EXPLORATION OF MATERIAL REMOVAL RATE OF SRF ELLIPTICAL CAVITIES AS A FUNCTION OF MEDIA TYPE AND CAVITY SHAPE ON NIOBIUM AND COPPER USING CENTRIFUGAL BARREL POLISHING (CBP).[*]

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Abstract

Centrifugal barrel polishing (CBP) for SRF application is becoming more widespread as the technique for cavity surface preparation. CBP is now being used in some form at SRF laboratories around the world including in the US, Europe, and Asia. Before the process can become as mature as wet chemistry like eletro-polishing (EP) and buffered chemical polishing (BCP), there are many questions which must be answered. One of these topics is the uniformity of removal as a function of cavity shape and material type [1]. In this presentation we show CBP removal rates for various media types on 1.3 GHz TESLA and 1.5 GHz CEBAF large/fine grain niobium cavities, and 1.3 GHz low surface field shaped copper cavity. The data also include calculated RF frequency shift modeled removal as a function of cavity and comparing them with CBP thickness measurement results.

INTRODUCTION

Centrifugal barrel polishing (CBP) for SRF application is becoming more wide spread as the technique for cavity surface preparation [2–7]. During the CBP process, a cylindrically symmetric hollow vessel is filled with an abrasive media, sealed, and rotated around the vessels symmetry axis in one direction, while also rotates in the opposite direction around an additional axis parallel to the vessel axis [8]. The rotation about the symmetry axis moves the abrasive along the surface, while the parallel axis rotation creates a radial force between the cavity and the media. This combination creates uniform surface finish and fast removal rate.

CBP is now being used in some form at SRF laboratories around the world. Before the process can become as mature as wet chemistry like eletro-polishing (EP) and buffered chemical polishing (BCP) there are many questions which must be answered. One of these topics is the uniformity of removal as a function of cavity shape and material type. We

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report the current status of mirror-like finish CBP removal rates at JLab on niobium and copper elliptical SRF cavities.

CAVITY REMOVAL RATES

The total CBP process for 4 cavities including, media and total run times, are shown in Table 1. The detailed procedure on how the cavities were handled and CBP steps are outline in a previous paper [3]. After each CBP step, the cavities wall thickness were measured at 6-8 locations along the cavity wall and beam pipe using a Panametrics NDT gage 25DL-Plus and Probe: M202 10/.25" 661010 tip. The measurements were taken at the end of each CBP step after the cavity was cleaned and dried. For each scan location, 3-4 thickness measurements were taken and the mean calculated. If the standard deviation of the measurements were greater than 10 microns, the largest outliers were dropped, i.e. for all measurement presented the error on the total thickness measurement is below 10 microns. The measurements for the colloidal silica polishing step was always below our measurement sensitivity.

TESLA Large Grain Niobium

TE1G002 is an ILC TESLA shape experimental large grain single cell cavity. The cavity was prepared with the standard JLab cavity welding and has standard ILC aluminum/magnesium seals for end flanges. Prior to CBP no chemistry performed. The hourly removal rate as a function of cavity position for the first three CBP steps is shown in Figure 1.

Low Surface Field 1.3 GHz 1/2 Hardness Copper

LSF1-1CU is a ILC 1.3 GHz low surface field prototype made out of 1/2 hardness oxygen free copper. The cavity was made by the standard EBW procedure for niobium where all the welds are full penetration outside welds on a 1/2 material trimmed thickness butt weld. After welding the cavity did not receive any chemistry or cleaning prior to CBP. The hourly removal rate as a function of cavity position for the first three CBP steps is shown in Figure 2.

