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VIBRO-TUMBLING AS AN ALTERNATIVE TO STANDARD MECHANICAL POLISHING TECHNIQUES FOR SRF CAVITIES*

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Abstract

Centrifugal Barrel Polishing (CBP) is a common tool in the Nb bulk SC cavities production, prior to electropolishing (EP). Indeed, the mechanical polishing is fundamental also in the superconducting thin film resonant cavities in which one of the main issues that limits the performances is the surface preparation [1]. A promising vibro-tumbling technique is being studied and implemented with a possibility to replace or improve mechanical treatment steps (grinding, barrel polishing) [2, 3]. The simplicity of the technology allows it to adapt to any cavity geometry, both for Nb and Cu materials. The presented work contains last results on 6 GHz cavities obtained at LNL-INFN, both Nb bulk and Cu cavities.

INTRODUCTION

The initial inner surface of the resonant cavities plays a key role for the reproducibility of the RF performances. The forming technique applied for the manufacturing of seamless 6 GHz cavities is spinning. This method produces unwanted damages in the surface of the cavities affecting the reproducibility of the RF characterization. For this reason, an alternative surface treatment is being under studies – vibro-tumbling. The technique takes from CBP motion of the cavity, adding the frequency of the vibro-motor, that make abrasive to move inside the cavity. Due to relative angular velocity between working surface and abrasive, polishing and cutting effects occur.

The small dimensions of 6 GHz cavities represent a challenge to improve their internal surface. Due to geometrical limitations, conventional mechanical treatments are not efficient or even are not feasible to use (lathe and milling). Compromise option is being used – grinding, that produce deep scratches. Thus, it is required to find more reliable and less destructive mechanical treatment to substitute grinding or improve the surface afterwards.

The study of the effect of vibro-tumbling treatment is not only important for 6 GHz cavity preparation, but also it could be useful for bigger sizes of the cavities (1,3 & 1,5 GHz) [1]. Vibro-tumbling is relatively easy to scale, since vibro-finishing is widely used in industry and there are not limitations.

At this moment, it is required optimization of abrasive materials usage to improve finishing steps and achieve high removing rate (hard cutting step).

EXPERIMENTAL

The materials under studies were Cu (OFHC) and Nb. Two types of samples were studied: 6 GHz cavities and cylindrical samples with a planar surface (10 mm diameter) placed in the cavities. Roughness measurements were obtained with linear profilometer on coupons, (working distance 1 mm, force – 12 mg, triple scan for each sample), cavity internal surface photo with dentist camera. Removing rate data was calculated using gravimetric analysis (weight loss method).

Vibro-tumbling system (see Fig. 1) consisted on eccentric vibro motor, step motor, bearing & rolls, and inverter (to modify working frequency).

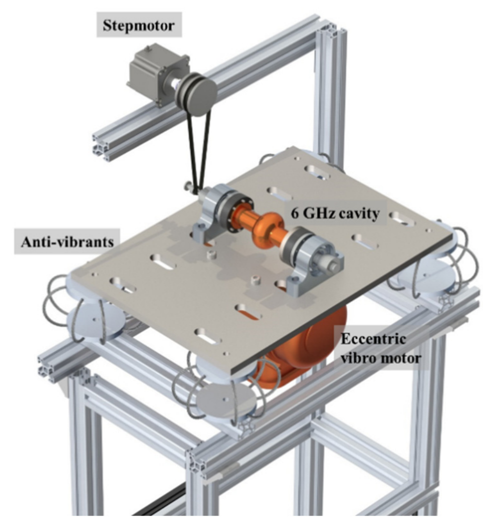

Figure 1: Vibro-tumbling system overview.

Involved abrasives: SiC (prism), diamond powder, Al_2O_3 embedded in matrix (pyramid shape), coconut and corn (see Fig. 2).

RESULTS AND DISCUSSION

During optimization process of the technique and followed by application on 6 GHz cavities standard treatment protocol at LNL-INFN, it was done ~120 treatments on 17 cavities and 10 samples. Statistical data regarding treatment time, removing rate, type of abrasive, filed volume, weight loss, and working frequency were collected since

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July 2018. Obtained optimal recipes are shown in Table 1.

Figure 2: Applicable abrasive: SiC, Diamond, Al_2O_3, coconut, corn.

Effects and Behaviours

It is observed, that various modes of vibration can differently effect on temperature of the cavity. Overheating can lead to additional oxidation of surface, in case of Cu has to be avoided. However, the rise of temperature sometimes can indirectly tell us, that with these parameters, the removing rate increased.

