Aspects on RF for DQW cavity fabrication

(questions in email by C. Zanoni, February 12, 2016)

Silvia Verdú-Andrés (BNL)

Question 1) RF surface machining **and 2)** defect size

Machining on the RF surface, requirements. Machining RF surface near edges. Risks.

- Machining to correct defects, pits, etc? The BNL procedure for fabrication of SRF cavities foresees the machining of RF surface in case of surface imperfections. It also details necessary tooling. This information is included in the latest version of BCP procedure. See next slide.
- Defect → damage with a size larger than 15 µm
- Defects → field-emission, multipacting, Q-degradation, field enhancement and quench.

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Specification CAD 1244
Revision A
January 4, 2011

Specification for Superconducting RF Components

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CAD 1244 1

Specificities for DQW Crab Cavity Surface Treatment			
EDMS No.			
AUTHORS			DATE
Silvia Verdú-Andrés (BNL)			Dec 17, 2015
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Description
This document provides the specifics for the Buffer Chemical Polishing (BCP) and the High Pressure Rinsing (HPR) of the SPS Double-Quarter Wave (DQW) crab cavity. It provides the guidelines to follow in the surface treatment of the cavity parts prior to Electron Beam Welding (EBW) and of a fully assembled cavity.[1]

Contents

[1] The procedure is based on the BNL procedure "Specification for Superconducting RF Components", CAD 1244, on the CERN procedure "Superconducting RF cavities. Chemical polishing of niobium RRR> 300", EDMS 1388794 and on the BCP procedure of JLAB.

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Question 1) RF surface machining **and 2)** defect size

In BNL procedure for SRF Cavity fabrication and form latest version of BCP procedure:

All surfaces exposed later to ultra-high vacuum are functional surfaces that can critically influence RF operation.

3.1. Inspection of functional surfaces

- All functional surfaces must be inspected for imperfections before welding.
- All functional surfaces must be free of scratches and mechanical damage with a size larger than 15 μm, free of inclusions of foreign material, free of visible surface oxides, free of fingerprints, and free of silicone.
- If this requirement is not fulfilled, reworking can be carried out (see Section 3.2.), being restricted to areas of defects.
- Note that weld joint areas are particularly sensitive to inclusions.

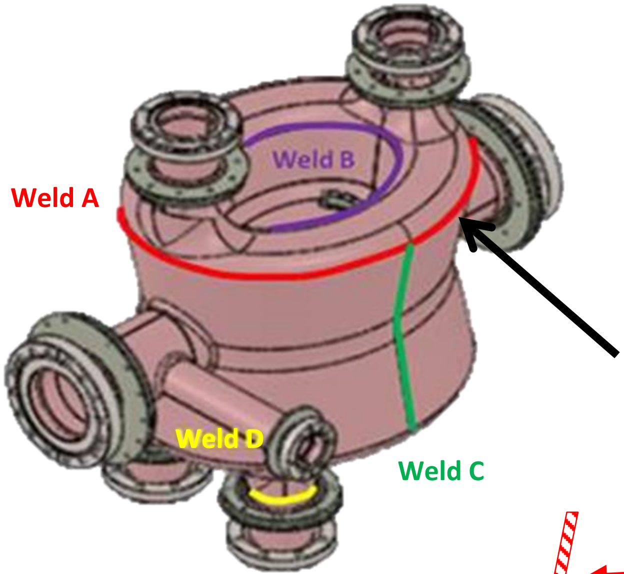
3.2. Surface machining to correct imperfections

- Imperfections shall be removed by reworking and subsequent BCP treatments.
- Reworking must be avoided as much as possible and it must be restricted to areas of defects to produce a smooth surface.
- Imperfections shall be removed with a metallic grinding tool or an aluminum oxide wheel. Recommended grinding wheel material is an aluminum oxide abrasive embedded in fibrous material or equivalent and shall be approved by CERN&BNL representative.
- Cutting, grinding and abrasive tools shall be niobium dedicated and shall not be used on other materials.
- Grinding of defects at the “inner” surface shall produce a smooth surface and a smooth transition to the untreated surrounding area.
- During rework operations surface temperatures on niobium surfaces shall not exceed 150°C.
- No deep scratches shall be produced at the ground area.