Table 1: CBP Processing Step for each Type of Cavity Measured

Cavity material (shape)	step 1 (time)	step 2 (time)	step 3 (time)	step 4 (time)
Large grain Nb (TESLA)	K&M ceramic (20hr)[a]	RG-22 cones (17hr)[c]	3μm diamond (30hr)[f,d]	0.04μm silica (90hr)[g,d]
Fine grain Cu (LSF)	K&M ceramic (20hr)[a]	RG-22 cones (17hr)[c]	3μm diamond (30hr)[f,d]	0.04μm silica (90hr) [g,d]
Fine grain Nb (TESLA)	K&M ceramic (6hr)[a]	RG-22 cones (20hr)[c]	alumina (40hr)[e,d]	0.04μm silica (80hr)[g,d]
Large grain Nb (CEBAF)	AH-41 ceramic (5.5hr)[b]	RG-22 cones (10hr)[c]	corn cobs (17hr)[h]	

[a] K&M ceramic 3/8 X 3/8 22 degree angle cut triangles
[b] Mass finishing AH-41 aggressive ceramic mix
[c] Mass finishing 1/2" RG-22 plastic cones
[d] Raytech untreated 5mm hardwood cubes (40 lbs/cu ft.) as a media carrier
[e] 800 mesh aluminum-oxide power
[f] Buehler 3 μm MetaDi Supreme Diamond Suspension
[g] Allied high tech products 0.04 μm Non-Stick/Rinsable Colloidal Silica
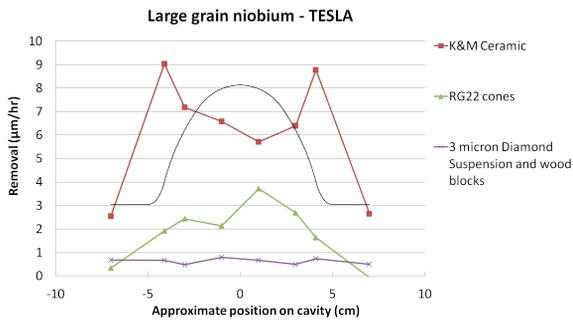[h] Mass finishing MFI Premium Corn Cob for Polishing - Medium Grade

Figure 1: CBP removal rate for large grain niobium as a function of cavity position. The physical profile of the cavity is shown in thin black.
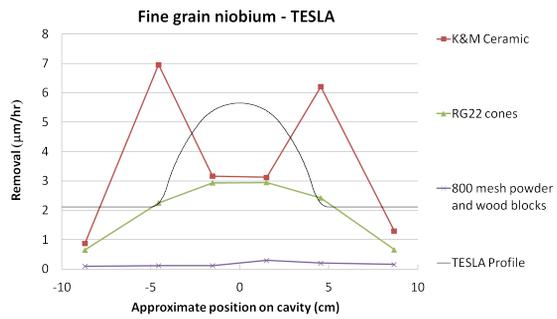

Figure 3: CBP removal for TESLA fine grain niobium. The physical profile of the cavity is shown in thin black line.
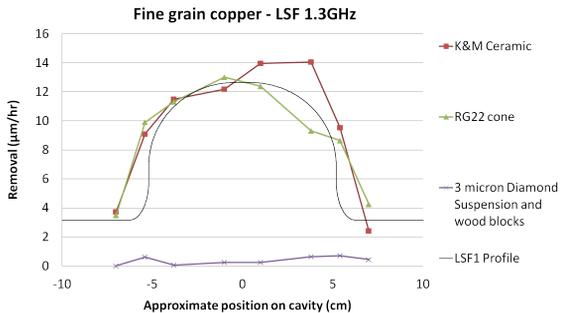

Figure 2: CBP removal rate for low surface field 1.3 GHz, 1/2 hardness copper as a function of cavity position. The physical profile of the cavity is shown in thin black.
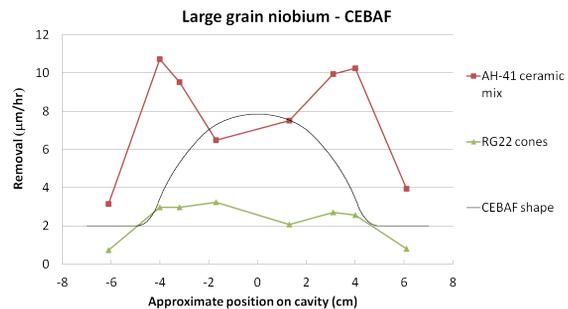

Figure 4: CBP removal rates for large grain niobium CEBAF shape. The physical profile of the cavity is shown in thin black line.

