A REVIEW OF THE 1.3GHZ SUPERCONDUCTING 9-CELL CAVITY FABRICATION FOR DESY

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Abstract

Since 1993, DESY ordered 166 1.3GHz 9-cell superconducting cavities. The cavities have been developed for the TeV-Energy Superconducting Linear Accelerator (TESLA) [1-4] and are used in the LINAC of the Free Electron LASer in Hamburg (FLASH). The fabrication of all cavities was done in 10 production groups at industry. From the beginning the industrialization was carried out in close collaboration between DESY and the industry. From order to order the cavity design was optimized and the fabrication sequences were improved to realize a high level cavity performance and to safe costs. Now a final cavity design for the European XFEL is defined. We summarize the development phases and design changes up to the final European XFEL design. An outlook on the near future production of hundreds of cavities for European XFEL based on our experience will be given.

INDUSTRIAL CAVTY FABRICATION

Five different cavity producers have fabricated in total 166 1.3GHz nine-cell cavities for DESY since 1993. They are listed in table 1 in alphabetic order with the information of the amount of fabricated cavities per company. Several orders of cavities were divided by DESY in 10 production groups. The cavities were classified in these groups according their main characteristic features e.g. design or used material (Table 2).

For all fabricated cavities DESY supplied the semi-finished products of Nb and NbTi alloy for its fabrication. Six different vendors delivered the semi-finished products for the cell production (Fig. 1).

For the cell section of the cavities, three types of semi-finished products were used. Fine grain niobium sheets were used as standard, but 11 cavities were fabricated from large grain sheets [5]. For three cavities, hydroformed 3-cell units fabricated by DESY were used (Fig. 2).

Table 1: Producer List

	Company	Amount of cavities
1	Ansaldo STS & E. Zanon Spa, Italy	6
2	CERCA, France	15
3	Dornier GmbH, Germany	14
4	E. Zanon Spa, Italy	57
5	Research Instruments GmbH (former company Accel/Siemens), Germany	74

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Table 2: Production Groups

Production group	Amount of cavities	Cavity serial number
0	2	P-1, P-2
1	27	D1-D6, S7-S12, A13-A18, C19-C27
2	27	S28-S36, D37-D42, C43-C48, Z49-Z54
3	27	AC55-AC81
4	30	Z82-Z111
5	3	AC112-AC114
6	35	AC115-AC129, Z130-Z144, AC146-AC150
7	3	Z145, Z163, Z164
8	8	AC151-AC158
9	4	AC159, Z160-Z162

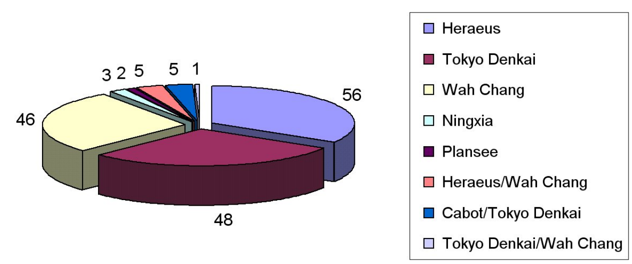

Figure 1: Amount of cavities sorted by the Nb-sheet vendors.

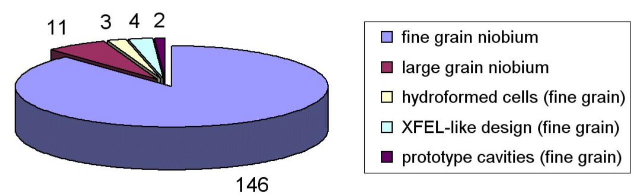

Figure 2: Amount of cavities sorted by material and design information.

FROM THE FIRST PROTOTYPE CAVITIES TO THE EUROPEAN XFEL DESIGN

General

The cell section of the cavity was designed asymmetrically [6]. This means that both end half cells have different geometries to avoid the trapping of the higher order modes (HOM) as good as possible. All 166 cavities were fabricated with the same middle half cell shape and asymmetric end half cell shape.

First TESLA Design and Drawings

The consideration of TESLA cavity design(fig.3)[6] was done in 1993 and the design drawings for the mechanical fabrication were completed for its use for the order of 18 cavities. They were welded with DESY HOM couplers [7] and Nb sealing surfaces. The cavities D1-6, S7-12, A13-18 were fabricated under these conditions.

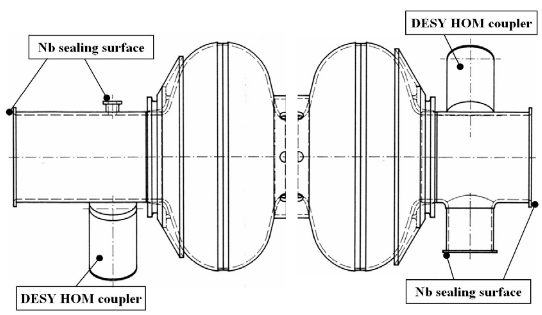

Figure 3: Base design of the first 1.3GHz TESLA cavity.

Cavities with SACLAY HOM Port

The cavities C19-C27, C43-C48 and Z49-Z54 were produced with SACLAY HOM coupler ports (fig. 4) to realize the connection and testing of HOM coupler designed by SACLAY.

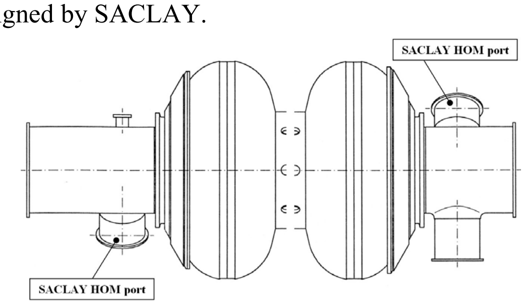

Figure 4: Cavity with SACLAY HOM coupler ports.

