FREEZING WATER CLEANING – A POSSIBLE IMPROVEMENT IN SRF CAVITY RINSING*

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Abstract

A new method of high pressure rinsing - freezing water cleaning - consists in preliminary cooling down the cavity to be rinsed. Expansion of water in the phase transition to ice can lift particles from the surface and overcome van der Waals forces. Different expansion coefficients of ice and niobium make the ice surface unstable and self-removing. The ice crust falls off together with trapped surface particles and finally the rinsing turns into regular high pressure rinsing.

INTRODUCTION

High-pressure water rinsing (HPR) is a necessary stage of SRF cavity preparation [1] because it provides cleaner, field emission free surfaces removing any chemical and particulate residue from the niobium surface. Attempts to further increase accelerating gradients do not cease. Dry ice cleaning [2, 3] is a prominent example of this work in spite of more complicated set up: you need two clean gases – carbon oxide and nitrogen to transport CO_2, a cooler, special nozzles and much more. However, all necessary components for improving the traditional HPR are at hand in any SRF lab, a simple cooling down of the cavity before rinsing can be beneficial because many new effects will be involved which can lead to better cleaning. The cavity can be cooled down by emerging its end into a dewar with liquid nitrogen. Possibly a plastic bag with a positive dry nitrogen pressure can be used to prevent premature ice formation. Isolation of the cavity from the metal supports by, for example, teflon spacers can be also needed. Then the procedure of HPR can be started in a regular way.

EXPANSION OF WATER BY FREEZING

Density of ice near 0°C is 917 kg/m^3. So, a water cube with a size of $\sqrt[3]{0.917} = 0.972\,\mathrm{m}$ will become an ice cube of 1 meter high producing an expansion of 28 mm/m or 28 nm/μm. A particle 1 μm big, if it is wet, will be lifted by 28 nm, Figure 1.

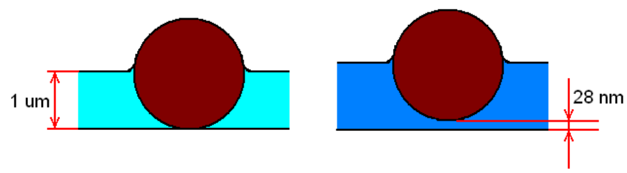

Fig. 1. Water when freezing lifts the particle over the surface.

This value is much bigger than the van der Waals radii for any elements, (100 – 200 pm) and intermolecular forces will not attract the particle to the surface any more. Further, thermal expansion coefficients of ice and niobium are, respectively $50\times10^{-6}/°C$ and $7.1\times10^{-6}/°C$, so the ice will further cool down after freezing and its contact with the metal surface will be lost. The cooling of the ice can be more than 100°C (metal is liquid nitrogen cooled) and a relative shrinkage of a 1 mm segment on the ice surface will be more than 4 microns. A simple experiment shows that the ice cracks immediately after freezing on the surface cooled in liquid nitrogen and then most part of it falls off.

SUCCESSIVE HPR AND FWC

A series of experiments was performed with a successive high pressure rinsing and following freezing water cleaning. The other sequence of operations: FWR first and then HPR was also performed. The samples of niobium plates were of different quality: from chemically treated (BCP) surfaces to the scrap plates with the drops of melted niobium after welding. The samples before and after rinsing were analyzed under a scanning electronic microscope with magnification up to 2000. The removal of particles can be seen easier if a difference between two pictures is found with the help of Photoshop. Regretfully, we cannot see any difference for a clean BCPed surface. Obviously, more elaborate methods of analysis are needed in this most important case. Field emission scanning microscopy used in a more detailed investigation [2, 3] would be adequate to this task. Unfortunately, not all the laboratories have the equipment of this level.

An example of rinsing a rough surface is shown in Figure 2. The surface was first HPRed and then cleaned with freezing water. The removed (or the newly appeared) particulates are seen as the white ones on the third picture.

