MEASUREMENTS ON PARTICLE CONTAMINATION DURING CAVITY ASSEMBLY#

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Abstract

At the TESLA test facility (TTF) infrastructure at DESY 8 cryomodules have been assembled up to now. After the first assemblies, a degradation of some cavities In each of the modules was observed in respect to their previous test results in vertical and horizontal tests. Most of the degradations were caused by field emission. As we know, particle contamination on the surface of a superconductor can induce field emission and limit the accelerating gradient. Therefore, a clean method to assemble cavities is very important for the performance of a module.

To understand the origin of particulates and to improve the assembly method a test set up is built. Two air particle counters are installed, one inside the cavity and the other outside to monitor the total amount of particulates . We report on measurements of different orientations of the resonator during assembly as well as on various sequences of disassembly. In addition measurements with clean gas overly inside the cavities were also reported.

The improvement of the assembly methods could be validated by RF tests after the latest module assemblies.

INTRODUCTION

One major requirement for the realization of the TESLA project is the reproducible set up of high gradient cavity modules, Every module will house eight cavities, each transferring an energy gain of 35MeV/m to the electron beam. Several papers have been published in which cleaning procedure and treatments of high gradient superconducting (s. c.) cavity are described [1,2]. Until today four 9-cell cavities in vertical measurements and two in a horizontal test set up reached the TESLA_800 goal of 35MV/m. But there is only limited experience for the module assembly of high gradient cavities. In particular, no detailed description of methods for the clean assembly of high gradient cavities in modules is available yet.

A test set up has been built at DESY to study the processes and to define cleaning and handling procedures. A single-cell test cavity is used for measurements of different assembly and disassembly methods. To study disassembly procedures for resonators vented to an over pressure of argon and continuous argon flow, a four-and –half-cell cavity is in use.

On our test set up two air particle counters are in operation (see Figure 1). The probe of the fist counter is located inside the cavity close to the top flange, to detect particles falling into the cavity. The second air particle counter has two applications. In general, it is used to control cleaning the bore holes and outside area of the top flange. This monitor position can be used for quality control during cavity assemblies. An overlay of ultra pure argon gas is applied during module and power coupler assembly. For disassembly measurement with argon flow, the second counter is located downstream of the laminar flow under the outside of the top flange, just before the top flange is removed.

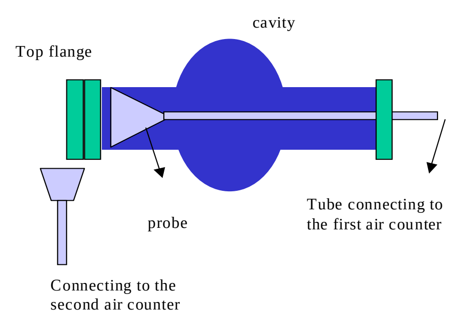

Figure 1: Sketch of particle measurement system

ASSEMBLY OF TOP FLANGE TO CAVITY

Preparation of Components

After BCP or EP treatment, a cavity will be cleaned by means of pure water rinsing and high pressure rinsing before flanges and antennas are assembled. For this assembly, the components (flanges, screws and nuts) are cleaned in an ultrasonic bath at 44 ~ 50°C, and by means of ultra pure water rinsing until the electrical resistance of the rinsing water reaches 12.4 MOhm cm. After drying in the clean room class 100 area the residual particle contamination is controlled with an air gun, blowing ionized and particle filtered nitrogen gas towards an air particle counter.

To reduce the preparation time for our measurements with no reduction on cleanliness, the cavity undergoes the same cleaning process like the components for a cavity assembly. Gaskets are cleaned right before the installation with particle filtered alcohol instead of ultrasonic cleaning. The particle contamination of the gaskets is controlled by the air particle counter as well.

The test flange (top flange) is assembled to the test cavity in the class 10 area. To Study the influence of gravity and flow direction of the laminar clean room air, vertical and horizontal positions of assemblies are tested.

Orientation

Fig2 shows the result from air particle counter 1, located inside the cavity during the assembly of the top