Improvement of the Flange Design

For the base design of the cavity, Helicoflex® gaskets were used on all flange connections directly at the Nb sealing surfaces. During the following use of these cavities, leak tightness problems occurred after multiple assemblies and after cool down at liquid helium temperature.

This problem was solved by using a new flange system which was developed and designed by DESY and successfully used from the 28th cavity on. The flange system is consisting of flanges made from Nb55%Ti alloy that is by factor of three harder compare to Nb and gaskets made from full metal Aluminium alloy (diamond shape in the cross section).

This very successful improvement allows reaching high reliability and was taken over by many other projects (SNS etc.).

Changing of the HOM-coupler Position

After intensive HOM measurements in the FLASH linac an improvement of the damping of the higher order modes [8] was done in 2002 by changing the HOM-coupler position at one side of the cavity. The new so-called mirrored design was used from the 82nd cavity on. The old and the mirrored position are shown in fig. 5+6.

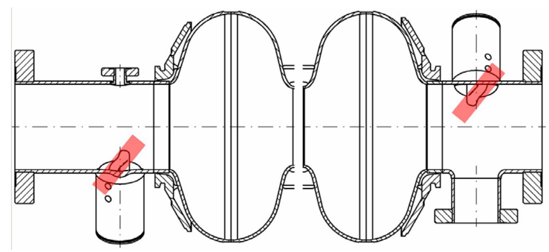

Figure 5: "in line" position of the DESY HOM-couplers.

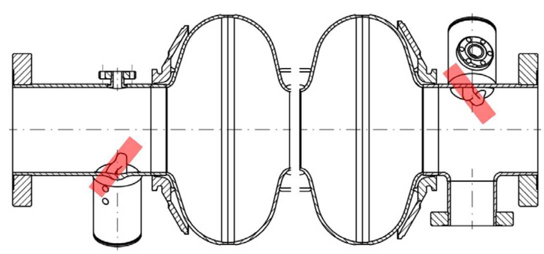

Figure 6: "mirrored" position of the DESY HOM-couplers.

Material Changes Since 1993

The materials of two semi-finished products were changed:

The Nb material of quality RRR300 for the *Connecting Flange (*connected at the beam tube and the end half cell) was replaced by lower Nb quality RRR40. This was proven as a cost effective and acceptable from the purity level solution.

The material for the *Conical Disc* (connected at the *Connecting Flange)* was changed from Nb to Nb55%Ti alloy. The advantage of NbTi is the much higher yield strength after high temperature backing in addition to lower costs. Conical discs on cavities from production group 4 (see table 2) on were made of NbTi alloy.

Length Adjustment Procedure

The length-adjustment method serves for optimization of the correct frequency and correct length within tolerances of the finished cavity. This procedure takes into account the deviation of the cell-shape from the ideal shape, shrinkage during electron beam welding and the removal of material during subsequent surface treatment procedures. The procedure was developed by DESY [9] and used successfully from production group 2 on.

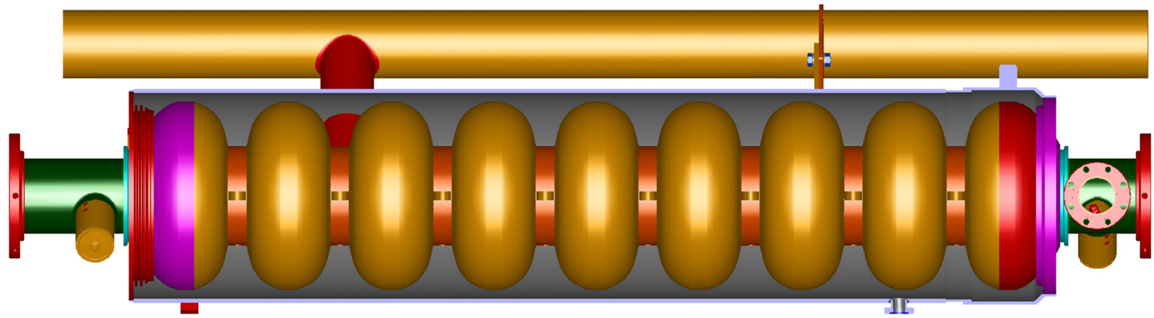

Figure 7: Picture of the 3D-Modell of the 1.3GHz cavity in helium tank for the European XFEL.

SUMMARY

Since 1993, DESY ordered 166 nine-cell 1.3GHz cavities at the industry. The cavities were fabricated successfully at five different vendors in a fruitful cooperation. The cavity design and the design of the connected parts e.g. HOM-couplers and their fabrication procedures were improved from order to order. The collected experiences have been taken into account in the final design for the fabrication of the cavities for the European XFEL (fig. 7).

OUTLOOK

For the European XFEL more than 600 cavities are ordered [10] at the companies Research Instruments, Germany and E. Zanon, Italy.

The order includes the fabrication of cavities and integration of the helium tank as well as the preparation of the inner RF-surface of the cavity.

In the past, the length adjustment procedure at the half cells, warm RF-testing and warm cavity tuning was done by DESY. For the production for European XFEL these activities will be taken over by the producer. Due to the fact that the cavity in helium tank for the European XFEL was classified as a pressure vessel according to Pressure Equipment Directive PED 97/23 EC special test procedures e.g. a pressure test must be applied.

All semi-finished products will be supplied by DESY.

ACKNOLEDGEMENT

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