Another result with the FWC first and then with HPR is shown in Figure 3. Here, the defects on the surface were made by a 0.5 mm bore; the depth of the holes was also about 0.5 mm. With so rough imperfections, cleaning also continued even after FWC.

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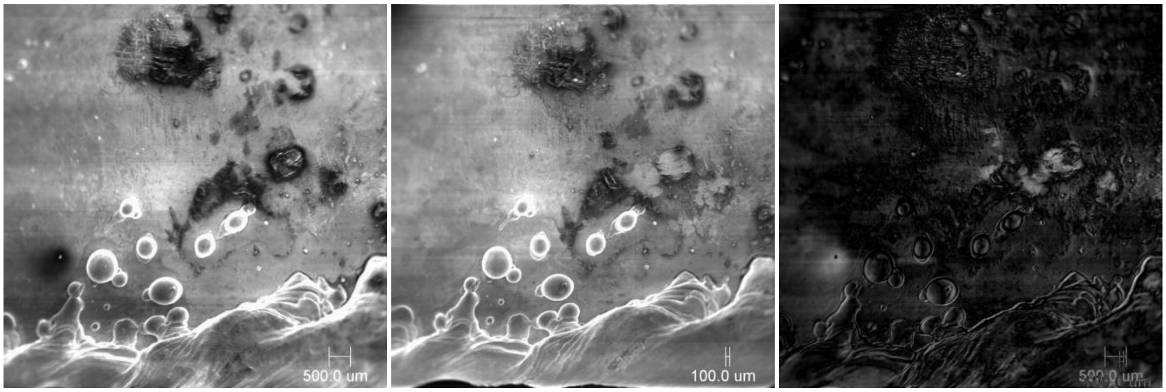

Fig. 2 Sample from the scrap with metal drops after welding: after HPR, following FWC and their difference.

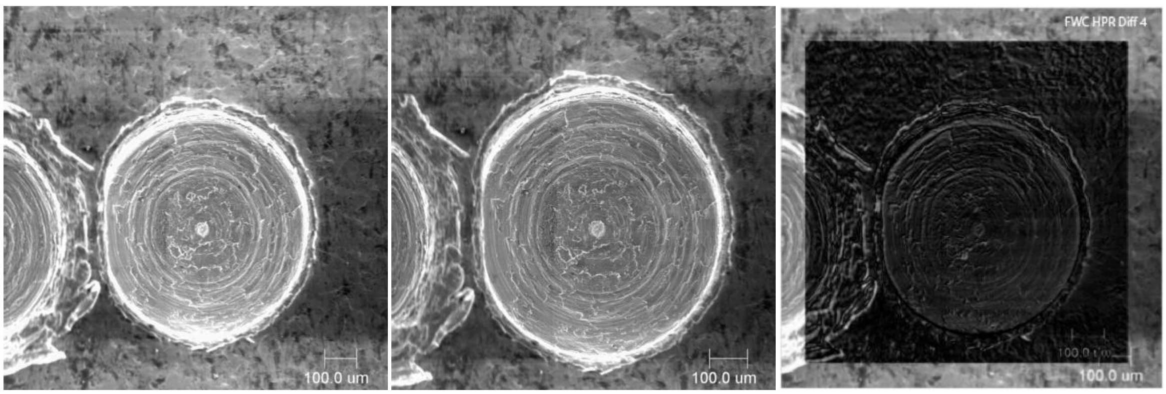

Fig. 3. Imperfections made with a bore: after FWC, HPR and their difference. Different scales can be corrected with Photoshop.

CONCLUSIONS

A simple new method of cleaning the metal surface – Freezing Water Cleaning – is proposed. The experiments show that the cleaning takes place; however, more detailed experiments are needed to prove its benefits. The author hopes that the method can be tested somewhere with better equipment than he has at hand at the moment.

ACKOWLEDGEMENT

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