SERIES FABRICATION TECHNOLOGIES FOR NORMALCONDUCTING LINAC AND STORAGE RING CAVITIES

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Abstract

Twelve HOM damped 476 MHz single cell cavities have been delivered for PEP II [1] and the production of 805 MHz CCL modules for SNS has recently been finalised by ACCEL Instruments [2]. Based on those two examples, required key technologies for cavity production will be introduced. Final prove of successful manufacturing is given by low level rf measurements. Results of those measurements for above mentioned projects will be presented within this paper.

KEY TECHNOLOGIES

The fabrication of copper rf cavities requires a series of fabrication technologies, which have to fulfil the special boundary conditions for accelerator equipment. These are high mechanical tolerances, ultra high vacuum compatibility and fault free surface finish.

Metal machining

Turning and milling at high accuracy are standard of modern machining work shops. Additionally special care has to be taken to guarantee good ultra high vacuum and high electric field performance of the finished cavity. All turning and milling machines for cavity production run with sulphur free coolants to minimize outgassing of the machined surfaces. The machining of cavity materials like copper and stainless steel is strictly separated from non vacuum compatible or corrosive materials like brass or carbon steel. The requirement on the surface finish is depending on the cavity frequency. As a rule of thumb the surface roughness should be less than a quarter of the rf penetration depth. Polishing after machining is forbidden in most cases to avoid the intrusion of grinding material into the rf surfaces. These are possible sources for field emitters in high electric field regions.

Metal joining

Metal joints at the inner surfaces of rf cavities have to fulfil UHV leak tightness and require a high electrical conductivity and smooth surface finish to avoid field emission. The two methods for the fabrication of the aforementioned projects are electron beam welding and vacuum brazing. EB welding of the PEP II cavities (Fig. 1) requires full penetration welds with a penetration depth of approx. 15mm. Laying the weld stop next to the inner surface of the cavity bears the risk of having pores on the rf surface. Special care has to be taken for the evaluation of the weld parameters. In some cases the weld roots were smoothed by wash welding from the inside, whenever the weld region was accessible by the electron beam.

For the SNS CCL cavities mainly vacuum brazing was applied. High conductivity braze materials like copper silver alloys were used for interior cavity braze joints.

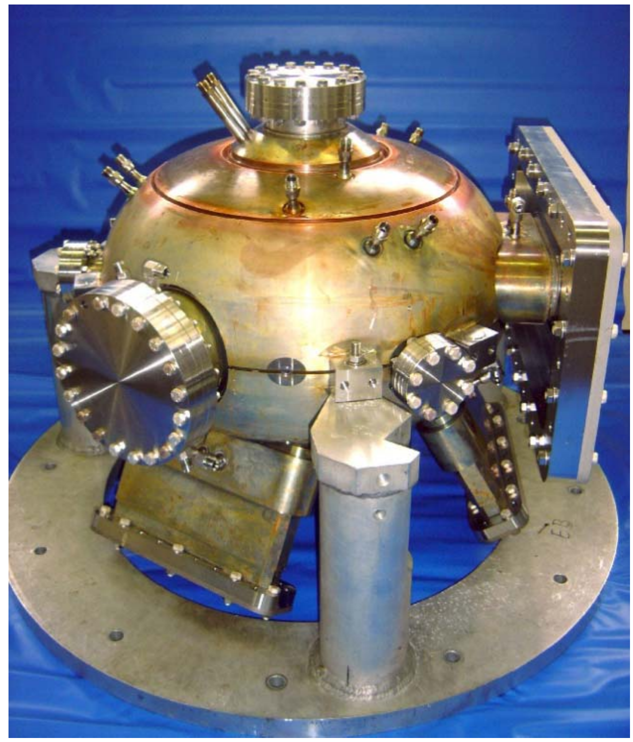

Figure 1: PEP II cavity ready for delivery

Eletroforming

For storage ring cavities operating in cw mode like for PEP II the water cooling channels are of complex path design and incorporated into the cavity body. The cooling channels are milled into the cavity body. The milled channels are temporarily filled and the hole cavity is covered with electroformed copper afterwards (Fig. 2). For the PEP II project the electroformed copper had to fulfil special requirements. The galvanic layer has a thickness of approx. 10 mm, which needs long deposition time and intermediate turning operations to get a homogeneous layer. Additionally attachments had to be EB welded to the electroformed layer. Therefore, the copper deposition had to fulfil high purity requirements.

