

ILC-HIGRADE CAVITIES AS A TOOL OF QUALITY CONTROL FOR EUROPEAN XFEL

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Abstract

Part of the quality control (QC) and quality assurance (QA) scheme applied for achievement of the designed parameters of the European XFEL cavities is presented. Results of the first tests of QC cavities from the “ILC-HiGrade program” as well as examples of a feedback to the cavity fabrication during the ramping up phase is presented.

INTRODUCTION

In order to ensure an achievement of the designed parameters of the European XFEL (EXFEL) [1] cavities, the production foresees an extensive quality control (QC) and quality assurance (QA) scheme. An additional quality control tool is given within the “ILC-HiGrade program” [2]. Details of the program and results of the first QC

cavities tests as well as examples of feedback to the cavity fabrication during the ramping up phase are presented and discussed.

EUROPEAN ILC-HIGRADE PROGRAM

The EXFEL cavity order includes an additional 24 cavities as part of the European ILC-HiGrade programme. Initially, these cavities serve as quality-control (QC) samples extracted from the serial production of EXFEL cavities on average once per month.

An overview flow scheme of the QC cavity preparation is given in Fig. 1.

The first few cavities have been already delivered and passed first cold RF tests. After this normal acceptance test, the cavities are taken out of the production flow and released for further R&D. The QC and QA have to

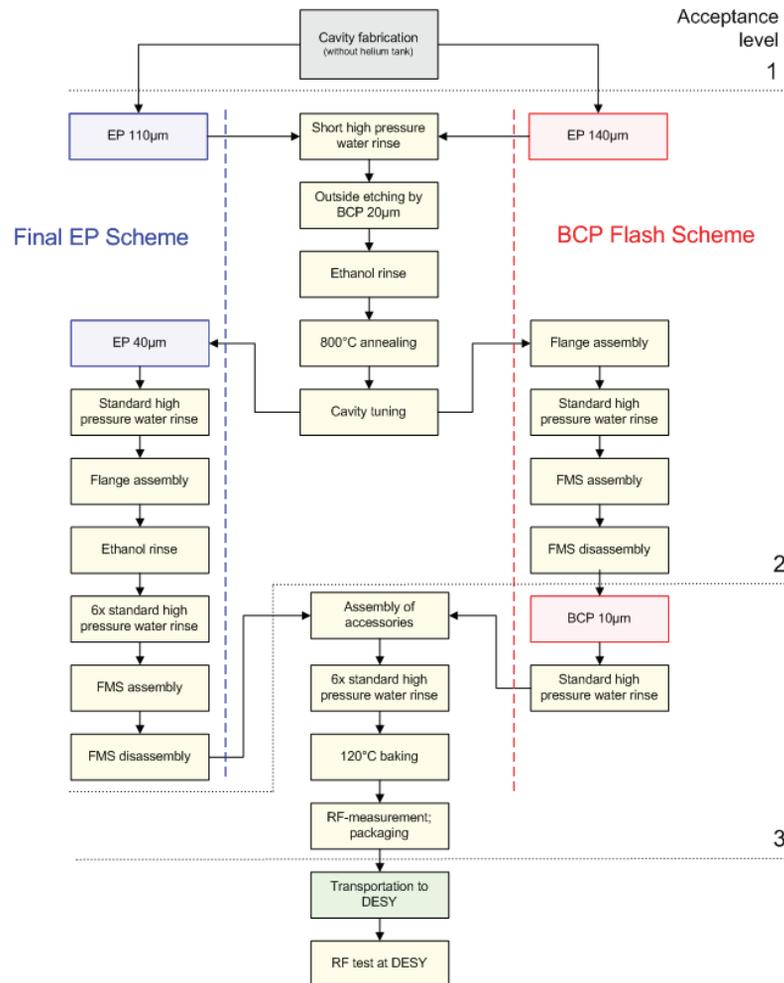


Figure 1: Flow scheme for the “ILC-HiGrade” cavity quality assurance.

include all processing steps of the EXFEL cavities. To maximize the data from these so-called QC cavities, a surface-mapping technique (“Second Sound” [3] and temperature mapping (T-mapping)) is applied in a second cold RF test. Therefore the cavities are delivered with the normal full treatment of the inner surface but without a helium tank. All other fabrication steps, specifically the mounting of the field profile measurement system into the cavity, including the measurement itself, and its removal from the cavity is carried out. This will allow checking whether contaminations of the handling in these steps pose a problem to cavity performance. The QC cavities are also equipped with HOM antennas to resemble the XFEL cavities as much as possible. A full documentation of the production steps is provided except some deviations due to the missing helium tank.

