ELECTROPOLISHING OF THE ANL DEFLECTING CAVITY FOR THE APS UPGRADE*

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Abstract

Studies on the application of electropolishing (EP) of the ANL superconducting deflecting cavity have shown promising results. This cavity geometry is a squashed single-cell cavity with Y-end group waveguide as well as on-cell LOM damper. The cavity works at TM110-like deflecting mode, in which the iris between the cavity cell and the Y-end group is the highest magnetic field region. Before EP, the cavity had been chemically etched (BCP) several times. Forty-μm EP processing was performed on one Mark II prototype deflecting cavity at Fermilab. No mild baking was performed before the cavity vertical test. The test showed that the low-field Q had improved from 2×10^9 to 3×10^9 and the high-field Q-slope had been successfully removed. The quench limit was slightly improved from 106 mT to 113 mT. Fast T-mapping had detected a significant decrease of local temperature rise in the cavity iris. Optical inspection before EP found a lot of grooves around the iris, which might be related to the gas bubbles generated during BCP. This suggests that horizontal EP is a promising processing technique to remove the high-field Q-slope and improve the deflecting cavity performance.

INTRODUCTION

Superconducting deflecting cavities are under development for a number of applications. The Advanced Photon Source (APS) at Argonne National Lab (ANL) plans to uses the superconducting deflection technique to generate x-ray on the order of 2 ps or less [1]. An optimized deflecting cavity design has been proposed. As shown in Fig. 1, the cavity is a single squashed-cell cavity with a waveguide damper on-cell and a Y-end group on the beam pipe [2]. The cavity works at 2815MHz . To provide sufficient deflecting modulation to the beam, the single-cell cavity deflecting voltage needs to reach 0.5 MV, which corresponds to a peak surface magnetic field of 106 mT. Unlike the accelerator, a deflecting cavity operates at dipole mode. The equator is not the peak surface magnetic field region. The iris between the cavity cell and the Y-end group has the highest surface magnetic field.

A proper treatment technique is necessary to achieve optimum cavity performance. Four deflecting cavities have already been fabricated under a collaboration between ANL and JLAB [3]. All of them used buffered chemical processing (BCP) as the baseline procedure. Electropolishing (EP) has proven to be a successful treatment procedure in achieving higher gradient with better Q in 1.3 GHz accelerators [4]. This paper reports our progress on an EP study on one of our cavity. The test result showed EP had successfully removed the high-field Q-slope and improved the cavity gradient.

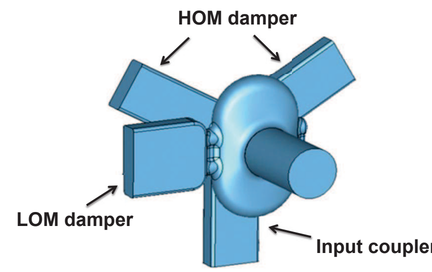

Figure 1: ANL deflecting cavity design.

ELECTROPOLISHING OF DEFLECTING CAVITY

Cavity Background

The cavity was made from large-grain niobium ingot with RRR larger than 300. One of our 2.815GHz deflecting cavities was chosen for the EP study. This cavity was the first cavity fabricated with all the waveguide couplers. BCP had been applied to this cavity several times. Detailed investigation had revealed that there was stronger than expected coupling between the on-cell damper and cavity cell. A tuning technique had been developed to significantly reduce the unexpected leaking [5], which had improved the Q at 2K from 8×10^8 to 2×10^9 at low field. However, there was still significant Q-slope at high field. Light BCP and mild baking had little effect on Q-slope.

