INDUSTRALIZATION OF TESLA-TYPE SRF TECHNOLOGY AT ACCEL

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Abstract

In the last 15 years the worldwide TESLA collaboration under the leadership of DESY performed successful development of SRF technology for possible use in a future international linear collider (ILC). Today this technology is also the baseline for other demanding projects like the European X-FEL at DESY site, 4GLS at Daresbury, BESSY FEL, Cornell-ERL, FEL at Peking University and others. Through all these years ACCEL has followed and supported this tremendous development by producing and processing SRF cavities, couplers and complete accelerator modules. The current ability and future prospects of ACCEL for manufacturing and processing such key components as well as turnkey SRF modules with guaranteed performance for such projects are described.

INTRODUCTION

Founded in 1993/1994 as a management buyout from SIEMENS Interatom, starting with a key staff of about 30 people, ACCEL Instruments has developed meanwhile into a medium size company of about 250 people, half of them being physicists and engineers, half of them being manufacturing specialists. From those about a third of the people are working in the field of normalconducting and superconducting RF. From the beginning ACCEL was committed to SRF technology and believed in the strong future of this technology in future accelerators. Therefore we have updated our infrastructure for SRF cavity and key component construction, design, development and production on a regular basis and also offered customers the possibility to purchase SRF cavities and complete accelerator modules with guaranteed performance for accelerating voltage and cryogenic losses. Fruitful collaboration with worldwide leading Universities and Institutes like Cornell, DESY or Forschungszentrum Rossendorf have been successfully concluded in order to supply other customers with state of the art SRF technology. Beside this, own design and development work was done to develop specially required and customized SRF applications. We concentrate here on TESLA-type technology but would like to point out, that all those techniques are applied for other frequency SRF cavities and modules for other applications like 500 MHz modules [1] for high current storage rings or 176 MHz half-wave modules [2] for proton/deuteron acceleration.

SRF CAVITY MANUFACTURING

More than 60 TESLA cavities have been produced at ACCEL so far. Customers have been DESY, but also Forschungszentrum Rossendorf, University of Stanford, BESSY, Daresbury and recently also FNAL. Another 15 cavities are currently under production for DESY.

Currently two electron beam welding machines are available. For the third machine the vacuum chamber and the vacuum system already exists and the electron gun and the control system can be integrated in short term to realize production rates necessary for projects such as the X-FEL. For the Spallation Neutron Source in Oak Ridge 109 superconducting 805 MHz 6-cell cavities had to be produced [3] between 2002 and 2004. With the current installation, a production rate of one cavity per week was achieved in a one shift operation and with additional parallel production of several other SRF cavities for different applications. For future highest cavity production rate modified tooling allowing to do multiple welds during one pumpdown will play a key role for reducing needed electron beam welding time per cavity.

Half cells for TESLA cavities are produced by deep-drawing using a stamp and a cushion rather than using inner and outer die. This reduces production steps and results in better cell geometry.

Turning and milling of niobium is standard procedure at ACCEL. If needed the amount of turning and milling machines can be easily enlarged and two or three shift operation can be established for a large series production.

In addition the welding of the helium vessel to the cavity whilst maintaining the field flatness thus avoiding detuning of the cavity by this delicate operation has been done on a regular basis. Figure 1 shows two TESLA cavities produced for BESSY, one already dressed with the helium vessel.

Figure 1: TESLA cavities produced at ACCEL; for one cavity the helium vessel is already welded and the high power coupler and the HOM antennas are assembled inside the clean room after preparation for horizontal test. The other cavity is mounted inside a transport frame.

SRF CAVITY PROCESSING

On TESLA cavities we have performed the buffered chemical polishing (BCP 1:1:2), high pressure rinsing with 100 bar DI water and assembly of test input antenna and pick-up antenna in the clean room for Daresbury and BESSY. For both customers we have guaranteed and exceeded an accelerating gradient of 15 MV/m at a unloaded quality factor of $5x10^9$ during cavity RF test in a vertical bath cryostat at 2.0 K. The chemistry is applied to the cavity in a closed acid cycle with temperature control to avoid hydrogen diffusion into the niobium material.

For the interior surface cleaning of the cavity by high pressure water rinsing (HPR), ACCEL recently introduced the particle monitoring of the rinsing water to control the cleaning process. For that a special water particle monitor is installed in the drain of the HPR system, which suppresses the influence of dissolved gas bubbles to particle counting. The particle rate is monitored with a frequency of approx. one sample per minute. Figure 1 shows the accumulated particle counts per sample during a high pressure rinse of a superconducting TESLA cavity. Particles down to 0.2 µm size are monitored. The peaks in the plot are correlated to the same positions of the spraying nozzles in the cavity during repeated HPR runs. The red line shows a test measurement with a rotating nozzle in a fixed longitudinal position. This measurement shows the sensitivity of the measurement for the cleaning process.

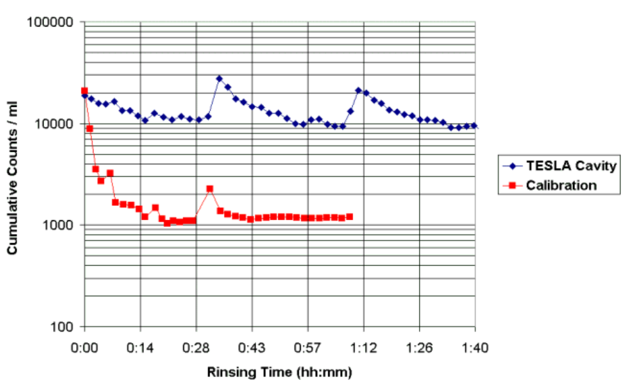

Figure 2: Particle sampling during high pressure rinse.