To ensure that the cavity can be later welded into a helium tank in the framework of the ILC-HiGrade program, leak tests at the conical disks are indispensable. To facilitate the handling of the QC cavities in the process steps after the omitted helium tank welding procedure, an appropriate handling fixture is foreseen.

Because of the omitted tank welding and conjugated production steps, the ILC-HiGrade cavities arrive roughly two weeks in advance to the main production stream. It allows better monitoring of the production processes and prediction of any fabrication difficulties.

A row of further R&D steps is foreseen with these cavities within the ILC-HiGrade and CRISP [4]

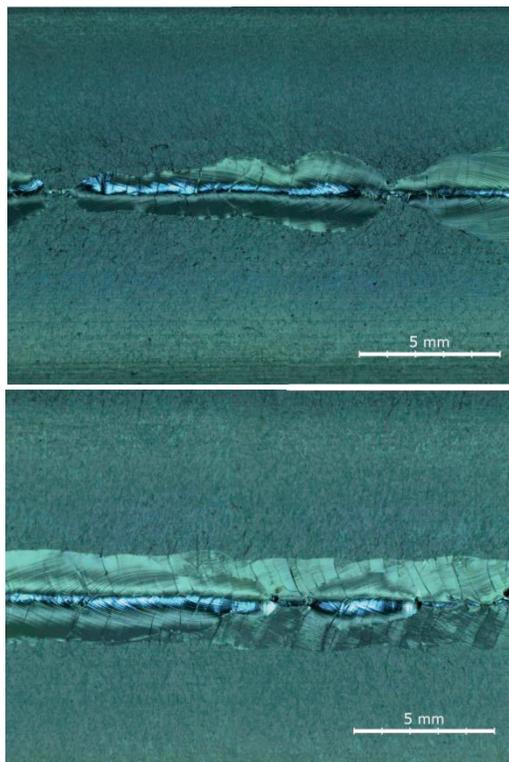


Figure 2: An example of the welding optimization process showing initial, not optimized (upper) and optimized (lower) equator welding seams.

programmes as a feasibility study for the ILC and carried out in close collaboration with the standing experts engaged in the EXFEL production to improve the understanding of defects and further exploration of new cavity preparation and repair techniques that can achieve high accelerating fields with high fabrication yield. The details of this programme can be found elsewhere [5].

FEEDBACK TO THE EXFEL FABRICATION

Optimization of the Electron-Beam Welding

One of the difficulties occurred during the ramping up phase of the EXFEL cavity production was not complete penetration of the welding seams as well as strong variation of the seam-width. Optical inspections with conventional endoscopes at companies gave some indications for the problem. Detailed analysis of the defects, however, was possible by applying the optical inspection system OBACHT [6]. The system provides much better resolution and image quality and can allow better tracing of surface modifications through the production steps by detailed recording and very good positioning repeatability as compared to the conventional endoscopes. An example of the welding optimization process showing initial, not optimized status with partially not penetrated welding seam and strong variation of the seam-width as well as an optimized one with fully penetrated homogeneous welding seam can be found in Fig. 2. Note, that due to production reasons the images of different cavities are shown.

