THE STATISTICS OF INDUSTRIAL XFEL CAVITIES FABRICATION AT E. ZANON

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Abstract

Serial production of superconducting cavities for European-XFEL was successfully started at E.ZANON at the end of last year. The production rate (3-4 cavities a week) allows us to summarize the results and present the statistics of industrial cavity fabrication. Many parameters have been traced during different steps of cavity production. The most interesting of them, as cavity length, frequency, field flatness and eccentricity, are presented and discussed.

INTRODUCTION

The cavity production rate at E.ZANON achieved the necessary level (3-4 cavities a week) on February (see figure 1). Additional growth in April and May allowed reduce the production rate during planned vacation in August.

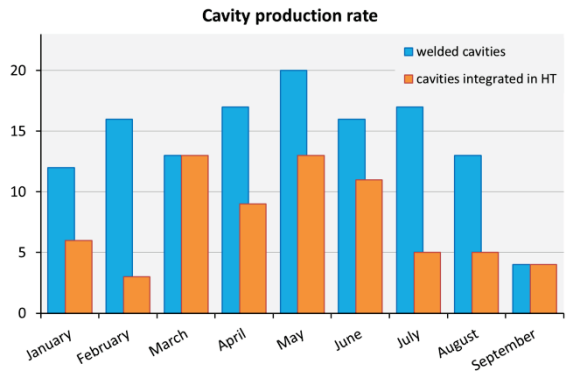

Figure 1: Cavity production rate.

In period of 36 calendar weeks since January 2013 E.ZANON:

- produced 150 cavities;
- integrated 64 cavities in helium tanks and sent to DESY.

It allowed to:

- test 43 cavities at DESY under cold condition;
- sent 37 cavities to CEA (Saclay) for module assembling;
- get 8 cavities already assembled in XFEL module, which waits the cold test at DESY.

We will concentrate our attention on RF aspects of the statistics for XFEL cavities fabricated at E.ZANON, separating them to mechanical and RF characteristics. The idea of the RF measurements procedure and first results for XFEL cavities production were already published in [1, 2].

The results of all measurements are collected in XFEL DB [3] and were used for analyzes.

MECHANICAL CHARACTERISTICS

The shrinkage welding parameter (see figure 2) depends on the characteristics of niobium sheets from different suppliers: Plansee, Tokyo-Denkai and Ningxia. It has to be taken into account for estimation of final length, before cavity welding.

The mean shrinkage values for Tokyo-Denkai material is 0.43 mm, for Plansee and Ningxia is 0.41 mm.

The average shrinkage for all produced cavities is (0.421 ± 0.015) mm. It overlaps the average values for all materials supplier.

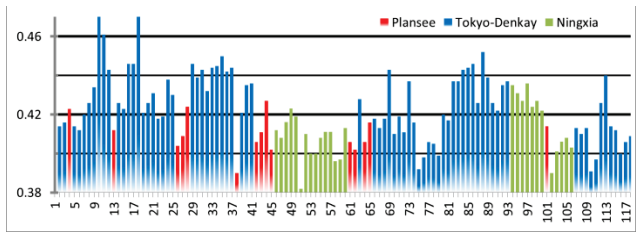

Figure 2: Shrinkage of equator welding for different materials.

The predicted lengths for cavities with helium tank and real values are compared on figure 3.

The difference between them should be 224.4 mm. It corresponds to: 2 mm length reduction during planned tuning and 222.4 mm (lengths of cavity tubes) due to different measurements (predicted length – between connecting flanges, real – between reference rings).

Average deviation relative planned difference is ± 0.4 mm. It's less than 15 % of the length tolerance.

Average length between reference rings of produced cavities is 1058.9 mm, as required by XFEL specification (1059 ± 3) mm.

One can see the average length reduction about 1 mm for last 40 cavities, according the additional requirements from DESY.

