DRY-ICE CLEANING ON SRF-CAVITIES

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Abstract

High pressure rinsing with ultra-pure water is the well-proven standard cleaning step after chemical or electrochemical surface treatment of SRF cavities. Dry-ice cleaning (DIC) is a powerful additional cleaning option which depends on the sublimation-impulse method. Particles and film contaminations, especially hydro-carbons, are removed without residues. Furthermore DIC offers the possibility of a final horizontal cleaning of a fully equipped cavity because water is not present in the cleaning process. Horizontal cleaning tests on single-cell cavities showed promising high gradient, high Q-value performances, but field emission is still the limiting effect. On the basis of these tests a new IR-heater module is installed to keep a high temperature gradient between the CO_2-jet and the cavity surface.

INTRODUCTION

Although many improvements of Cavity preparation procedures had been done, field emission still limits the high gradient of superconducting cavities.[1]
Advanced final cleaning steps and handling procedures must be applied to avoid surface contaminations like particles and hydrocarbons etc. High pressure rinsing with ultra pure water is a powerful method to reduce field emission, but dry-ice cleaning might have additional cleaning potential [2]. Dry-ice cleaning avoids a wet cavity surface, removes carbonhydrates and is applicable to ceramics, so the possibility to clean a cavity with power couplers is given. Improvements with a new IR-heater on the prototype setup to keep the cavity surface warm, lead to promising test-results on single-cell cavities.

DRY ICE CLEANING (DIC)

In comparison with high pressure water rinsing where a mechanical effect is the major cleaning contribution DIC additionally offers thermal and chemical effects as cleaning effects. Relaxation of liquid CO_2 in a nozzle (Fig. 1), results in a snow/gas mixture with approximately 45 % snow-rate at a temperature of 194 K. To ensure an acceleration and to focus the CO_2-stream, a supersonic jet of N_2 surrounds the stream. At the same time the N_2 prevents condensation of humidity on the cavity surface.
The mechanical cleaning effect is based on shock-freezing of the contaminations, strong impact of the snow crystals and a 500 times increasing volume after sublimation. Contaminations get brittle and start to flake off from the surface. When snow-particles hit the surface and melt at the point of impact, the chemical cleaning effect occurs. Liquid CO_2 is a good solvent especially for hydrocarbons and silicons. Achieving an optimal cleaning process, it is necessary to reach a high thermal gradient between jet and surface. It is essential to keep the cavity warm (20° – 30° C) during the cleaning process. Furthermore a sufficient exhaust system is needed to keep down the CO_2 and N_2-rate in the cleanroom atmosphere. Basic cleaning parameters are shown in Table 1.

Table 1: Basic cleaning parameters

CO_2-pressure	~ 50 bar
N_2-pressure	12 – 18 bar
Particle filtration	< 0.05 µm
Temp. of liquid CO_2	-5° - -40° C
Environment of cleaning	Laminar flow class 10

Figure 1: Nozzle inside a cavity.

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Installation

During cleaning the cavity turns round driven by a motor and the nozzle-bar is moving in horizontal direction. Compared to the first setup of the DIC device we changed the orientation of the nozzle to horizontal direction to test DIC with cavities in mounting position[3]. (Fig.: 2).

Figure 2: Horizontal orientation of nozzle-support with nozzle on the left side.

Former heating installations were not efficient enough, more heater power was needed. A commercially available IR-heater system with 8 contoured shortwave twin tube heaters and a maximum power of 5.6 KW is installed now (Fig.:3 and 4). The wavelength is optimized to the surface of the cavity (1.0 µm – 1.4µm). With the heating power at this wavelength the cavity is not frosted on the outer surface during the cleaning process. The temperature is measured with an IR-Temp.Sensor.

Figure 3: Showing the whole system the 1-cell cavity with the IR heater above and the horizontal nozzle outside of the cavity.