Study and Repair of Welding Spatters

Endoscope and OBACHT inspections discovered some mm big “spatters” on the surface occasional occurring during the welding (see Fig. 3). The reason for

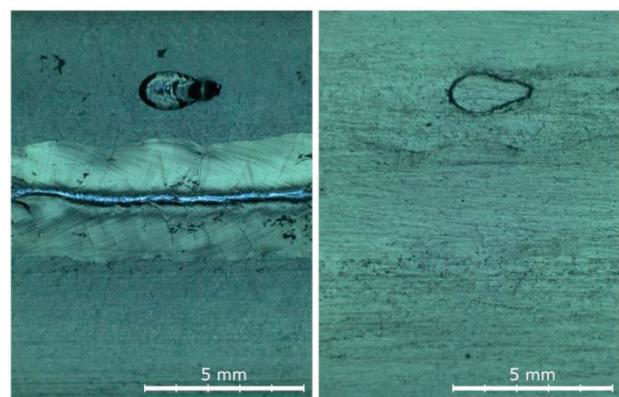


Figure 3: Spatter before (left) and after (right) local mechanical polishing.

them is not very clear yet and is under further investigations. As a consequence, additional local repair of the cavities is required to remove these defects, which are almost not effected by the actual polishing techniques. An optimum repair procedure is actually under study. An

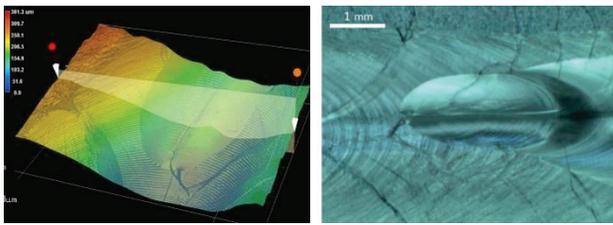


Figure 4: Comparison of 3D profilometry images with 2D optical image from OBACHT.

example of a local mechanical polishing, which was carried out manually, is shown in Fig. 3. Some difficulties, however, occurred due to the absence of simultaneous optical control of the grinding procedure and determination of the required material removal.

Replica Study of Some Conspicuous Welding Seams

Some areas of the cavity inner surface and especially the welding seams show occasionally some conspicuous features, which cannot be unambiguously interpreted by the OBACHT analysis due to mostly missing height information. In order to analyse the geometry of such areas, replica technique [5] is applied and the resulting profilometry data are compared with the OBACHT results. An example of such comparison is shown in Fig. 4. It turned out that the “snake head” at the electron-beam welding entry/exit is not protruded as it seems to be from

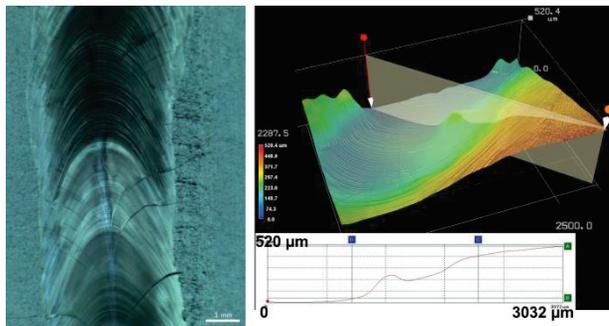


Figure 5: Optical image and profile of the welding seam.

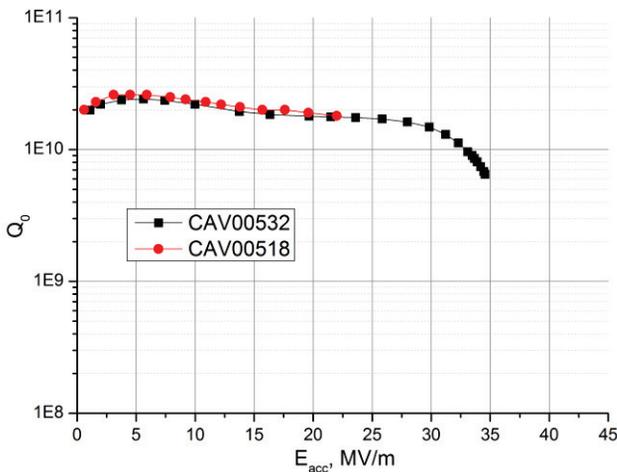


Figure 6: Cold test results of the cavity CAV00532 with no radiation, rf input power limited at 200 W and of the CAV00518 with no radiation and quench at 22 MV/m.

the OBACHT images and the cavity can follow the usual cavity polishing procedure.

