning only during the OFF time, while the other one with constant acid churning. They have revealed that the average roughness of the second sample was ~22nm which was almost a factor of 2 less than that of the first sample

Mean roughness 41.27 nm   Mean roughness22.79 nm



(a) #1 w/o constant churning   (b) #2 with churning

Figure 2: AFM images of Electro polished Nb samples

Post EP ultrasonic rinsing:

Chemical treatment of the niobium cavities leaves behind residues which are primarily sulphur and fluorides. These residues are not removed with an ordinary water rinse and serve as potential field emission sites. Ultrasonic agitation in warm DI water (55°-60°C) with a mild detergent (Liquinox, Micro-90 etc) has been found to effectively remove the contaminants. This procedure has therefore been adopted as a standard step in the cavity preparation at IUAC. To effectively clean the finer particles adhering to the RF surface it has been decided to use an ultrasonic cleaner with a higher frequency of 68 kHz as against the present 26 kHz, which is common with industrial cleaners.

SUMMARY

A multipronged approach has not only helped in overcoming the performance related problems with the indigenous cavities but also has led to an improvement in the average cavity performance. The fact that the majority of the cavities tested subsequently have given good results, exceeding the design goal, has provided the necessary confidence to proceed with the installation and testing of the second and the third Linac modules.

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