Description of Electropolishing Procedure

A $40 - \mu m$ EP was performed on this cavity at Fermilab. This technique has been found effective in 7-cell CEBAF cavities [6]. The EP system we used was a horizontal EP system designed for 1.3 GHz Tesla/ILC single-cell cavities. The total volume of acid stored was 15 L, the acid circulation rate was 1.3 L/min. The rotation speed of the

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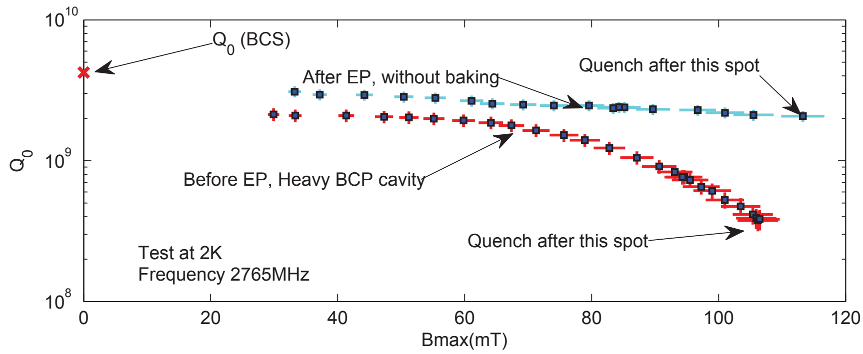

Figure 2: Q vs B curve comparison. Before EP, there was high-field Q-slope found with significant heating around the iris. After EP, the test was performed without baking and no Q-slope was found.

cavity was set at 1 rpm. At a voltage of 14 V, the equilibrium was established with current oscillating around 20 A. During the EP procedure, the cell wall temperature was maintained at 22^{o}C and beam pipe at 10^{o}C. The EP procedure lasted for 2 hours, followed by deionized water rinsing. The actual weight removed was 13 grams. There was some removal difference found at different locations of the cavity; 58 μm was removed at the iris, 20 μm was removed at the cavity equator, and an average of 30 μm was removed around the cavity cell.

CAVITY MEASUREMENT

Cavity Vertical Test

A cavity vertical test was performed at 2 K at JLAB. No mild baking was performed before the cavity test. Fig. 2 compares the results before and after EP. Before EP, the cavity Q was around 2×10^9 at low field and there was a significant Q-slope at high field. After EP, the low-field cavity Q had improved to 3×10^9, and the high-field Q-slope had been removed without mild baking. The quench limit had improved from 106 mT to 113 mT. X-rays due to field emission were also detected, but at a very small level.

Time-Resolved Temperature mapping

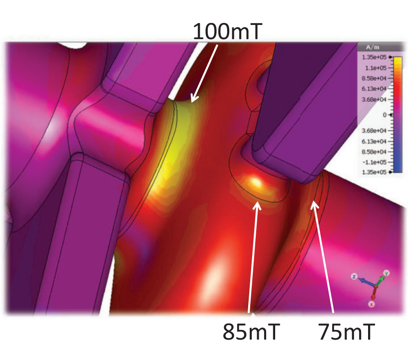

Figure 3: Surface magnetic field distribution of the ANL deflecting cavity.

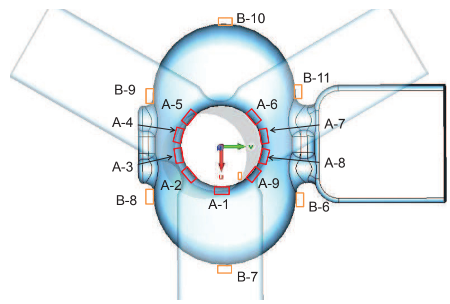

Figure 4: Sensor Layout around the cell and iris.

To fully characterize the surface loss, a time-resolved temperature mapping had been developed for the deflecting cavity test [7]. Compared with 1.3 GHz accelerators, our cavity had a compact size with different regions of high magnetic field. A fewer number of sensors were needed. Fig. 3 shows the calculated cavity surface magnetic field. The highest surface magnetic field was at the iris between the cavity cell and the Y-end group. Based on the surface magnetic field distribution, an optimized temperature mapping layout had been used during the cavity vertical test. The sensor layout is shown in Fig. 4. Before EP was applied, there was significant heating detected around the iris, starting at 70 mT when the Q-slope started, as shown in Fig. 5. All nine sensors around the iris could detect a significant heating signal. It was a global effect around the iris. Quench happened around the A-2 sensor. After EP, there was no obvious Q-slope. Temperature mapping showed only two hot spot at high field including the one set around the quench point. The detected temperature was less than 3 mK before quench happened. The quench happened at the A-3 sensor, which was one-half inch from the previous quench location. The quench location was detected by dramatic heating signals at the A-3 sensor, as shown in Fig. 6.