Another example of such comparison is shown in Fig. 5, where a big protrusion of the whole welding seam has been confirmed by the profilometry measurements of the replica. It turns out to be more than 500 μm, while the maximum specified value is up to 300 μm. In this case the welding parameters have to be checked and the welding seam is to be repaired first.

Cold RF Tests and Surface Inspection of the First QC Cavities

The first few QC cavities have been already delivered and passed first cold RF tests and detailed investigation of the inner cavity surface by means of the high-resolution

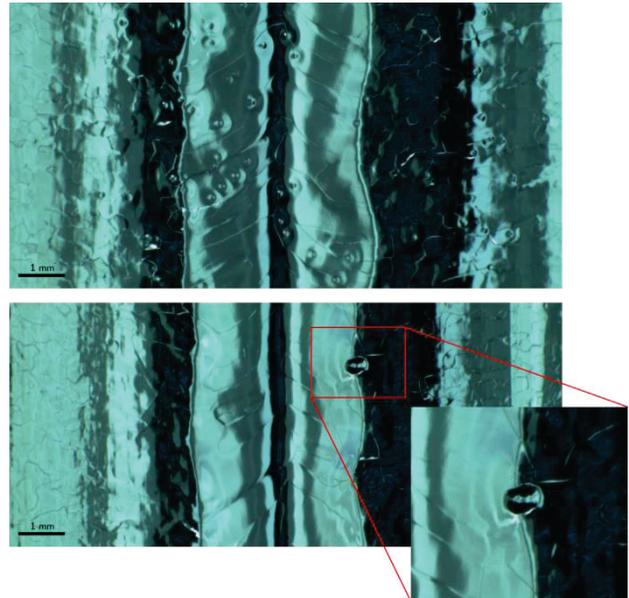


Figure 7: Optical images of some “pits” (upper) and “cat-eyes” (lower) on cavity CAV00532.

optical system OBACHT. The first cavity (CAV00532) showed a successful cold rf result with almost 35 MV/m (Fig. 6) maximum accelerating gradient with no radiation

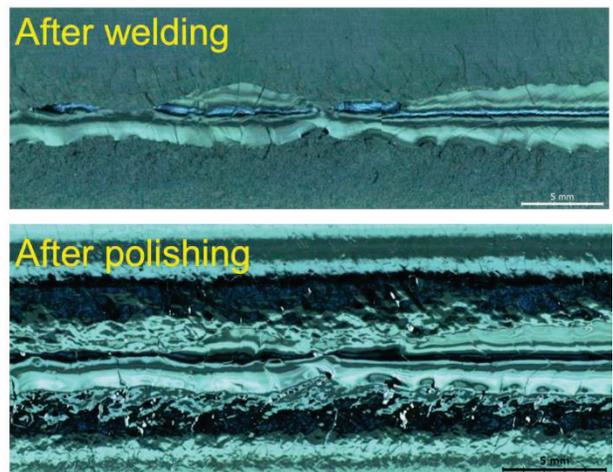


Figure 8: Optical images of the equator welding seam of the cavity CAV00518.

and the test was limited at 200 W due to maximum available input rf power. The cavity showed nice rf results despite of some tiny “pits” and “cat-eyes” on the surface (Fig. 7).

The second cavity (CAV00518) showed an unsuccessful cold rf result with only 22 MV/m maximum accelerating gradient with no radiation but limited by the quench. OBACHT inspection indicates defective equator welding seam as a possible quench reason (see Fig. 8). Further detailed studies with “Second Sound” and T-mapping will be applied for the quench localization and to clarify the limiting factor for these cavities.

CONCLUSIONS

An extensive QA and QC scheme geared to achieve the designed parameters of the European XFEL cavities has been implemented. 24 ILC-HiGrade cavities will be used to identified limitations in industrial production and serve as a tool for QC for the EXFEL

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