Table 1: Optimized Recipes to Treat Nb and Cu Cavities

Material & step	Abrasive and media	Comments
Cu 1 initial	Al_2O_3 pyramids, 12 ml of Rodastel 30 soap	Removing rate up to 0,3 g/h ~ 3,6 µm/h.
Cu 2 finishing	Coconut, 80% of volume	High glossy surface, improve microroughness.
Nb 1 initial	SiC + filler (ZrO_2 balls) + 10 ml soap solution	Removing rate up to 0,25 g/h ~ 3,2 µm/h.
Nb 2 finishing	Diamonds, 30% of volume + 10 ml of water	Absence of surface gloss

Additional wet media can improve the quality of the surface, eliminating unwanted surface covering during the treatment. Moreover, water can possibly work as a cooling element to avoid high temperatures during process. But, adding volatile liquids can provoke small overpressure inside the cavity.

The working frequency of eccentric motor plays an important role in efficiency of removing rate (RR). The increase of the frequency leads to higher removing rates, however after 200 Hz, values of RR drops significantly due to motor and inverter characteristics. Moreover, higher frequency leads to a faster heating, that is why the working frequency was established around 190-200 Hz.

Results after vibro-tumbling steps are shown below on Fig. 3. The surfaces were smoothed after each of them. However, gloss surfaces are obtained only after coconut granulate treatment on a Cu surface. Another abrasive used was smashed corn, but it showed less reflectivity. Unfortunately, grounded organic abrasive did not work with Nb surface. Which is possibly due to organic compounds released, that might attack oxides of Cu chemically, but not Nb. Another behaviour is observed when the granular coconut adsorbs powders from previous steps.

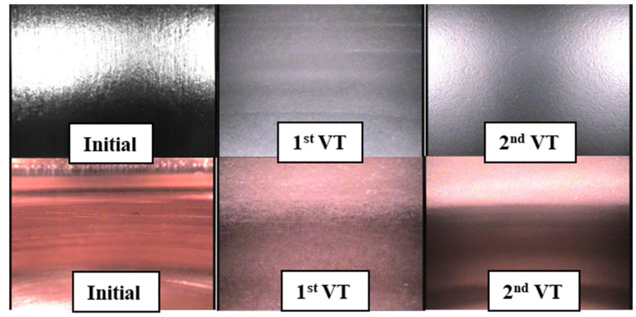

Figure 3: Internal surface of the Nb and Cu 6 GHz cavities.

Roughness measurements decreased after each step, as shown in Fig. 4. However, the curve roughness are showing different behaviours for Nb and Cu materials.

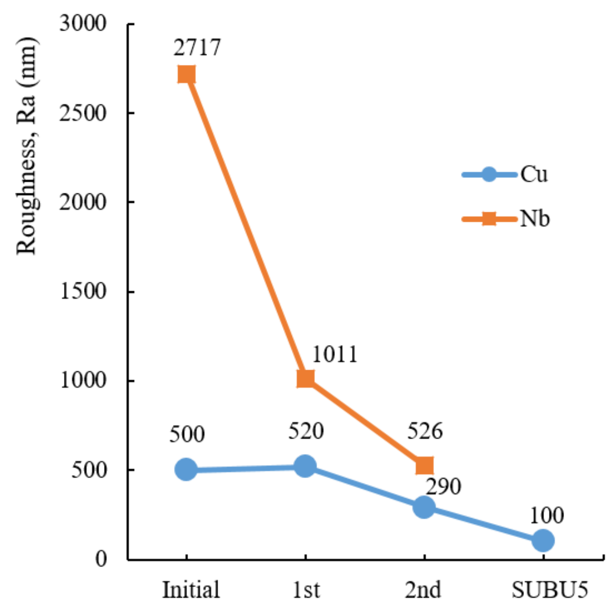

Figure 4: Roughness trend curve after treatments.

CONCLUSION

It was successfully used and applied promising vibro-tumbling technique for the surface treatment of 6 GHz cavities. Standard protocol of cavity preparation was modified with vibro-tumbling application to improve surface.

As a result, deep scratches (usually produced by grinding) are removed after ~ 8 hours with a 2 steps treatment. For Cu, Al_2O_3 and granular coconut, achieved roughness of 0,29 µm. For Nb, SiC and diamond step achieved a 0,53 µm roughness. This technique can be consider promising to be applied on Cu and Nb cavities.

However, for now, only 2 step process has been developed – medium cutting and finishing. That is why, future

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steps are required: continuous studying, collection of statistics, application on 6 GHz cavities that will be sputtered and RF measured in order to correlate the effect of the surface preparation with the RF performances. Future research on abrasives and medias will be aimed to improve removing rate up to 30 μm/h.

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