Figure 2: PEP II cavity at in electroforming bath with still visible cooling channels

Chemical Preparation

The final fabrication step of the PEP II cavities is a chemical surface preparation of the interior surface. The cavity is installed in a closed loop chemical cycle. The acid mixture, mainly sulfamid acid, is pumped through the cavity resulting in chemical surface polishing. The total surface removal is in the range of 30 µm.

3D Design Tools

The performance of a cavity is also highly depending on its design. Therefore production is supported by 3D design tools as Autodesk-Inventor, CST-Microwave-Studio, Ansys and inhouse developed analysing tools (e. g. multipacting analysis).

Precise Alignment

Especially long RF structures as the SNS CCL-Modules require precise alignment in the accelerator tunnel. Therefore each 14 m long CCL-Module consisting out of 12 segments was pre-aligned with a precision of 0.1 mm with respect to the theoretical beam axis (Fig. 3) by means of a laser tracking system.

Figure 3: Alignment of 12 CCL-Segments for SNS during assembly before delivery.

RF MEASUREMENTS

Besides mechanical dimension control full quality assurance is given by RF measurements of characteristic values during complete production process. Based on analysis of resonant frequency, quality factor, coupling factor, field flatness and/or mode spectrum important RF properties of each cavity are measured, optimised, tuned and tested before delivery.

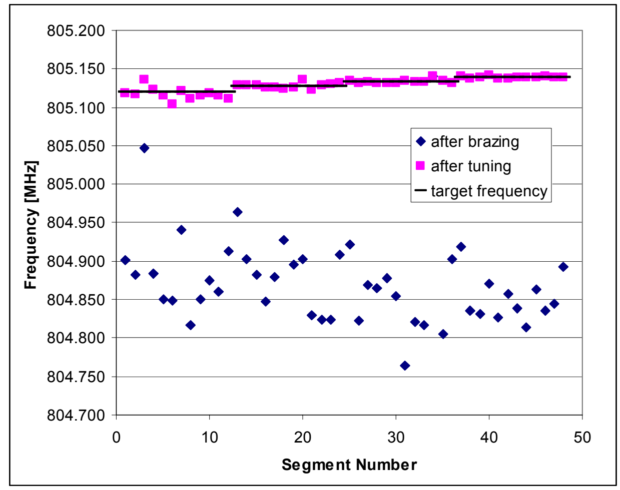

Figure 4: Measurement of the pi/2-frequency of all 48 SNS CCL-Segments.

ACCEL is open for and made good experience with close cooperation with the customer for development of measurement procedures and analysis of measured data. During the production of the SNS CCL-Structures the good cooperation with LANL and ORNL resulted in the successful tuning of 384 acceleration cavities, 424 coupling cells and 44 bridge cavities (Fig. 4 and Fig. 5) [3].

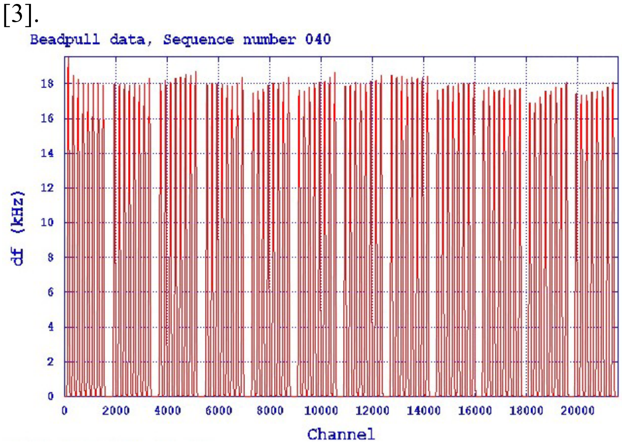

Figure 5: Beadpull measurement showing field distribution of 12 CCL-segments with 8 acc. cells each.

REFERENCES

[1] J. Seeman et al., “Progress of the PEP II B-Factory”, PAC 2003, Portland, May 2003, p. 2298
[2] http://www.accel.de
[3] J. Billen et al., “Tuning the Spallation Neutron Source Warm Linac RF Structures”, to be published LINAC 2004, Lübeck, August 2004