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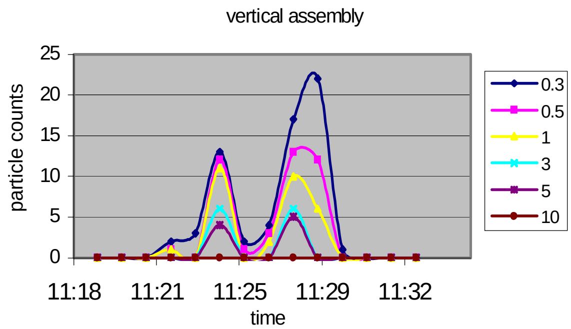
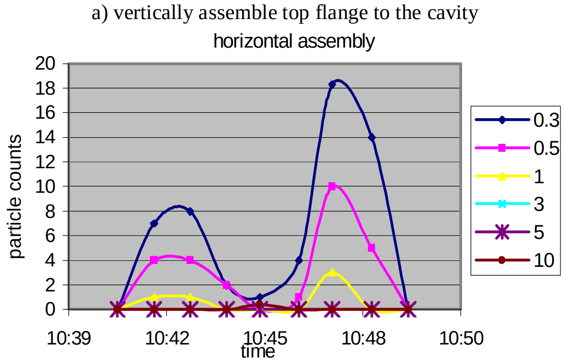
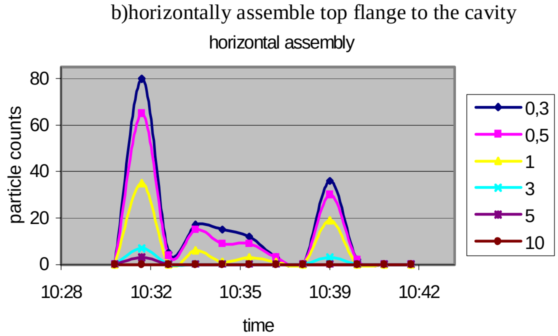
flange. The number of particle counts are given in cumulative values of the particle size. Each channel (right hand box) represents the particles of which diameters are bigger than x µm, calibrated to the normal of latex particles.



a) vertically assemble top flange to the cavity



b)horizontally assemble top flange to the cavity



c) horizontally assemble top flange to cavity with some errors

Figure 2: Assemble top flange to cavity vertically or horizontally

From Figure 2a and Figure 2b, we can see that very few particles falling inside the cavity for either the vertical or horizontal assembly. Both of them are suitable for cavity assembly especially if a high pressure rinsing follows the flange assembly. Lines of large particles are much deeper in horizontal position graphs, which means that less big particles (larger than 3 µm) falling inside the cavity during horizontal assembly than during vertical assembly.

Assembly Process

Figure 2c represents an assembly where errors in the assembly procedure, like frequently seen during assemblies, happened. The first peak results from a misalignment of the flanges where the bore holes of the two flanges did not match. After a carefully turn of the top flange to align the bore holes, we found lots of particles falling to the inside of the cavity. A second and frequently seen error during assemblies is the rotation of a screw during bolt on. The third peak of Fig2c represents the impact on the cavity by this action.

Conclusion

The first measurements show that vertical and horizontal assemblies have similar results in respect to particle contamination of the cavity interior. A strong impact on the cavity performance can be related to so called assembly errors. The components have to be pre aligned very precisely and the bold down of the flange connection has to be done by rotating the nut, located at the outside of the flange assembly, only.

The graphs indicate that cavity assembly must be done very precise and more studies on error handling have to be carried out.

DISASSEMBLY OF TOP FLANGE FROM CAVITY

Preparation of Measurements

After the test cavity has been assembled with flanges inside class 10, it is stored in class 10000 clean room for some days. This pollution of the cavity flange and gasket area shall represent the situation of cavities that have undergone a horizontal Chechia test and reenter the clean room, respectively are stored in class 10000 for module assembly. Here the flange region is exposed to normal or class 10000 air for several days[1] and can only be cleaned by alcohol and ionized air blowing. To compare the results of the different disassembly methods, the pollution of flanges for this test is done in a controlled way in class 10000 clean room.

The disassembly measurement are done in the class 10 clean room in horizontal position like in use for module assembly. Three disassembly methods of the top flange taken from the cavity are studied. Before starting the measurements, the air particle counter 1 (inside the cavity) is started to gain a pre-cleaning of the interior and a baseline measurement for comparison.

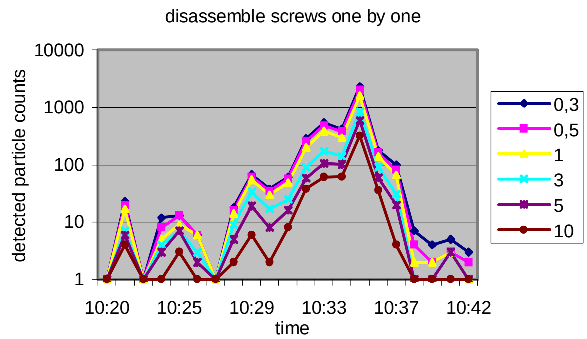
Disassembly Methods Without Argon Flow

In order to avoid the impact on the measurements by air gun blowing when the bore holes are cleaned, a piece of clean paper is used to cover the bottom of the test cavity, with only a hole for the tube of counter 1 to go through.