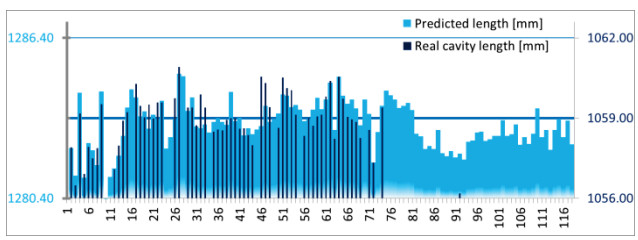

Figure 3: Predicted and real cavity lengths

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The next important mechanical characteristic for beam dynamics is cavity cell's eccentricity. It's used for cavity assembling into the accelerating module. The maximal from 11 eccentricity values (9 for cells and 2 for flanges) for each cavity are presented on figure 4.

Average maximal eccentricity value for cavities is 0.2 mm. So the cavities are twice straighter than it's required by XFEL specification

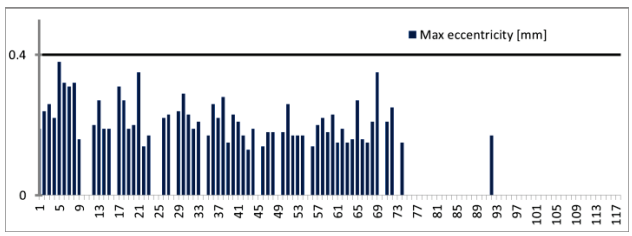

Figure 4: Maximal value of cavity eccentricity before welding in helium tank.

RF CHARACTERISTICS

The main RF characteristics for cavity production (TM010 pi-mode frequency and field flatness) are presented on figures 5 and 6.

After the cold measurements results for pre-series cavities the pi-mode frequency was increased, correcting the target values during the tuning. The further control and correction are planned.

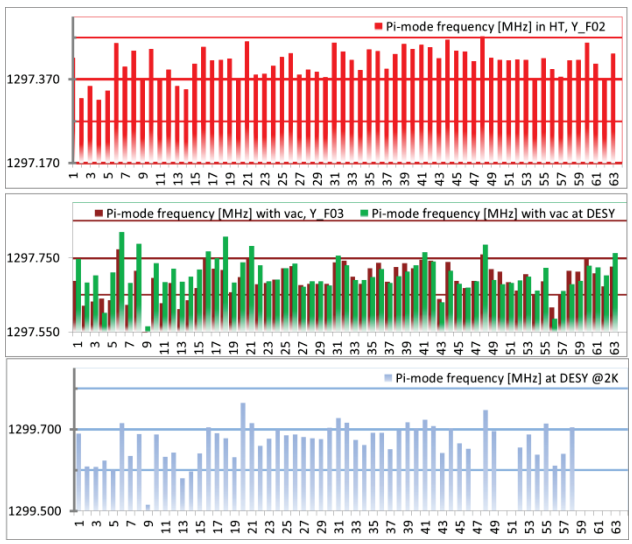

Figure 5: Pi-mode frequencies at different conditions.

Average field flatness of cavities, integrated in helium tank, is 96 % before final BCP. It's more than required by XFEL specification (> 90 %).

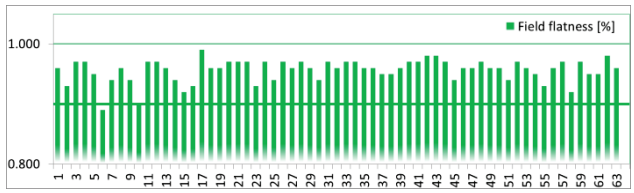

Figure 6: Cavity field flatness at TM010 pi- mode before BCP.

To have an indication on a possible cavity deformation during the last step of the production, the spectrum measured before shipment is compared with the spectrum measured when the cavity was integrated into the tank. As an example a comparison of two spectra for cavity is presented in Fig. 7. First spectrum is a reference (was measured just after cavity integration) and second one was measured just before the shipment to DESY. The relative spectrum graph shows the difference between frequencies ratio of each mode and ratio of pi-mode frequencies. The mean squared error (MSE) is calculated for relative spectrum and its linear fit curve shows the deviation of cavity field flatness. If this value does not exceed 10 kHz and relative spectrum curve stays within the limits, the field flatness change is less than 10%.

