

1.3 GHz Cavity Weld to Helium Vessel

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Abstract

At DESY Hamburg superconducting accelerator units (Cavities) are under development for the FLASH accelerator and the XFEL project. For accelerator application each cavity is equipped with an individual Helium vessel and cooled by bath cooling with Helium at 2K [1]. The improvements of cavity performance like gradient and quality factors require improvements on the processes of completion the He tank as well. An overview on the sequences and processes for tank welding for the DESY 1.3 GHz Cavities will be given.

INTRODUCTION

The helium vessel tubes are made from Titanium [2]. The interconnection to the conical discs of the cavities made out of a titanium-niobium alloy (Ti52 Nb48) and the Ti tank tube have to be weld by the electron beam welding [3]. All other joints of the He tank are interconnections from Ti to Ti and can be made by the TIG welding. After completion of the tank the access to the cavity body is limited. Therefore major requirements to the tank welding process are the preservation of the cavity characteristics like the geometry (field flatness), the frequency, the acceleration gradient and the quality factor Q_0 [4].

TANK WELDING PROCESS

1. Cavity assembly for vessel welding

1.1 The aim of the FMS

During the welding process a control of the cavity parameters, like field flatness and frequency; and if needed, a tuning of the cells has to be made possible. All process steps of the tank welding are done in workshops that can not fulfil the cleanness which is needed for superconducting cavities. Therefore a field profile measuring system (FMS) is developed where the inner surface of the cavity is protected for particle contamination while performing RF measurements and the tank welding procedures.

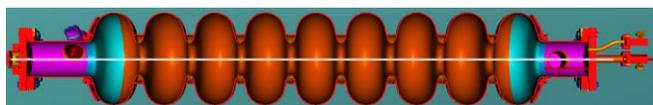


Figure 1: Cavity with field profile measuring system installed

1.2 FMS set up

The FMS set up consists of two stainless steel flanges equipped with a fixed RF antenna each. The flanges are connected to each other via a Teflon tube, located on the

beam axis of the cavity (Fig.:1). This Teflon tube guides the bead pull and separates the cavity and the bead pull volume. Two valves on one of the flanges and a sealing cap on the opposite, allow parallel pumping of the two volumes, cavity and Teflon tube.

Before applying the FMS on a cavity, the desorption of the Teflon tube and all parts of the FMS was measured and verified that even with temperatures appearing during welding no evaporations from the tube will appear [5].

1.3 FMS handling

The installation of the FMS and all other flanges is done inside a clean room witch is classified as ASTM 10 (ISO 4). Before leaving the clean room a depending leak check is done. Afterwards the cavity and the Teflon tube as well are back filled with ultra pure and particle free Argon to normal pressure.

2. Tuning and frequency control

For field profile control and tuning of the cavity, the middle valve and the cap have to be removed. After the RF antennas are connected to the RF equipment, the bead pull is pulled through the Teflon tube and the field profile measurement is performed. During that operation the cavity is protected against any contamination due to the separation of volumes by the Teflon tube. Beside the accuracy of the frequency (less then 100 KHz) and field flatness (better then 90%), the conic disc plane has to be adjusted as well. The adjustment of the conic disc is perpendicular to the beam axis to have no misalignment of the tank in respect to the cavity beam axis.

3. Electron beam weld of conic discs



Figure 2: Welding setup at Lufthansa Technik, Hamburg, Germany

3.1 Assembly

Before electron beam welding (Fig.:2) the edges of all parts have to be well cleaned. An etching by acid is not required here. The bellows and the reduction ring are

assembled and aligned to the cavity axis with fixtures and serve as a guiding bearing to unreel the cavity in the EB welding fixture at the same time.

Titanium shields are inserted between end cells and conic disc to protect the cavity against evaporations of the weld and thermal radiation during welding.

3.2. Electron beam weld 1/2

Electron beam welding is done under vacuum while the cavity is filled with Argon at normal pressure. The EB welding tool fixes the cavity and takes all forces, coming from the pressure differences between Cavity and exterior pressure during the EB welding process.

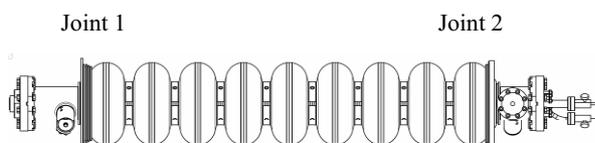


Figure 3: Location of the weld joints 1,2 on the DESY TESLA shape cavity

For welding of joint 1 and 2 (Fig.:3) identical weld parameters can be applied (Table 1). These welds are done in two steps. In the first step a deep penetration weld with a fast rotation and hard beam is done. In the second step a cosmetic seam is performed with a soft beam that oscillates it self.

Table 1a; b: Weld parameter for reduction ring and bellows (joint 1,2) to the Cavity conical disc

a) Penetration pass			
Beam Voltage	Beam current	Focus optimal	Focus condition
150 KV	15mA	1815mA	1815
Work distance	Beam amplitude	Beam form	Beam frequent
1140mm	X=0.2mm	Circle	80Hz
Velocity	Slope in	Slope out	Overlap
30mm/sec.	20°	20°	2°

b) Cosmetic pass			
Beam Voltage	Beam current	Focus optimal	Focus condition
150 KV	12mA	1815mA	1715
Work distance	Beam amplitude	Beam form	Beam frequent
1140mm	X=1.1mm	Circle	14Hz
Velocity	Slope in	Slope out	Overlap
10mm/sec.	20°	20°	2°

Welding procedure specification (WPS): Lufthansa Technik AG: Process Sheet No.: 2.1.2.006F

Before venting the vacuum chamber after the EB welding the cavity must cool down to 60° and below to prevent oxidation of the niobium.