Question 3) Trimming procedure

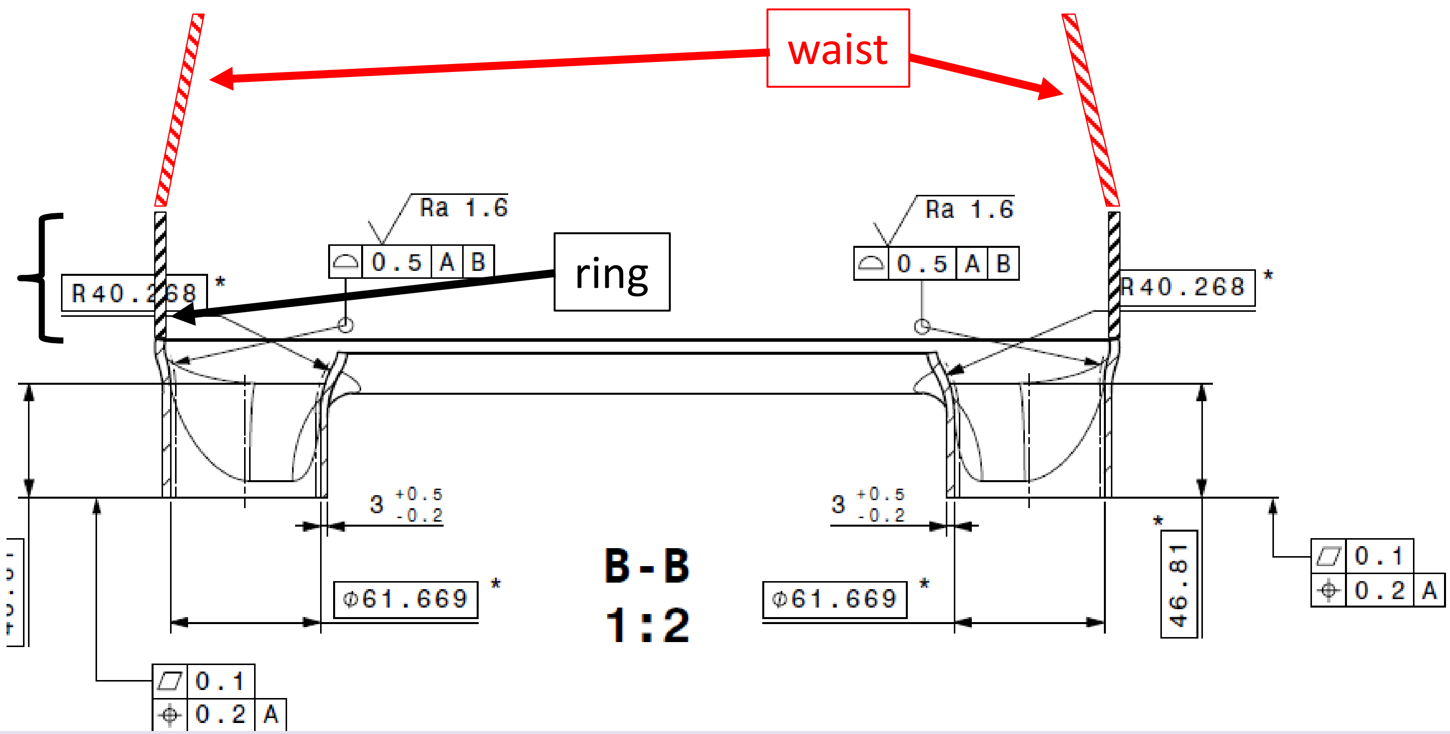
- According to my notes on meeting in November 2015, we agreed to just adjust the height of the lunette for the SPS crab cavities and avoid the complexity of adjusting both inductive and capacitive regions.