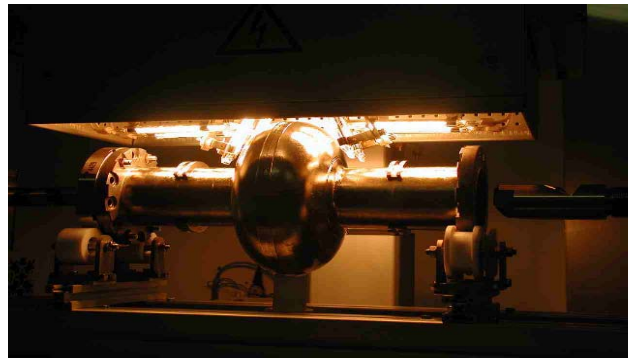

Figure 4: IR-heater under operation.

The exhaust system ensures a harmless CO_2 – concentration in the cleanroom and keeps particles away from the cavity. The CO_2 - and O_2 - concentration in the cleanroom atmosphere, the cleanroom fans and the exhaust are controlled by a safety-interlock-system, which automatically stops the gas-supply if one of these components or concentrations fails or gets too high. Due to turbulences in the area of the cavity-flange when the gas-jet is on and the nozzle-bar moves into the cavity, a rise of particle emission is observed. Therefore the particle-rate has to be monitored.

RF-TEST RESULTS

Table 2: RF-test result: Gradient and Limitation

Cavity	E_{acc} [MV/m]	Limitation
1DE7	33.9	Breakdown (BD)
1DE7	32.2	Field emission (FE)
1DE7	34.1	Available Power (PWR)
1DE4	28.8	Field emission(FE)
1AC4	38.2	Breakdown (BD)

Table 2. shows some RF-test results of several 1-cell cavities. No further cleaning steps were applied to the cavities after BCP or EP and before dry ice cleaning. The cavities were stored under cleanroom-air or kept under vacuum and vented with particle-filtered N_2. In all tests maximum gradients above or at 30 MV/m were achieved. The tests showed typical Q-values above 10^{10} at 2 K for superconducting cavities at 1.3 GHz. High Q-values indicate that DIC not contaminates the inner cavity surface. An optimized cleaning and handling procedure led to a RF-test with a gradient up to 38 MV/m limited by breakdown. Field emission is still a limiting factor as well, but most likely caused by particle contamination

during assembly of the cavities. Figure 5. illustrates the test results in a Q_0/E_{acc} plot.

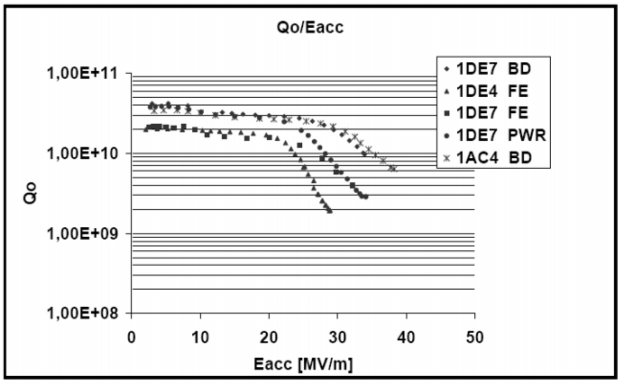

Figure 5: Q_0/E_{acc}

SUMMARY

It was shown that no previous cleaning steps like high pressure water rinsing applied to cavities is necessary to obtain high performance in RF-tests. The new IR-heater with optimal wavelength and contoured alignment of the tube heaters provides a high thermal gradient between CO_2-jet and cavity-surface. A safety interlock is build to control gas concentrations. Field emission is a limiting factor, but surely caused by particle contamination during final assembly of the cavity. Particle contamination during the cleaning procedure itself is almost negligible if the operator avoids turbulences in the flange area of the cavity by a careful handling and keep the airflow laminar as much as possible. Nevertheless particles must be monitored.

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