3.3 Final control

To perform a leak test to these weld seams, a vacuum container, covering the beam tube, needs to be installed to allow evacuation of the beam pipe side and full excess to the seams as well.

For quality control the frequency and field flatness are controlled and corrected if necessary.

4. TIG weld 3/4/5/6

All operations during final welding of the Ti vessel have to be done with special care. Major errors in cavity geometry like plastic deformation occurring at this production step can not be corrected without cutting away the vessel tube.

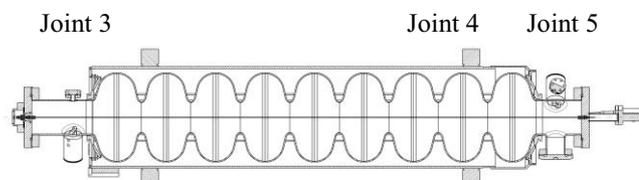


Figure 4: Location of the weld joints 3-5 on the DESY TESLA shape cavity

The connecting welds of the Titanium vessel tube to the cavity are done by orbital TIG welding in a cabin (Fig.: 6) with an integrated weld nozzle holder in Argon atmosphere with less than 20ppm oxygen during welding. To allow shrinkage with out forces acting on the cavity, joint 5 is not tacked and acts as a sliding connection, while tacking and welding of joint 3 and 4.

4.1 Alignment

To ensure a precise orientation of cavity axis and power coupler port a fixture for alignment and tack welding is developed (Fig.:5).



Figure 5: cavity and vessel installed in alignment fixture, (tank brackets and power coupler port settling on fixture)

The tank is horizontally inserted into the fixture where the tank brackets are fixed in position. The power coupler port of the cavity, inserted into the He tank tube, is aligned in this fixture as well.

4.2 Tack weld

The joints No.3 and No. 4 are tack welded manually in horizontal fixture with additional Argon flow on the inner side of the tank.

4.3 Weld 3

After tack welding a handling frame is assembled and the cavity is oriented vertically. For welding it is inserted into the Argon welding cabin (Fig.:6). The orbital arm with the nozzle holder and the tungsten electrode is mounted and adjusted. After welding this position (Table 2), the bellows is fixed by clamps for the next weld operation.



Figure 6: Cavity installed in Argon cabin with orbital arm and tungsten electrode

Table 2: Weld parameter for bellows to vessel

TIG Weld parameter of weld joint 3			
Pulse current	Ground current	Pulse time	Ground time
120A	40A	0.10 sec.	0.15sec.
Velocity	Slope out	Electrode Ø	Gas flow
377mm/min	18 sec.	2,4mm	40 l/min.
WPS: DESY-Hamburg: Beleg Nr.: 001-2007			

4.4 Weld 4

To arrange weld joint 4, the cavity is turned head over top. Because of some oval shape of the tank tube due to production errors, there can be gap between tank tube and connected collar. To close that gap without adding Ti, high current is required during TIG welding (Table 3). This high power insertion results in higher shrinkage of

this weld. This shrinkage is taken and compensated by displacement of the sliding collar tube at the position of weld No 5 which is not fixated at this time.

Table 3: Weld parameter sliding collar to vessel

TIG Weld parameter of weld joint 4			
Pulse current	Ground current	Pulse time	Ground time
200A	70A	0.10 sec.	0.15sec.
Velocity	Slope out	Electrode Ø	Gas flow
399mm/min	18 sec.	2,4mm	40 l/min.
WPS: DESY-Hamburg: Beleg Nr.: 002-2007			

4.5 Weld 5

This weld lay out and weld parameters (Table 4) result in a minimum of shrinkage transferred to the cavity. Even this small displacement deforms the cavity elastically. This compression on the cavity is eliminated by turning the cavity back to horizontal position and removing the bellows clamps. The cavity expands to a force free position and the clamps are connected again and fix the cavity in this neutral position.

Table 4: Weld parameter of sliding collar to reduction ring

Weld parameter sliding collar to reduction ring, joint 5			
Pulse current	Ground current	Pulse time	Ground time
100A	30A	0.10 sec.	0.15sec.
Velocity	Slope out	Electrode Ø	Gas flow
406mm/min	18 sec.	2,4mm	40 l/min.
WPS: DESY-Hamburg: Beleg Nr.: 003-2007			

4.6 Weld 6

To weld the adapter manually on the sliding collar, the cavity is fixed to the tank now, it is brought back to the horizontal fixture and a holder with the adapter is installed and welded, while the inside of the He tank is flushed with inert gas.

5. Final operations

After all seams are welded and brushed, a final vacuum leak check and a beat pull measurement is done. The cavity enters the clean room again to disassemble the FMS under clean room conditions and to perform the following up cavity preparation steps necessary to install the cavity into a module.

CONCLUSION

After the last changes in tank welding procedure, done in 2006, twelve cavities have undergone this optimized tank welding process. During the horizontal test all those cavities do not show variances in field profile, the resonance frequency or gradients in respect to the vertical

measurements, which can be implicated to the welding procedure.

OUTLOOK

There was the idea to weld the Titanium rings to the conic disc with the TIG welding as well. This option would not require an EB welding machine during industrial production and could bring significant cost savings. Experiments on samples showed very good melting and interconnections between Nb and TiNb alloy. Actually no welding parameters are found to realize this option without significant changes on the existing weld area design.

ACKNOWLEDGMENT

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