Figure 3 shows the correlation between the particle counts and particle size for a specific sampling point. This distribution can be described in good approximation by a power law. The exponent b (negative) for samples with high particle contamination is approx. 2. For samples with relatively low particle content b is approx. 3 to 4.

Up to now the measurement basis is still too poor to have a direct correlation between particle counts during HPR and cavity RF performance. Nevertheless, this particle monitoring already proved to be an efficient debugging tool for our HPR system. Currently we are working to improve the particle underground in our HPR system.

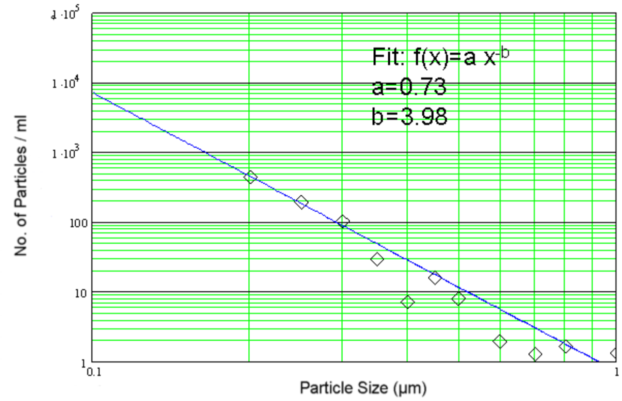

Figure 3: Particle size distribution of a “clean” sample.

After cavity preparation the cold RF test of the cavity was done at DESY. A cooperation agreement exists with DESY allowing using the DESY infrastructure to carry out those tests. Figure 4 shows the results of cold RF tests for two TESLA cavities produced and prepared for vertical test at ACCEL. After some RF processing the cavity reached a Q0 of more than 10^{10} at 20 MV/m.

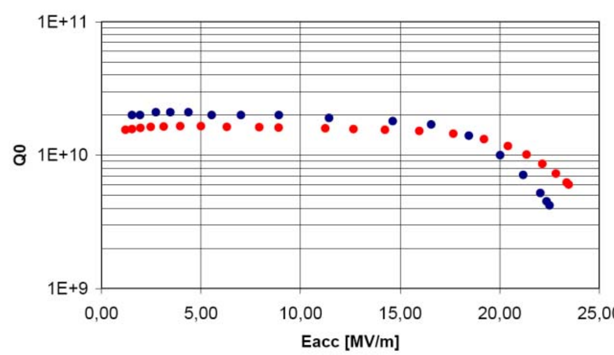

Figure 4: Vertical test result of TESLA cavities produced, tuned, etched, high pressure rinsed and assembled in the clean room at ACCEL. The test took place at the vertical test cryostat at DESY.

COUPLER PRODUCTION

From the other key component, the RF power input coupler more than 50 pieces have been produced so far, mostly of the TTF-III style, but also of the Rossendorf style and the TTF-II style and prototypes of the TTF-V and TW 60 style for LAL in Orsay, France.

Currently ACCEL is involved in an industrialization study contracted form LAL to turn the TTF-III coupler into a X-FEL coupler by reviewing the manufacturing processes and optimizing the current coupler design in view of cost reduction and series production. During this study two prototype X-FEL couplers will be produced and will be tested at LAL. A commitment for a series price of such couplers for the X-FEL project needs to be given at the end of the study.

Figure 5: TTF-III coupler manufactured at ACCEL.

TURN KEY SRF MODULES

Based on a license agreement with Forschungszentrum Rossendorf, ACCEL can deliver complete accelerator modules to customers worldwide. The Rossendorf module integrates two (TESLA module: eight) cavities into one accelerator module. Starting from the TESLA cryomodule design other key components like helium vessel, input coupler, tuner, thermal and magnetic shield, cryogenic distribution and vacuum vessel were modified or redesigned by Forschungszentrum Rossendorf to allow for cw operation (TESLA module pulse operation at duty cycle of up to 1 %) of the module. Therefore this module is ideal for applications like medium size FEL projects. Presently ACCEL guarantees an accelerating voltage of 25 MV per module and is ready to review those guaranteed values for future projects. Peking University is currently considering using one of those modules for their FEL project.

For Daresbury Laboratory two such modules have been already produced recently for their 4GLS project test facility and were already delivered to the 4GLS site in March respectively June of this year.

Figure 6: Improved HOM antennas in view of thermal cooling produced at ACCEL for the 4GLS project

While working on the 4GLS project at ACCEL it was found out at JLAB for a similar application (FEL upgrade module), that at gradients above 10 MV/m the feedthrough of the HOM antennas used so far might not sufficiently be cooled and therefore experienced over-heating during cw operation. JLAB developed a new feedthrough using sapphire with improved heat conduction and ACCEL was able to agree with JLAB on a license agreement to produce such HOM antennas in house for the 4GLS modules. In figure 6 those HOM antennas are shown. Today we can offer those improved HOM antennas also for other customers like for example Cornell who require improved HOM antennas for their ERL project.

Before delivery the two SRF modules for Daresbury have been completely assembled and cooled down to helium temperatures at ACCEL to demonstrate correct cavity frequency and damping of the HOM couplers. The proper function of the tuners was checked at 4 K and the leak tightness of helium vessel, thermal shield, insulation vacuum and cavity vacuum at cryogenic temperatures was demonstrated. The high power test of the module can not be done at ACCEL as radiation shielding and RF and cryogenic infrastructure are not yet available. This will be done at the 4GLS installation at Daresbury and is planned for autumn this year, when 4GLS will integrate the delivered modules with the cryogenic and RF distribution system. Figure 7 shows a module after assembly and ready to ship.

Figure 7: SRF module for 4GLS after successful cold test at ACCEL and ready to ship.

REFERENCES

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