Optical Inspection

Before EP, an optical inspection was performed and a lot of grooves were found around the Y-end group damper as

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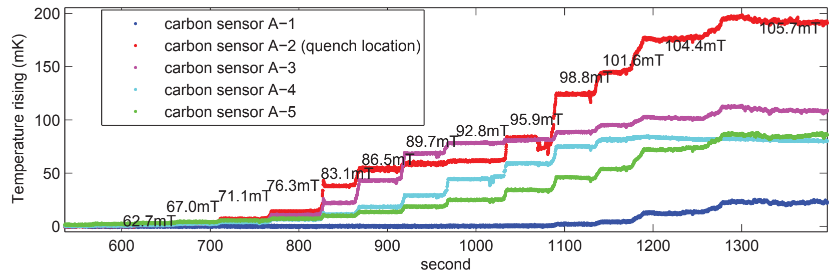

Figure 5: Before EP, global heating was detected around iris with Q-slope. This picture shows the temperature rise of sensors A-1 to A-5. The same heating was also detected at sensors A-6 to A-9.

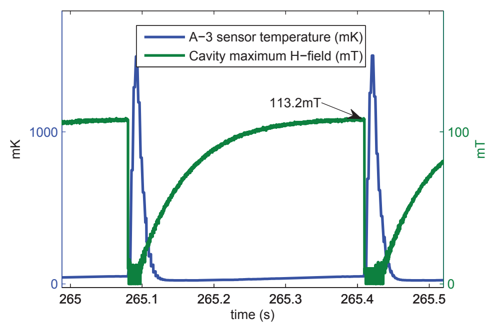

Figure 6: After EP, quench happened when the cavity Bmax 113 mT. The 1.4 K pulse heating was detected when quench happened at the A-3 location.

well as on the iris. As shown in Fig. 7, the grooves were much more significant in the low-surface-field Y-end group compared with the high-surface-field iris. The grooves were believed left during the BCP as the track of gas bubbles. More power loss would be generated due to this geometric feature, which would lower the Q. After EP, the surface is smoother, and it might be the reason of Q increase. We speculate that the high-field Q-slope before EP is related to the niobium hydrides in the near-surface layer [8]. The horizontal EP can remove the near-surface layer, and it has the advantages of minimizing the danger of H absorption when forming the new niobium hydrides. This can explain the Q-slope removal without baking, but further analysis is required to verify this mechanism.

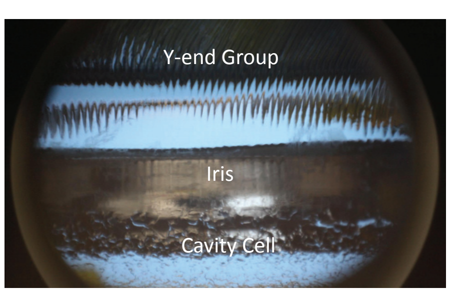

Figure 7: Numerous grooves found on the Y-end group and the iris between the Y-end group and thecavity cell.

SUMMARY

Electropolishing has successfully removed the high-field Q-slope and improved the Q on one of the ANL deflecting cavities. Before EP was applied, BCP had been applied to this cavity several times. High-field Q-slope was found at high field with significant heating around the iris between the cavity cell and the Y-end group damper. Light BCP had little effect on the high-field Q-slope. Optical inspection had found numerous grooves that were believed to be left by the BCP. However, after 40 μm EP was applied, the Q-slope was completely removed without mild baking. The quench limit had increased from 106 mT to 113 mT.

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