ISBN: 978-3-95450-233-2 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2021-TUPTEV006

DEVELOPMENT AND ADUSTMENT OF TOOLS FOR SUPERCONDUCTING RF GUN CAVITIES

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Abstract

For the superconducting radio frequency (SRF) 1.6-cell gun cavities (CV) developed at DESY, a similar fabrication and treatment process, as for the European XFEL 9-cell cavities [1] is foreseen. The different length and geometry of these cavities lead to a number of adjustments to existing and the development of new tools. This paper covers the new designs and adaptations of a tuning tool, chemistry flanges, a wall thickness measurement device, as well as a new high-pressure rinsing spray head and an optical inspection camera for the 1.6-cell 1.3 GHz DESY SRF gun cavities under the development for the European XFEL.

TUNING TOOL

In order to be able to modify the frequency changes after the production of the SRF 1.6-cell gun CVs and to adjust the cells to the respective conditions, a tuning device is designed and built up.

During the fabrication of SRF 1.6-cell gun CVs, it is necessary to adjust the resonance frequency, while ensuring the field flatness at DESY, straightness and length of the cavity. Therefore, a simple manually driven tuning tool prototype was constructed, which makes it possible to correct the length and frequency of the full cell. As part of a collaboration between DESY and KEK (High Energy Accelerator Research Organization), this tool was handed over to KEK, to check the field flatness during the horizontal electropolishing process of the gun CV 16G4.

For further improvement, adjustments on the cell design had to be made. In order to have a universal tuning device for all existing and maybe upcoming cell geometries a 2nd prototype was developed, built and tested (Fig. 1).

Changes in the cell geometry can now easily be adapted with new tuning inserts. It is possible to use the new gun tuning device in horizontal and vertical position. It allows to tune prototype gun CVs without cathode hole or with installed plug. For this purpose, a "bead-drop"-system was developed, that allows to perform the well-established RF measurements even on cavities with only one open end where standard bead-pull systems cannot be applied. The new device enables to change the frequency, while tuning the effected cells without disassembling the cavity during the process. This leads to significant time savings.

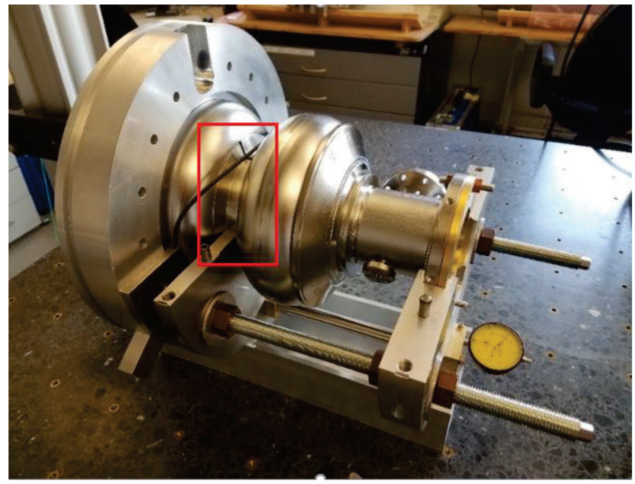

Figure 1: New tuning device with bead-pull system assembly and new tuning inserts.

CHEMISTRY FLANGE

At DESY the etching of multicell cavities is an established working process. Due to the gun CV design, several adaptations of this etching procedure as well as the tools are necessary.

During the usual etching procedure of XFEL CVs, the acid is filled through the bottom beam tube into the CV and is drained off the second upper tube as well, as over the other ports. In contrast, SRF gun CVs have only one beam tube to fill and drain the acid, (Fig. 2). The cavity is etched vertically, but must be turned several times 180°, back and forth for draining the acid after the chemistry and for refilling the water, during the rinsing procedure. During filling in the acid, no gas bubbles must remain in the gun CV. Gas bubbles can cause insufficient removal of material, as well as bubble traces can show up after etching. For this purpose, a "chemistry flange" with filling tube and nozzle head, which sits close to the cover plate, was designed.

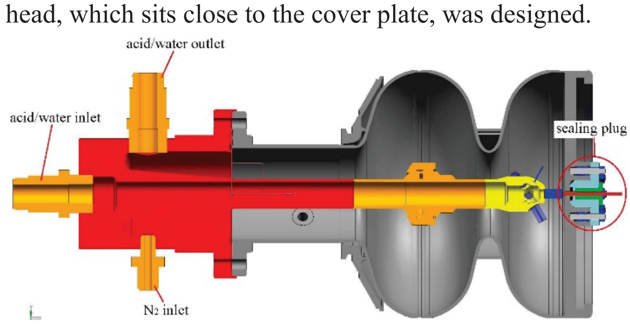

Figure 2: SRF 1.6-cell gun cavity with etching flange.