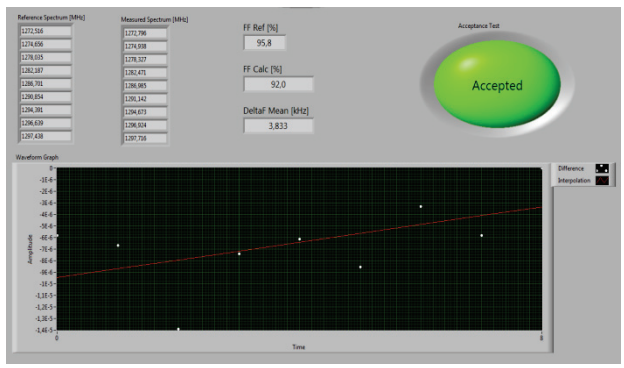

Figure 7: comparison between spectra and parameter MSE measured.

From this step on all procedures are carried out by DESY. All cavities will be tested before being installed into the European XFEL tunnel.

One of the most important cavity parameters is the maximum accelerating field which is measured in the vertical cryostat at 2 K. During the test the interdependency between the cavity's quality factor and its accelerating field is measured (see Fig. 8). The design values for XFEL cavities are an accelerating gradient of 23.6 MV/m at a Q-value of $1 \cdot 10^{10}$.

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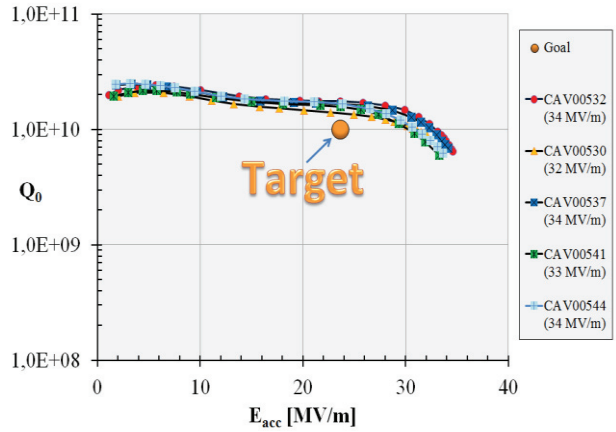

Figure 8: Vertical test result of some cavities.

SUMMARY

For 36 calendar weeks in 2013:

- E.ZANON produced 150 cavities;
- 64 cavities were welded in helium tanks by E.ZANON and sent to DESY;
- 43 cavities tested at cold condition at DESY;
- 37 cavities were sent to CEA (Saclay) for module assembling;
- 8 cavities are assembled in module and waiting the cold test.

The main results of the statistics analyzes are:

- average shrinkage of cavities is (0.421 ± 0.015) mm. For Tokyo Denkai material (0.43 mm) it is 0.02 mm higher than for Plansee and Ningxia;
- average length between reference rings of produced cavities is 1058.9 mm, as required by XFEL specification;
- real cavity lengths are very close to predicted values. So we can wait the length reduction to 1 mm according the additional requirements from DESY;
- average maximal eccentricity value for cavities is 0.2 mm. So the cavities are twice straighter than it's required by XFEL specification;
- after the cold measurements results for pre-series cavities the pi-mode frequency was increased, correcting the target values during the tuning. The further control and correction are planned;
- average field flatness of produced cavities before final BCP is 96 % (over required 90 %).

ACKNOWLEDGMENT

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REFERENCES

[1] A. Sulimov et al., "Description and First Experience with the RF Measurement Procedure for the European XFEL SC Cavity Production", 2nd IPAC'11, San Sebastian, Spain, 2011, pp. 277-279.

[2] A. Sulimov et al., "First RF Measurement Results for the European XFEL SC Cavity Production" Proceedings of LINAC2012, Tel-Aviv, Israel, 2012, pp. 195-197.

[3] http://xfel.desy.de/cavity_database/

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