TESLA Fine Grain Niobium

TE1G003 is an ILC TESLA shape experimental fine grain single cell cavity. The cavity was prepared with the standard JLab cavity welding and has standard ILC aluminum/magnesium seals for end flanges. This was the second run of CBP, but initial removal was not tracked. The hourly removal rate as a function of cavity position for the first three CBP steps is shown in Figure 3.

Large Grain CEBAF 1.5 GHz

G1-G2 is an CEBAF 1.5 GHz shape large grain single cell cavity. The cavity was prepared with the standard JLab cavity welding and has standard CEBAF indium sealed flanges. There was no chemistry before the CBP process. The hourly removal rate as a function of cavity position for the first two CBP steps is shown in Figure 4.

Table 2: Measured and Calculate RF Frequency Shift from Large Grain Niobium TESLA Shape and Fine Grain Copper LSF Shape after CBP.

Material (shape)	ΔF Measured	ΔF Superfish uniform	ΔF Superfish profiled	ΔF Superfish profiled/deformed
LG-Niobium (TESLA)	-2.06MHz	-2.3MHz	-2.15MHz	———————-
FG-Copper (LSF)	-8.39MHz	-5.5MHz	-5.9MHz	-8.3MHz

CBP Profile Results

Looking at all three niobium cavities, one can see the removal rate at different locations along the surface is not uniform. For the course media the highest removal rate is along the side wall, while the highest removal rate for all other media is on the equator. This is contrast to the copper cavity which showed the highest removal rate at the equator. In addition, course and medium media have the same removal rate on copper, while for Niobium it is 2-3:1. While not graphed in this publication, the total removal ratio between the equator and side wall close to the iris for JLab current 4 step recipe (10:20:40:80 hr) the ratio is about 0.8. So, if one wants to remove 100 micron at the equator the assumption is the removal on the side wall is 20% more.

RF MEASUREMENTS

Before and after the total CBP process, RF frequency measurements were completed for LSF1-1CU and TE1G002. We wanted to compare the assumed uniform removal frequency shift to a profiled RF frequency shift to see if a single RF measurement could be used to replace the tedious thickness measurements. The measured frequency shift for both cavities are in Table 2. All calculation were made in Superfish, assuming a removal deviation from the theoretical cavity shape. The calculations were done in two ways, first assuming a uniform removal from a single thickness measurement near the equator; and second, breaking the cavity up in 8 uniform section along the profile and changing removal rate to match that of the thickness measurements. Between the points a linear interpolation of the removal rate was assumed except for on the beam pipes which were assumed to be uniform. For the niobium cavity, the difference between the uniform uniform removal and the actual removal was 15%, while the the difference between the profiled and actual was 6%. For the copper cavity neither calculation came close to the measured frequency change. This can be explained because the much softer copper cavity deformed at the equator weld region from the CBP. We measured a 0.7 mm deformation at the equator; adding this deformation to the profiled calculation moved the frequency shift to within 10% (Table 2 far right). The data suggests a single RF measurement could be done to determine the removal rate, but a assumption of the removal profile and cavity deformation is need for accurate measurements.

CONCLUSION

The systematic removal rates for three types of niobium and one type of copper elliptical cavities has been mapped. For each cavity type, the removal in the course media type has removed a greater amount from the side wall with the exception of the copper which had the highest removal at the equator. Our results also indicate the CBP of copper cavities is very different than that of niobium and special care should be taken as the materials yield strength after welding in less than niobium. In addition to the ultrasonic measurements, total removal RF frequency measurements were also complete showing the need to profile removal rates to understand the frequency shift from systematic CBP.

ACKNOWLEDGMENT

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09 Cavity preparation and production

H. Basic R&D bulk Nb - Other processing