UPDATE ON 1.3GHz CAVITY WELD TO HELIUM VESSEL AND APPLICATION OF THE FMS

A. Schmidt*, G. Kreps, A. Matheisen, H. Weitkämper
DESY, 22603 Hamburg, Germany.

Abstract

Super conducting resonators are cooled by liquid helium. For the application in accelerator modules most superconducting resonators are equipped with individual helium containers [1]. During the welding of the helium tank to the super conducting resonator special care has to be taken not to change the resonator specific data like acceleration gradient, resonance frequency and the cell to cell distribution of the accelerating field. At DESY a tank welding process and an in situ field profile measurement system (FMS) on the basis of the bead pull field profile measurements is set up.

INTRODUCTION

In the past decade the helium tank welding was done at DESY after a successful radio frequency test at 2 K (CW test). For the European XFEL laser project [2] the goal is to optimize and industrialize al required work steps for preparing a cavity [3]. Therefore the welding of the surrounding vessel shall take place before 120 C baking and before the RF test.

Two preparation methods named “final EP” scheme and “BCP flash” scheme are established at DESY. An overview of the schemes is shown in figure 1. The general flow schemes of theses preparation are mostly identical but differ in details [3]. For industrialization the integration of the tank to the resonator has to take place at an earliest state possible, which is different in these two preparation cycles. The tank welding process itself where resonators are equipped with the FMS and filled with argon is identical for the “final EP” and “BCP flash” schemes.

In the final EP scheme the tank welding takes place right after the final surface removal. No further surface treatment, other than high pressure rinsing (HPR) takes place. Here the welding procedure has to conserve the quality if the surface as gained during the EP treatment without influence on the cavity performance, frequency or field flatness. In the BCP flash sequence the final surface removal is done after the tank is welded on the resonator.

→ Main EP
→ Outside BCP
→ 800°C annealing
→ Tuning

Final EP	BCP flash
→ Final EP	→ **Tank welding**
→ **Tank welding**	→ Final BCP

→ Add accessories
→ 120°C baking
→ CW test

Figure 1: Overview of “final EP” and “BCP flash”.

Welding of cavities into their individual helium tank includes multiple work steps [1]. The cavity is located in a clean room class ISO 4 and all openings of the cavity are closed with standard blank flanges. Only the beam tube flanges are equipped with the special flanges for the field profile measurement system. After assembly an overall leak check has to be performed and the cavity is handed over to the Tuning machine outside of the clean room. The cavity is ready for welding of the Titanium rings and the tank tube. Before the FMS is removed, the tank has to be leak checked and the cavity enters the clean room with the standard cleaning procedure at DESY.

1. Assembly of the FMS in clean room
2. Vacuum leak check
3. Tuning control
4. Assembly of bellow unit and reduction ring
5. Electron beam welding
6. Tuning control
7. Adjust cavity and tank tube for arc welding
8. Spot weld and orbital weld by TIG welding
9. Vacuum leak check
10. Tuning control
11. Cleaning for clean room
12. Removal of the FMS

INVESTIGATIONS ON THE FIELD PROFILE MEASUREMENT SYSTEM

Since several years the field profile measurement system (FMS) is applied to all prepared cavities. The FMS allows bead pull measuring at any time even outside of a clean room, without contaminating the cavity interior (fig. 2). Main part of the FMS is a Teflon tube that separates the cavity volume into two independent volumes. This tube allows guiding the distortion body for bead pull measurement on the cavity axis without any impact on to the resonator surface. The tube is fixed on stainless steel flanges which can be bolted to the cavity beam tube flanges vacuum tight. To prevent chemical reactions of the niobium, even if it is heated up during the welding processes, the cavity is filled with ultra pure Argon after installation of the FMS. Insertion of the FMS to the resonators takes place in a clean room class 4 (ISO). This assembly as well as the disassembly after tank welding is done manually and bear the largest risk of contaminations or of damages of the superconducting surfaces. In the BCP flash sequence an additional surface removal of 10 µm is done after FMS removal. Cavities in the final EP sequence do not see any material removal after tank welding and hence are extreme sensitive for any errors occurring during the tank welding process.