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It is inserted into the gun CV to ensure a complete filling for homogeneous removals, while etching vertically. The first prototype design showed difficulties with the centrical alignment of the used tube, which led to an inhomogeneous surface removal. This removal is measured with an ultrasonic thickness measurement device (see next chapter).

The present design includes a tube, made of PVDF (Polyvinyl fluoride), placed centrically into the gun CV. In addition, a nozzle head has been built to ensure a homogeneous acid flow onto the niobium surfaces. This head is exchangeable and can be adjusted to different dimensions of the gun CV. The treatment with the new chemistry flange design leads to significantly smoother surfaces and more homogeneous removals.

Further attention is paid to the material removal, while the etching process is applied at the cathode hole with a diameter of 4.0 mm. According to beam dynamic simulations, the cathode needs to sit very precisely in the cathode hole with a gap not wider than 0.1 mm. That makes it necessary to protect the hole while etching. For this purpose, a sealing flange was designed to close the sample hole from the inside of the cavity. So far, no leaks appeared during the chemical treatment, the diameter of the cathode hole remained unchanged.

WALL THICKNESS MESUREMENT

The European XFEL standard procedures to determine the removal of material during chemical treatment steps are carried out by measuring the weight loss of the cavities as well as the etching time.

To get more precise surface resolved results during individual chemical treatment steps, a wall thickness ultrasonic measurement device (UT), Olympus 38DL+, has been established. A reproducible measurement, regardless of the surface form or the executing person was the aim of this device.

A measurement probe sends ultrasonic waves perpendicular to the surface into the material. The returning echo is measured by the device and converted into thickness values. This method allows reproducible wall thicknesses measurements at all free accessible areas of the cavity wall.

A crown-shaped contact surface of the probe, together with a new designed former plate, allows a precise vertical and local reproducible measurement of the rounded gun CV surfaces (Fig. 3).

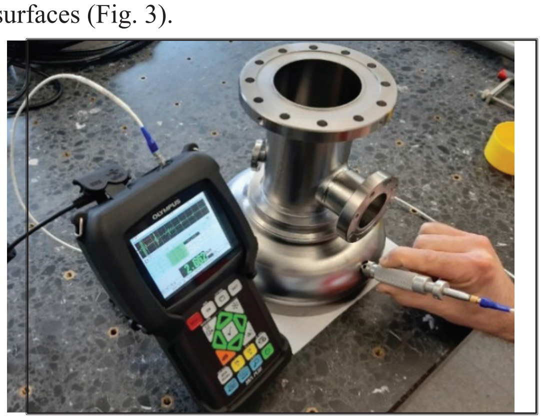

Figure 3: Ultrasonic wall thickness measurement device.

Several measurements with the UT device show a strong local variation of the removal rate on the back wall, as well as in the cells. An asymmetric removal rate, resulting from the prototype chemistry flange, could be identified and led to a new construction. The measurements after the adaptations show promising results. Continuous measurements with the UT device will discover, whether further adjustments of the chemistry flange design will be necessary in the future.

HIGH PRESSURE RINSING SPRAY HEAD

The established standard design of DESYs high pressure rinsing (HPR) spray heads, used for rinsing single and nine cell cavities [2], is inconvenient for 1.6 cell SRF gun cavities. This treatment is not sufficient as the surface of the back wall is not fully covered with water, while rinsing. Therefore, a new HPR spray head was designed to improve the rinsing efficiency.

Initially, it was analyzed how a standard spray head is operating, by using a PMMA (acrylic glass) nine cell cavity model, in one of DESYs HPR systems. These findings led to the following design ideas.

The ideas for new HPR rinsing head were transferred into a hard metal model, using a new SLM (Selective Laser Melting) method to create a more complex spray pattern. It was shown that the surface quality of this new spray head is not useful for the application. Due to the insufficient surfaces of the SLM method, the current used design was then manufactured by using the standard fabrication methods, which led to significantly better surfaces.

The new design has 12 nozzles instead of 8. Furthermore, the nozzles are arranged spirally around the head and two of them are placed upwards, to rinse the cover plate directly (Fig.4).

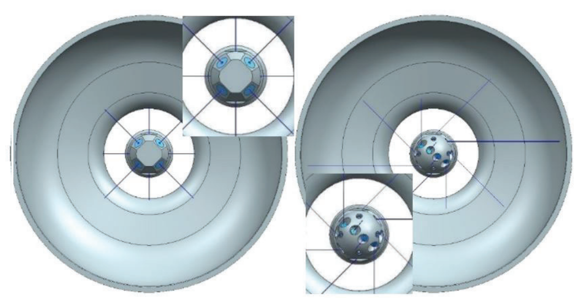

Figure 4: Water distribution, standard (left) vs. new design (right).

To test the spray and flow pattern of the new HPR spray heads in more detail, a rinse test stand, based on an existing DESY single-cell HPR system is presently under construction.

For this purpose, the movements of the rinsing lance, at the existing system, has to be changed to an independent rotational and transversal movement of the CV itself using a fixed lance. Furthermore, investigations are needed to get a better glimpse on the water coverage of the surfaces on resonators.