Question 3) Trimming procedure



- Learn sensitivity from weld-A at the bottom
- Sensitivity for current position of weld line: 2.4 MHz/mm

straight part; few millimeters; part of ring piece SECTION TO BE TRIMMED



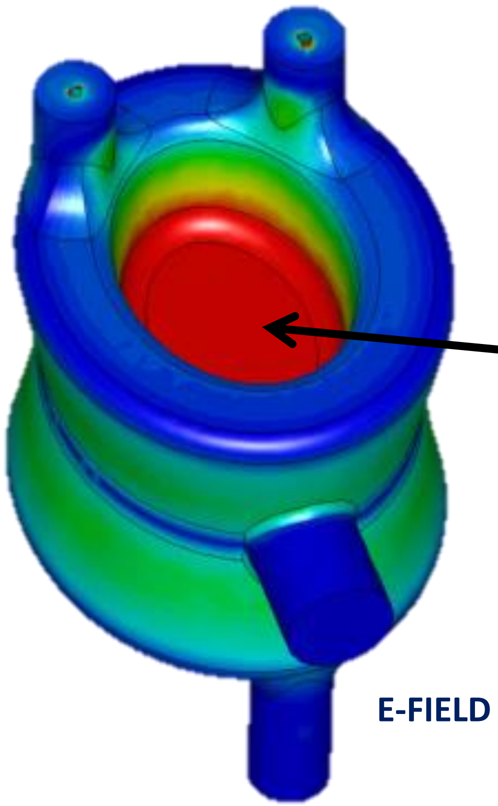
Question 4) Dimensional acceptance criteria

Critical dimensions that would become showstoppers or require corrective measures:

- Height (inductive rings distance), capacitive plates distance and waist: significant impact on RF frequency.
- Coordinates of interfaces.

The DQW cavity – *sensitive regions*

FIELD DISTRIBUTION FOR OPERATION MODE



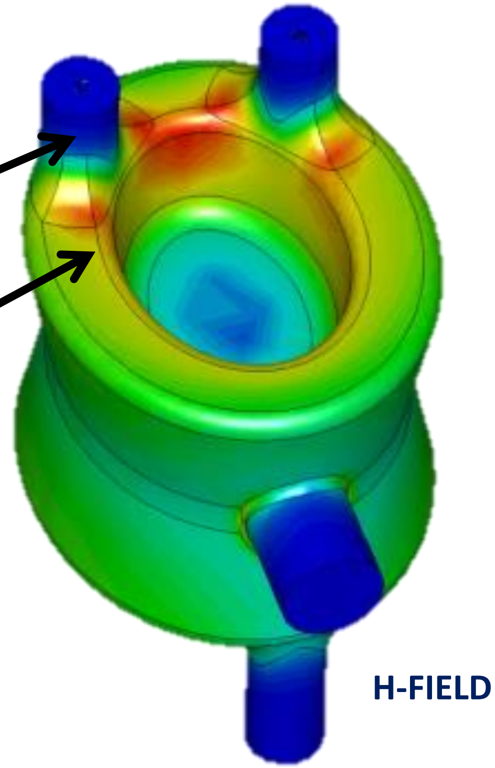
Critical areas:

inner surface

small ports

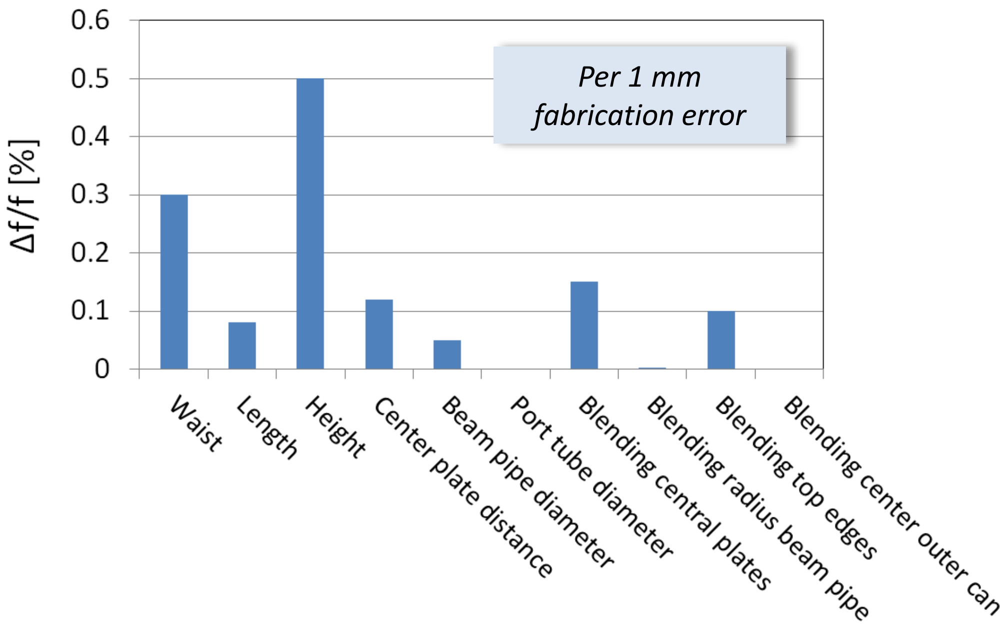
capacitive plates

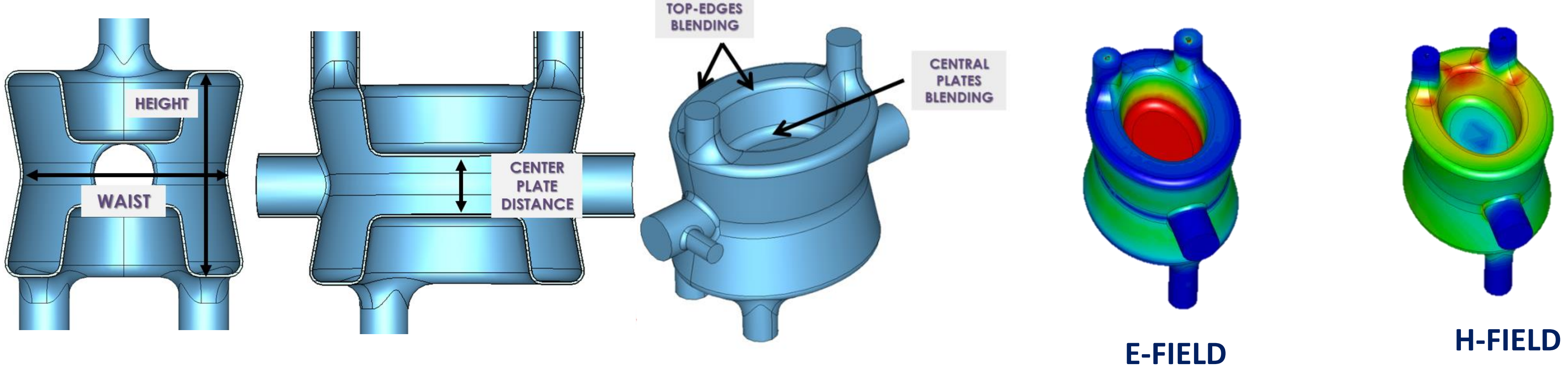
inductive rings



The DQW cavity – *sensitive regions*

Cavity height and waist are the most sensitive geometry parameters.





The DQW cavity – *sensitive regions*

Specificities for Tuning a DQW Crab Cavity		
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AUTHORS		DATE
Silvia Verdú-Andrés (BNL)		Oct 5, 2015
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Description

The narrow resonant peak of SRF cavities makes the cavity tuning a critical aspect. This document provides the guidelines to follow at different stages of the manufacturing process to produce a of a SPS Double-Quarter Wave (DQW) crab cavity with the goal resonant frequency at operation. The document describes the main sources of frequency shift and uncertainty and tuning mechanisms developed to correct the cavity frequency.

Contents

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Frequency shifts expected from tolerances specified in functional drawing.
Note: full cavity height is 2*HT+APER; full cavity waist is 2*Rmi and full cavity length is L1.