* andreas.schmidt@desy.de

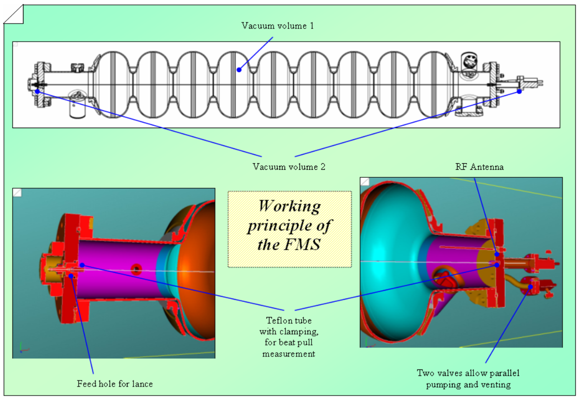

Figure 2: Layout of the FMS.

INFLUENCE OF TANK WELDING ON TO FIELD FLATNESS

The cavity has to be handled with special care to avoid bending the cavity during aligning and welding of the helium tank. Every misalignment or weld shrinkage effecting the cavity will decrease the field flatness and hence the accelerating gradient. The tank welding is performed in two phases. In phase one a bellow unit and a reduction ring are welded onto the cavities conical discs by electron beam welding (EB). In the second phase the tank tube is welded by orbital TIG welding. After closing the helium tank there is no more access to the cells and a re-tuning can only be done on very limited ranges. In case of deformations a re-tuning can only de done after rings welding and before welding the tank tube.

The FMS installed for tank welding allows measuring the frequency, the mode spectrum and the field flatness at any time and at any work space during welding. In the actual developed process the spectrum and the field profile are measured at four hold points.

1. After tuning, before welding the below unit and reduction ring
2. After welding the below unit and reduction ring
3. After tuning, before welding the tank tube
4. After welding the tank tube

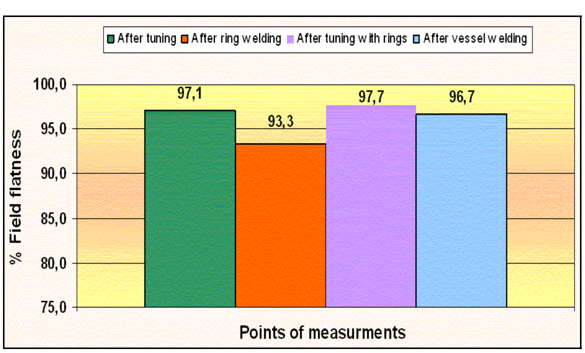

Figure 3: Average field flatness shift during welding.

Figure 3 shows that the ring welding always results in some significant changes of the field flatness. While welding the tank tube to the cavity no significant decreasing of the field flatness is observed.

Analysis of Deformations During Ring Welding

Until 2008 welding of the reduction ring and bellow unit to the cavity could only take place at an industrial factory, the Lufthansa Technik [4]. Since 2008 these welds can be done at the electron beam welding plant at DESY as well (fig. 4).

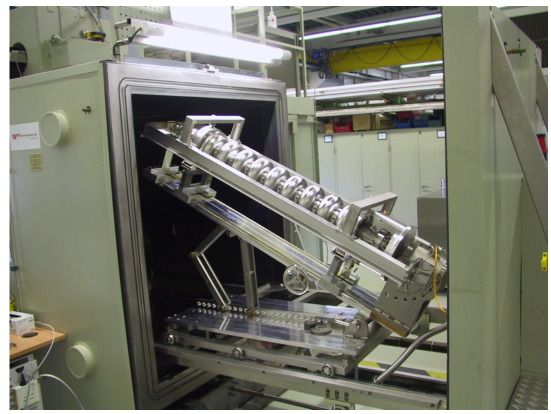

Figure 4: Electron beam welding plant at DESY, prepared with cavity for welding.

The tools for both EB facilities are designed for cavities annealed at 1400°C. The Niobium gets extremely soft during that heat treatment and the cavity becomes mechanically instable. Therefore the cavity rotates on bearings aligned in a stabilizing frame. The elongation of the cavity resulting from the pressure forces of the Argon filled cavity and the vacuum of the welding chamber is limited by a so called elongation blocker which can be adjusted to the actual length of the cavity.