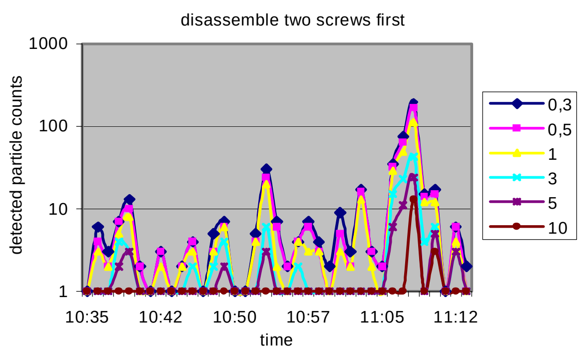
Disassembly method No. 1 is the very simple dismounting sequence as applied on industrial components outside of a clean room. Method 1: All screws and nuts are taken apart, one by one. After that the top flange is removed from the cavity.

The sequence of flange disassembly of Method2 and Method3 are procedures, adopted to the requests of clean room assemblies.

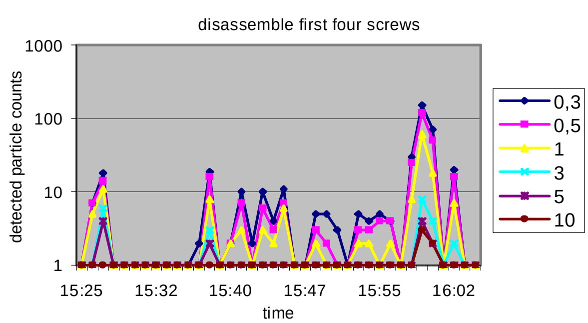
Method2: Two screws are taken apart first, bore holes are cleaned by clean nitrogen gas blowing and under control of air particle counter 2, two clean screws are replaced and are fixed tightly. Then all the other screws are taken apart and all these bore holes are cleaned as well; at last the two clean screws are taken apart and the top flange is removed.



a) Method1



b) Method2



c) Method3

Figure 3: Three disassembly methods without Ar flow

Method 3 is similar to Method2. Instead of two screws, four screws are taken apart at first. The bore holes are cleaned and 4 new cleaned bolds are inserted and fixed tight.

Figure 3 shows the results of the measurements. From these graphs it can clearly be stated that Method1 produces lots of particles falling into the cavity during this process. Method2 is a general improvement in respect to the ordinary dismounting processes. But never the less it seems that the two bolds (Method 2) can not hold the gasket down particle tight during dismounting the remaining bolts. Method 3 shows the lowest overall particle number. Especially in the regime of particle diameters of 3 µm and larger the numbers are significantly reduced.

Disassembly Method With Over Pressure of Argon Flow

The bottom flange of the four-and-half-cell test cavity (see Figure 4) is closed by a plate made from plastic (cover plate). It is equipped with a small center hole to feed in the air particle counter tube for the particle detection inside the resonator. A CF35 pumping flange connection for the clean argon gas venting is integrated in the cover plate as well .

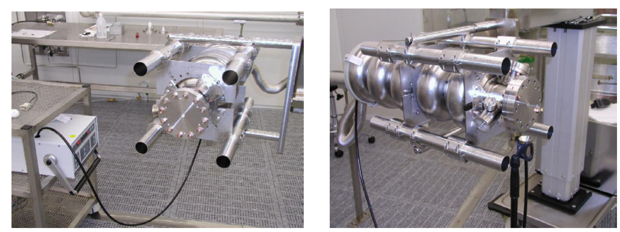
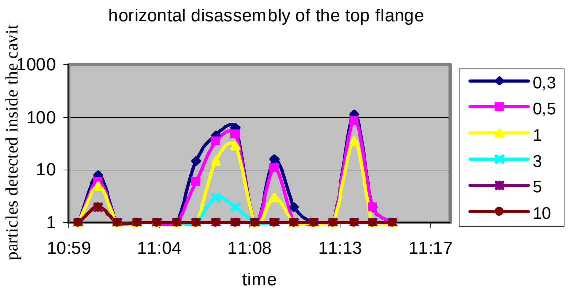


Figure 4: Particle measurement set up with argon flow

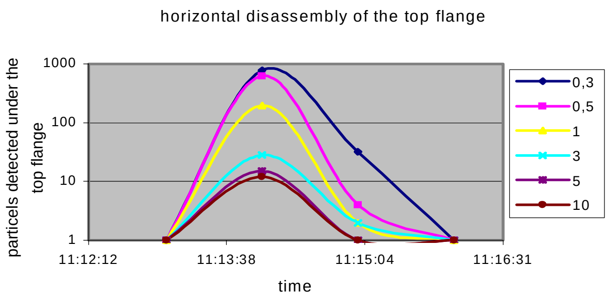
After the CF35 pumping flange has been carefully cleaned with alcohol, the cavity is connected to the argon venting of the TTF pumping units. The disassembly of the top flange is done according to step 1-7 of the sequence shown below.