20th Int. Conf. on RF Superconductivity SRF2021, East Lansing, MI, USA JACoW Publishing
ISBN: 978-3-95450-233-2 ISSN: 2673-5504 doi:10.18429/JACoW-SRF2021-TUPTEV006

OPTICAL INSPECTION

During the XFEL cavity production, welds and surfaces have been visually inspected with different types of endoscopic camera systems. The systems differ in size, structure, imaging and location of the facilities.

The standard optical inspection (OBACHT) used at DESY [3] is located outside a cleanroom. Due to its design it is not possible to inspect the half-cell of a 1.6-cell gun cavity.

To ensure not to contaminate clean surfaces, a new inspection system, applicable for different cavity types was set up and implemented inside of the cleanroom. In its first design of 2017 [4], which was regularly operated, is used a See3Cam CU 130-13MP USB 3.0 (V1.0).

In response to changing requirements of SRF gun cavity inspections and the desire to get better image resolutions, the V1.0 has been further developed. Key improvements are the application of a new sensor head. The new Keyence IV2-G500CA (V2.0) is working with higher resolution, an auto focusing for a large variance of working distances, as well as a compact design. The significantly improved resolution of V2.0 shows the great gain in imaging in comparison to V1.0 at its maximum resolution. The difference can be seen in (Fig. 5) sharing the same cavity region, observed with the old and new system.

The usable swivel range, of the new V2.0 sensor, is 210° (inclination) in addition, to the already existing 360° rotation, around the longitudinal axis of the lance. It ensures a perpendicular view from the camera to all surfaces of the interior structure, like the back wall or cell surfaces between equator and iris.

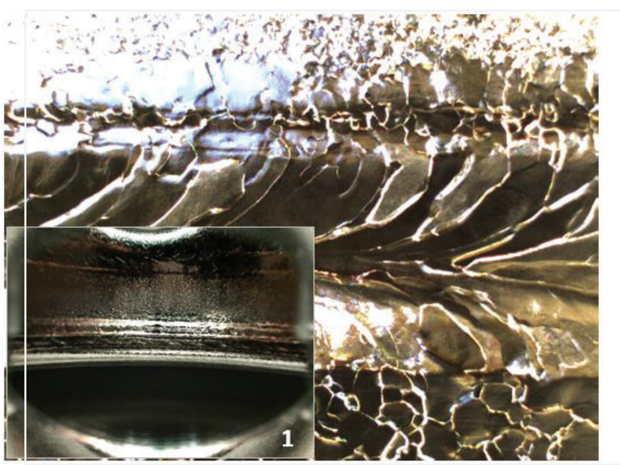

Figure 5: Same view of iris weld, IV2 vs. V1.0 (1).

The manual swivel range of the V1.0 is only 60° and in comparison, to IV2, the mirror of V1.0 must be disassembled to inspect the cover plate.

An improved lighting system combines a dimmable illumination (white) and a polarity filter, to reduce light reflections on high-gloss surfaces.

During the operation of V1.0, it has been shown, that light of certain wavelengths can improve the contrasts of the pictures and simplify the imaging. Good observation results are made mainly under green and yellow light. For this reason, a RGBW LED ring is part of the upgrade. It is concentrically arranged around the lens and can optionally be switched on, dimmed and changed in color.

RESUTING CAVITY PERFORMANCE

Our first prototypes of SRF gun cavities showed gradients meeting our requirements. However, these first cavities where still not suitable for helium vessel integration [5]. Step by step we improved the mechanical stability of the back wall, the mechanical production process to obtain the desired frequency with field flatness and the surface treatment by electropolishing (EP) and buffered chemical polishing (BCP). This led to the development and adjustment of the tools presented in this paper. As a result of our efforts, all recent prototypes show the desired peak on axis gradients with a flat RF field and the back wall is mechanically stable. We actually recovered an initially bad performing cavity, Fig. 6.

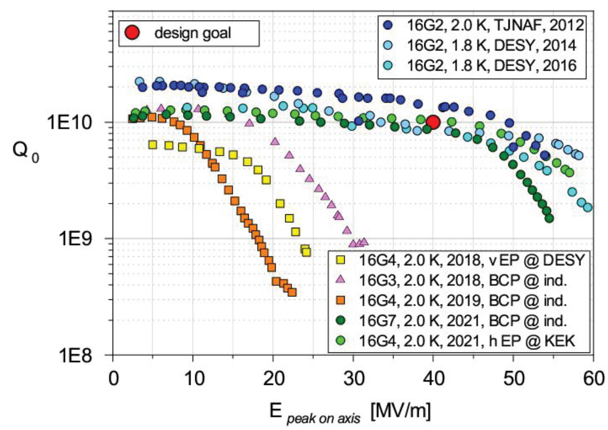

Figure 6: Typical vertical test results of SRF gun cavities.

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