The scatter of field profile deformation for cavities welded at Lufthansa or at DESY is almost similar (fig. 5/6).

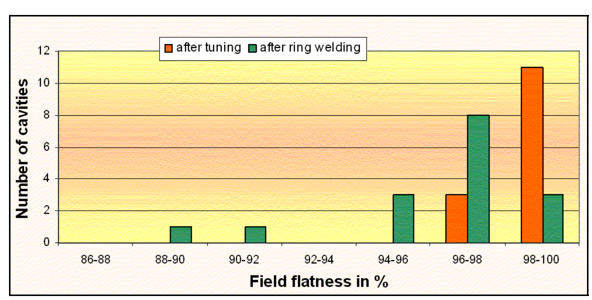

Figure 5: Field flatness shift during ring welding at Lufthansa.

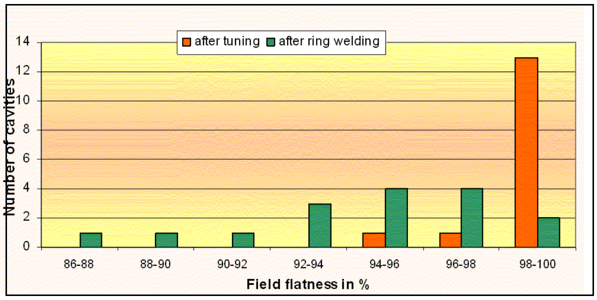

Figure 6: Field flatness shift during ring welding at DESY.

Cavities annealed at 800°C are stiffer and expand only elastically under these vacuum forces. It is found, that for cavities which are fixed in length by the blocker, the pressure forces squeezes the cavity in a "banana shape" during welding and causes a degradation of the field flatness.

At the DESY EB plant, two cavities have been welded without the elongation blocker and the decreasing of the field flatness is two percent only.

The conclusion is, to weld all following cavities without the elongation blocker, to get a better statistic of the field flatness degradation during ring welding.

RF TEST RESULTS [5]

Influence of Tank Welding in the Optimized Preparation Sequences

The cavities of the sixth production at DESY are analyzed to verify that there is no negative influence on the cavity performance (fig. 7). The cavities of the sixth production are manufactured by two industrial manufacturers and are statistically assigned to the preparation schemes, final EP or BCP flash. For analysis only the first power rise of the first CW test is referred. To study the influence of tank welding, cavities tested with tank and the once tested without tank are sorted and analyzed. To restrict the dark current in the Flash linear accelerator at DESY [2], a maximum radiation level of 1e-2 mGy/min, measured in the vertical test stand at DESY, is defined. The acceleration gradient at this acceptance level (E acept) is one of the indicators for the quality of the preparation and in use for the analysis here.

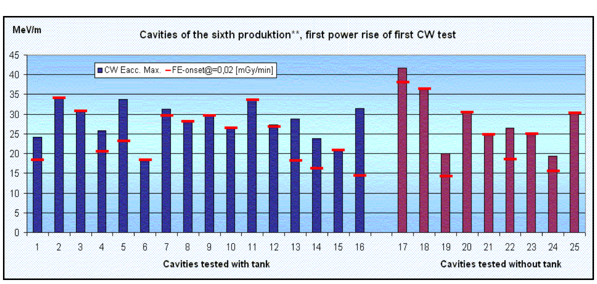

Figure 7: RF test results of cavities of sixth production.

The average of the relation of maximum gradient and applicable gradient expressed in % shows that there is no significant reduction due to the tank welding procedure. For cavities tested without tank a yield of 90% is calculated while for cavities undergone the tank welding procedure the yield is 87%.

From the analysis (fig.7) the cavity with sorting number 16 shows an early start of field emission which could be a hint for a contamination by the FMS, the welding procedure, or a failure in one of the other preparation processes. This cavity is still under inspection.

No tendencies of reduction of cavity performance or acceptance gradient is observed.

Influence of the FMS

For approval of applicability of the FMS in the cavity preparation sequence the electro polished cavities are the most sensitive candidates. Therefore only electro polished resonator from the fourth and sixth production of DESY, where no further chemical treatment on the cavity surface is done after tank welding are referred and analyzed (fig. 8), to verify that the FMS has no negative impact on the cavity performance.