Geometric parameter in CST model		**Parameter value d [mm]**	**∂f / ∂d [MHz/mm]**	**Tolerance band in functional drawing Δd [mm]**	**Max. freq. shift due to specified tolerances +-df|[MHz]**
Waist	Rmi	137.9	-1.22	0.8	±0.49
Length	L1	343	0.32	1.6	±0.26
Height	HT	96.8	-2.13	0.8	±0.85
Center plate distance	APER	84	-0.49	-0.2 +0.4	+0.1 -0.2
Blending central plates	b2	20	0.59	0.6	±0.18
Blending top edges (int)	b4in	15	1.8	0.5	±0.5
Blending top edges (out)	b4out	15	0.27	0.8	±0.11

Minutes

Attendees:
BNL: Qiong Wu, John Skaritka, Ilan Ben-Zvi, Silvia Verdú-Andrés.
CERN: Ofelia Capatina, Carlo Zanoni, Marco Garlaschè, Raphael Leuxe, Paula Freijedo, Laurène Giordaninno

Indico event: https://indico.cern.ch/event/496592/

Agenda:
1. RF surface manufacturing
2. Defect size
3. Trimming procedure
4. Dimensional acceptance criteria

Minutes

1. <u>RF surface manufacturing (I)</u> (slide #2-3)

- S. Verdu-Andres: step in weld edges will lead to field enhancement. For DQW, some weld edges are in regions with high peak surface fields...
- M. Garlasche explains that part edges might need remachining in case that edges of one piece and the other in an elliptical line do not coincide to bring the whole edge to the same thickness so that it can be welded easily.
- J. Skaritka says that remaching of the interior edge surface would demand challenging precision and control especially given the gummy nature of Nb during machining. He proposes to adapt fixturing for this purpose or use fixturing features to avoid different thickness overlapping. M. Garlasche also mentions key configuration.
- Q. Wu asks how much misalignment is foreseen. O. Capatina replies that misalignement will be within profile tolerance band stated in functional spec drawing. M. Garlasche says about few tenths of mm. Frequency shift due to this misaligment will hence be small and can be corrected during trimming step. However, field enhacment in edge may still be an issue for cavity performance.
- I. Ben-Zvi recalls that surface defects can be corrected by surface machining and chemistry, but also by tumbling technique (considered as part of machining process) before conducting any BCP. O. Capatina mentiones that tumbling must be performed after full cavity is assembled and that cavity shape makes the tumbling technique not so evident.

Minutes

1. RF surface manufacturing (II) (slide #2-3)

- I. Ben-Zvi comments that penetration depth of the weld may vary along elliptical weld due to distance variation from electron gun to cavity edge as one is performing the weld along the elliptical edge. There is a technique to control the 100% weld penetration described in paper entitled «Simple device for controlling 100% penetration in electron beam welds» by I. Ben-Zvi, L. Bogart and P. Turneaure.
- Q. Wu mentiones that it is common practice among different labs to use brite to smooth down surface defects.
- J. Skaritka does not advice to use metallic grinding tool to avoid possible inclusions of particles into Nb. AlO wheel is much better.
- O. Capatina asks how to remove AlO from Nb. She will ask CERN chemistry department if there is any technique to remove AlO from Nb surface. BNL mentions that most likely BCP will remove any remnants of AlO.

2. Defect size (slide #3)

Minutes

3. Trimming procedure (slide #5)

- We all agree that baseline fabrication of cavity only envisages trimming in edge between inductive ring and cavity main body. This option is preferred because it shows less complications than trying to adjust both inductive and capacitive sections.
- M. Garlasche asks if it would be possible to displace the union of inductive ring to main body further close to capacitive region. This would reduce frequency sensitivity to weld penetration and also facilitate the depp-drawing of the cavity bowl. S. Verdu-Andres comments that this may change cavity performances. O. Capatina mentions that a first approach will try to keep the cavity profile within the tolerances specified in the functional spec drawing. This approach will not require any further evaluation of RF perofmrances with new model. If a more dramatic change of the cavity shape is needed, RF simulations will be required to determine changes in frequency, peak surface fields and HOMs.

4. Dimensional acceptance criteria (slides #6-9)
5. Others

- M. Garlasche updates on cavity manufacturing status. Information on CERN manufacturing meetings can be found at: https://indico.cern.ch/event/491369/