1) flush the cavity with argon flow
2) start the air particle counter 1 whose probe is inside the cavity for pre-cleaning for at least 5 minutes
3) start particle recording inside the cavity and begin to disassemble the screws according to disassembly Method2
4) clean all the bore holes of the top flange under control of the second air particle counter
5) place the second probe under the top flange (outside) and begin particle recording just before taking off the top flange
6) stop particle recording after no more particles are detected by both air particle counters
7) stop argon flow and finish the measurement

The graphs of Figure 5 are recorded simultaneously. The top flange was removed at 11:13 on the x time scale. We know that the time when the top flange is removed from the cavity is the most dangerous time for cavity pollution. Compared to the measurement without argon flow (see Figure 3b) the decay of the detected particles during taking the top flange off is faster. We can also see that most particles are detected by the second air particle counter (outside of the cavity). This higher numbers can be explained by the vertical laminar flow in the TTF clean room which guides the particles, resulting form the movements of bolts and nuts, downstream towards the counter. Only few particles are measured by the first particle counter.



a) particles detected inside the cavity



b)particles detected under the top flange (outside of the cavity) just after the top flange is removed

Figure 5: Horizontal disassembly with over pressure of argon flow

For real cavity assembly, there is no air particle counter inside the cavity. So we made some other measurements in which we did not start the air counter 1 until the top flange was taken away. In the disassembly sequence, step 3, 6, 7 were changed.

3) stop the air particle counter inside the cavity and begin to disassemble the first two screws
6) stop argon flow, at the same time start the air counter inside the cavity
7) finish the measurement after no more particles are detected by the air particle counter

The maximum number of the detected particles inside the cavity was 45 for the vertical measurements and only 11 for the horizontal measurements with argon flow during disassembling the bore holes. Because of the lamina air flow in the clean room, horizontal disassembly has less particle contaminations after the top flange is removed from the cavity than vertical disassembly. To see the effect of argon flow, another measurement without argon flow at all but for which the other process is the same as the above, gave 70 total particles for the horizontal disassembly. Compared to 11 particles, it shows that clean gas overlay inside the cavity for disassembly of the flange from the cavity is a good solution.

INSTALLATION OF CAVITIES TO A STRING FOR A MODULE

The baseline for module assembly of modules 4+5 of the actual TTF linac configuration are our above given measurements. Eight cavities, closed with one blind flange and one pumping flange (with valve), are aligned horizontally in the clean room for string assembly (see Figure 6). The removal of the flanges from the beam pipe is done with the Ar flow out of the cavity and disassembly Method3 (see Figure 3c) is applied.

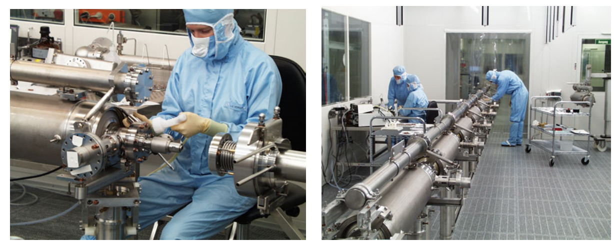


Figure 6: Cavity assembly in clean room

The recent RF measurements of module5 at DESY (Figure 7) showed that no significant reduction in performance was seen after the module had been installed in the beamline. Basing on this first experiences it can be concluded that the instructions, set up on the basis of our experiments, are fundamental for reproducible cavity string assemblies. More studies, especially on the so called assembly errors and the position of the particle monitor during the assembly, have to be done to set up an process manual for reproducible cavity string assembly of high gradient resonators.

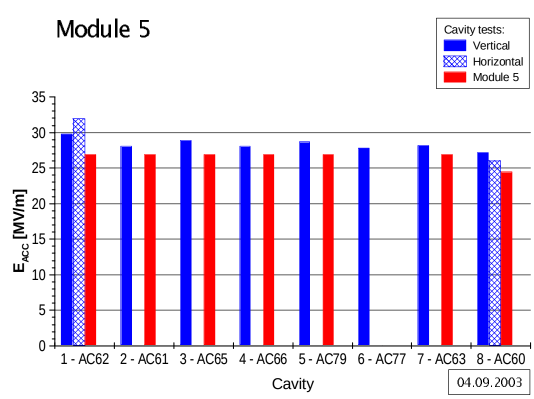


Figure 7: Cavity performance of module5 at DESY

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