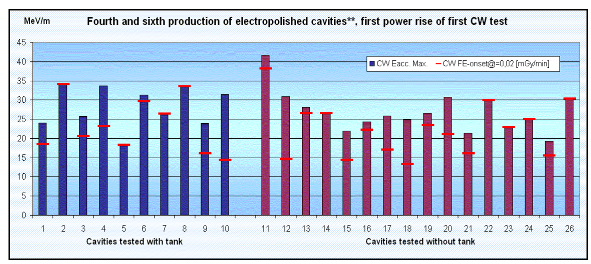

Figure 8: RF test results of electro polished cavities of the fourth and sixth production.

For cavities tested without tank the yield is calculated to 83% wile a yield of 83% is calculated for cavities undergone the tank welding procedure as well. For the calculation the average of the relation of maximum gradient and applicable gradient is taken into account.

The cavities listed with the sorting number 10, 12, 15 and 18 in the analysis of figure 8, are still under inspection. In case of early onset of radiation it is a hint for a failure in the preparation. But only the cavity with the sorting number 10 is tested with tank, wile the number 12, 15, 18 are tested without tank.

There is no indication found that the application of the FMS can lead to limitations or degradation of resonators performances.

***Cavities with low gradients due limitations on or near by equator welds [6] as wells the once limited by HOM coupler probes or input coupler problems excluded in the analysis.*

Direct Comparison

Two cavities have been tested just before and after the welding process (fig. 9). The direct comparison of these tests shows no reduction of the field emission onset level and gives an indication for an accurate conception of the FMS and the welding procedure.

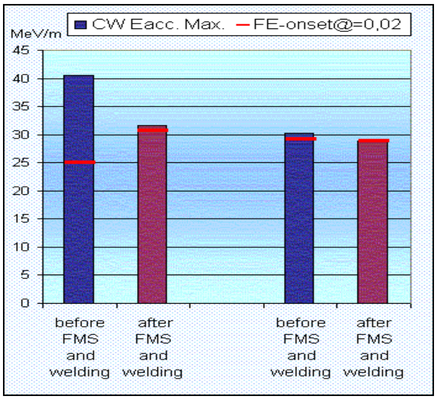

Figure 9: Comparison of AC112 test 10 and 11; and Z146 test 1 and 2.

ANALYSES ON WELDS

For approving the cavity design and to determine the maximum stress of the construction under working conditions a finite element analyses (FEM) is performed.

To guaranty that the required weld penetration is full filled and the welding work is qualified, a dummy tank was build up. The dummy tank was build with identical dimensions and with the same weld equipment than it is used for the original cavities.

Several destructive and non destructive tests have been conducted to the dummy tank.

Non-destructive tests:

- Visual examination
- Color penetrate testing
- Radiographic testing on weld no. 4

Destructive tests:

- Micro polished cut images (fig. 10)
- Appraisal of the microstructure
- Hardness measurements to Vickers (HV)

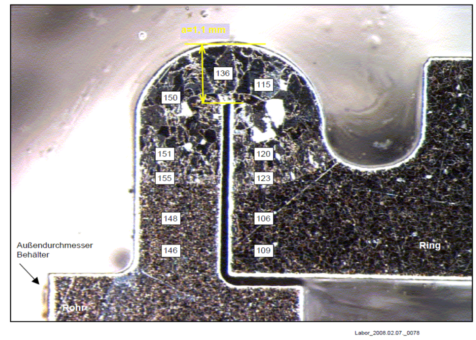

Figure 10: Micro polished cut image of seam 3.

SUMMARY

Since end of 2007 more than thirty five cavities have been welded into a helium tank.

- ➢ All cavities have been equipped with the FMS during welding the tank
- ➢ Most of the cavities have undergone the optimized preparation sequence
- ➢ The EB welding process have been improved keeping 95% field flatness during welding
- ➢ More than sixteen cavities have been welded in the EB plant at DESY
- ➢ **No hints for a performance limitation due to a contamination by the FMS and tank welding have been observed**

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